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S. Choliy, I. Perga

HISTORY OF SCIENCE AND TECHNOLOGY

**Textbook for students
of the Faculty of Applied Mathematics**

*Recommended by the Methodical Council of KPI named after Igor Sikorsky
as a textbook for bachelor's degree holders by specialty
113 “Applied Mathematics”, 121 “Computer Engineering”,
123 “Software Engineering of Multimedia and Information Retrieval Systems”*

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Educational and methodological materials contain a summary of the lecture course
“History of Science and Technology” and are designed to help students during preparation
for seminar classes, independent work, and preparation for semester control. The
publication describes the history of the development of world scientific thought, examines
the history of the development of technology, presents the main stages of the development
of engineering education.

For students of the Faculty of Applied Mathematics who are studying in specialties
113 “Applied Mathematics”, 121 “Software Engineering”, 123 “Computer Engineering”.

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Introduction

Welcome to the "History of Science and Technology" textbook, a comprehensive guide designed to provide students with an in-depth understanding of the evolution, progress, and impact of scientific discoveries and technological advancements throughout human history. As you embark on this fascinating journey, you will explore the milestones and achievements that have shaped our world and learn how they have revolutionized the way we perceive, interact with, and manipulate our surroundings.

The study of the history of science and technology is essential to appreciate the foundations of our modern society and the countless innovations that have improved our quality of life. From the earliest tools used by our ancestors to the latest breakthroughs in fields such as artificial intelligence and space exploration, this textbook will take you on a chronological journey through the significant events, inventions, and discoveries that have transformed our world.

Throughout this textbook, you will delve into the lives of pioneering inventors, visionary scientists, and influential thinkers who have made groundbreaking contributions to various fields, including physics, chemistry, biology, mathematics, engineering, and computer science. You will also learn about the complex social, political, and economic factors that have influenced the development of scientific thought and technological progress across different civilizations and historical periods.

Each chapter in this textbook is dedicated to a specific era, highlighting the key scientific and technological breakthroughs that occurred during that time, as well as the historical context in which these innovations emerged. By understanding the interconnectedness of science, technology, and society, you will gain a deeper appreciation for the countless ways in which human ingenuity has driven progress and helped us overcome the challenges of our ever-changing world.

As you navigate through the pages of the "History of Science and Technology," we hope this textbook serves not only as an informative resource but also as a source of inspiration. May it spark your curiosity, fuel your passion for learning, and encourage you to make your own mark in the world of science and technology. Enjoy the journey!

CHAPTER 1. THE THEORY AND METHODOLOGY OF THE DISCIPLINE “THE HISTORY OF SCIENCE AND TECHNOLOGY”

- Subject, objective, goals, and periodization of the history of science and technology.
- Historiography and sources of the history of science and technology.
- The most important stages of development in history. The significance of science and technology for humanity.

1.1. Subject, objective, goals, and periodization of the history of science and technology

The discipline ‘the history of science and technology’ emerged as a distinct field of study at the end of the 19th century. This distinction was marked in 1892 when a French university established a separate chair for the history of science. From that point, numerous university courses were introduced, focusing on the history of science and eventually the history of technology as well. The rapid advancements in technology during this period played a significant role in emphasizing the importance of this branch of historical study, with the primary subject being the reconstruction of historical knowledge and the examination of the development of scientific processes. This is achieved by analyzing trends and interconnections that influence scientific progress.

The course "history of science and technology" seeks to deepen students' understanding of the development of scientific and technological fields, ranging from rudimentary tools to contemporary innovations. Science is a human endeavor that involves the acquisition and theoretical systematization of objective knowledge about reality. Technology, on the other hand, is a complex method of human activity aimed at fulfilling both productive and non-productive societal needs.

The history of science and technology has evolved into an interdisciplinary branch of study, integrating the achievements from various scientific fields. This dynamic discipline continuously adapts by incorporating new knowledge, concepts, and facts. The primary objectives of the history of science and technology are to search for, systematize, analyze, and synthesize scientific and technical information, expand the source base for research, identify rules and patterns of technological development, assess the role of science in the cultural and historical development of society, and enhance the methodology of scientific research.

Periodization is a crucial aspect of any scientific discipline. Throughout history, various periodization schemas have been proposed. Lucretius suggested three consecutive periods of social development: prehistory, hunting-gatherer, and cattle breeding-agricultural. Arab scientist Al Biruni introduced the idea of large historical cycles, while the Enlightenment philosophers emphasized the concept of progress as a key process in human development. Arnold Joseph Toynbee's concept of civilization in his book "A Study of History" highlighted the differences between progress in science and technology. David Bell's contemporary approach categorizes history based on social relations and the existence of preindustrial, industrial, and post-industrial societies.

Two primary tendencies in periodization and analysis of historical processes can be identified. The first approach, which is widely used in other historical disciplines, divides history into long-term periods such as Prehistory, Ancient History, Middle Ages, Modernity, and the Contemporary Period. The second approach advocates for a specific methodology and periodization exclusively for the history of science and technology. This method divides human history into two major periods: the traditional society before the Industrial Revolution and the industrial society during and after the Industrial Revolution.

The proposed schema of periodization for the history of science and technology is based on a chronological and thematic approach, dividing human history into several extensive periods:

1. Prehistory, before the emergence of the first civilizations,
2. Period of Ancient Civilizations (Egypt, Mesopotamia, India, China),
3. Period of Antiquity,
4. Middle Ages,
5. Early Modern Period (manufacture production),
6. The Industrial Revolution, 18-19th century,
7. The Industrial society (until the mid-20th century),
8. The information-oriented society (the scientific and technological revolution).

1.2. Historiography and sources

The historiography of the history of science and technology is the study of the various approaches, methods, and interpretations that historians have applied to the analysis and understanding of the development of science and technology over time. It encompasses a wide range of perspectives and methodologies, which have evolved and diversified throughout the years. In order to provide a comprehensive overview of the historiography of the history of science and technology, we can divide it into several key stages and discuss the prevailing themes and approaches of each stage:

Early historiography (19th - early 20th century): During this period, the history of science and technology was primarily focused on the chronology of scientific discoveries and inventions, with an emphasis on the "great men" of science. This approach often presented a linear and progressive narrative of scientific and technological advancement, highlighting the contributions of prominent figures such as Isaac Newton, Galileo Galilei, and James Watt.

Internalist and externalist approaches (mid-20th century): By the mid-20th century, historians began to explore the internal and external factors that influenced the development of science and technology. Internalist approaches focused on the intellectual context and the logic of scientific discovery, examining the conceptual frameworks and methodologies employed by scientists. Externalist approaches, on the other hand, considered the social, political, and economic contexts that shaped the development of science and technology, emphasizing the role of institutions, patronage, and cultural values.

Social constructivism (late 20th century): As historians increasingly recognized the complex interplay between science, technology, and society, social constructivist approaches emerged. These approaches argued that scientific knowledge and technological artifacts are socially constructed, emphasizing the role of social negotiations, controversies, and power relations in shaping scientific and technological developments. Influential works in this vein include Thomas Kuhn's "The Structure of Scientific Revolutions" and Bruno Latour and Steve Woolgar's "Laboratory Life."

Comparative and global perspectives (late 20th - early 21st century): With the increasing globalization of scientific and technological research, historians began to adopt comparative and global perspectives in their analyses. These approaches sought to understand the development of science and technology within a broader geographical and cultural context, examining the interactions and exchanges between different scientific traditions, the diffusion of knowledge, and the role of colonialism and imperialism in shaping global scientific and technological trajectories.

Interdisciplinarity and integrated history (21st century): In recent years, the historiography of the history of science and technology has been marked by a growing interdisciplinarity and an emphasis on integrated history. This approach combines insights from various disciplines, such as the history of science, technology, and medicine, as well as sociology, anthropology, and philosophy of science. Integrated history also aims to understand the complex interactions between science, technology, and other aspects of human culture and society, such as art, religion, and politics.

1.3. The stages of development, the importance of science and technology for humanity

The development of science and technology has played a critical role in the progress of human civilization. These advancements have shaped the way we live, work, and interact with our environment, enabling us to overcome challenges and improve our quality of life. The stages of development and the significance of science and technology for humanity can be categorized into several key periods:

Prehistoric era: In this stage, early humans developed rudimentary tools and techniques for hunting, gathering, and agriculture. The mastery of fire and the invention of simple tools like the wheel, lever, and pulley allowed our ancestors to manipulate their environment more effectively, improving their chances of survival and laying the foundation for the development of complex technologies.

Ancient civilizations: During this period, significant advancements were made in various fields of science and technology, including mathematics, astronomy, engineering, and medicine. The ancient Egyptians, Mesopotamians, Chinese, and Indians, among others, contributed significantly to the development of human knowledge. Their innovations, such as the invention of writing, the development of irrigation systems, and the construction of monumental structures, played a crucial role in shaping the course of human history.

Classical antiquity: In this stage, the civilizations of ancient Greece and Rome made substantial contributions to science and technology. Greek philosophers, such as Plato and Aristotle, laid the groundwork for the scientific method, while Roman engineers developed advanced technologies for infrastructure, including aqueducts, roads, and bridges. These advancements facilitated the growth of knowledge and the expansion of empires.

Middle Ages: Although often regarded as a period of stagnation, the Middle Ages witnessed important scientific and technological innovations. Islamic scholars preserved and expanded upon classical knowledge, contributing to fields such as mathematics, astronomy, and medicine. Meanwhile, in Europe, the development of technologies like the windmill and watermill revolutionized agriculture and industry.

Renaissance and Early Modern Period: This era marked a resurgence of scientific inquiry and technological innovation, fueled by the rediscovery of classical texts and the expansion of global trade. The invention of the printing press revolutionized the dissemination of knowledge, while advancements in navigation and shipbuilding facilitated exploration and colonization. The development of modern science, with figures like Copernicus, Galileo, and Newton, laid the foundation for a deeper understanding of the natural world.

Industrial Revolution (18th - 19th century): This transformative period witnessed rapid advancements in science and technology, which revolutionized industry, agriculture, and transportation. The development of steam power, mechanized textile production, and modern chemistry spurred economic growth and urbanization, dramatically altering the social and environmental landscape.

20th century - mid-20th century: This stage was marked by the rise of the automobile, the invention of the airplane, and the development of electrical power generation and distribution. Breakthroughs in physics, chemistry, and biology led to innovations such as antibiotics, plastics, and synthetic materials, which significantly

improved the quality of life. However, this period also saw the development of destructive technologies, such as nuclear weapons.

Late 20th century - present: The information age has been defined by the development of digital technologies, including computers, the internet, and mobile devices. These advancements have revolutionized communication, education, and commerce, connecting people globally and enabling the rapid exchange of information. Biotechnology, renewable energy, and nanotechnology are among the emerging fields poised to transform the future of humanity.

Throughout these stages, the development of science and technology has played an essential role in shaping human civilization. These advancements have enabled us to overcome challenges, improve our quality of life, and expand our understanding of the universe. As we continue to progress, science and technology will remain at the forefront of human achievement, driving innovation and shaping our future.

Control Questions:

1. Define the subject, objective, and goals of the history of science and technology. Why is the study of this discipline important in understanding the development of human society?
2. Explain the concept of periodization in the context of the history of science and technology. How does periodization help organize the study of this discipline?
3. Discuss the historiography of the history of science and technology. How have various scholars approached the study of this discipline, and what have been some of the major debates and perspectives in the field?
4. Identify and describe the different types of sources used in the study of the history of science and technology. What challenges do historians face when working with these sources, and how can they overcome these challenges?

5. Outline the most important stages of development in the history of science and technology. How do these stages reflect broader changes in human society and culture?
6. Evaluate the significance of science and technology for humanity throughout history. How have scientific and technological advancements shaped the human experience and contributed to the progress of civilizations?
7. Discuss the role of interdisciplinary approaches in the study of the history of science and technology. How can integrating perspectives from different disciplines enhance our understanding of this field?
8. Explain the importance of considering the social, economic, and political contexts in the study of the history of science and technology. How do these factors influence the development of science and technology and their impact on society?
9. Reflect on the relationship between science and technology throughout history. How have these two areas of human endeavor influenced and shaped each other over time?
10. Considering the importance of the history of science and technology in understanding the human experience, what do you think are the most important lessons to be learned from studying this discipline?

Basic literature: [2]; [5]; [13].

Additional literature: [23]; [26]; [37]; [41].

CHAPTER 2. THE ACCUMULATION OF THE SCIENTIFIC KNOWLEDGE AND DEVELOPMENT OF TECHNOLOGY IN ANCIENT CIVILIZATIONS

- Human evolution and invention of first tools and technologies.
- The invention of bow and arrows.
- Neolithic revolution.
- Metallurgy and usage of metals in everyday life. The emergence of prescience.

2.1. Human evolution and invention of first tools and technologies

Human evolution is the lengthy process by which our species, *Homo sapiens*, emerged as a distinct species from our early hominin ancestors. This process took millions of years and involved a series of biological, behavioral, and cultural changes that led to the development of the first tools and technologies.

Early hominins (approximately 6-2 million years ago): The earliest hominins, such as *Ardipithecus* and *Australopithecus*, were bipedal, meaning they walked upright on two legs. Bipedalism offered several advantages, such as increased energy efficiency and the ability to see greater distances. This adaptation allowed early hominins to explore new environments and exploit new food resources, setting the stage for the development of early tools and technologies.

The emergence of the *Homo* genus (approximately 2 million years ago): The *Homo* genus, which includes our species *Homo sapiens*, is characterized by a larger brain size and more advanced cognitive abilities compared to earlier hominins. Early *Homo* species, such as *Homo habilis*, began using simple stone tools known as Oldowan tools. These tools were primarily used for processing food, such as cutting meat from animal carcasses and cracking open bones to extract marrow. The

invention of tools marked a significant milestone in human evolution, as it allowed early humans to access new food sources and adapt to changing environments.

Homo erectus and the Acheulean tool culture (approximately 1.8 million to 300,000 years ago): Homo erectus was a highly successful early human species that developed more advanced stone tools, known as Acheulean tools. These tools were characterized by large bifacial handaxes and cleavers, which were more versatile and efficient than the earlier Oldowan tools. Homo erectus also harnessed the power of fire, which provided warmth, protection from predators, and a means to cook food. The mastery of fire and the development of Acheulean tools allowed Homo erectus to expand its range and adapt to a wide variety of environments across the Old World.

Neanderthals and other archaic humans (approximately 400,000 to 40,000 years ago): Neanderthals and other archaic humans, such as Homo heidelbergensis and Homo rhodesiensis, developed more refined and specialized tools, known as Mousterian tools. These tools were made using the Levallois technique, which involved the careful preparation of stone cores to produce thin, sharp flakes. Mousterian tools were used for a variety of tasks, such as hunting, butchering, and woodworking. Neanderthals and other archaic humans also developed more complex social structures and cultural practices, such as burying their dead and creating symbolic artifacts.

Anatomically modern humans (approximately 300,000 years ago to present): Anatomically modern humans, Homo sapiens, emerged in Africa around 300,000 years ago and began to develop more advanced technologies and complex cultural practices. By 50,000 years ago, Homo sapiens were creating sophisticated stone, bone, and antler tools, as well as art and personal adornments. They developed new technologies for hunting and fishing, such as the atlatl and the bow and arrow, and invented early forms of pottery, textiles, and agriculture.

Throughout human evolution, the invention of tools and technologies has played a critical role in enabling our ancestors to adapt to their environment and

exploit new resources. These early innovations laid the foundation for the more advanced technologies and complex societies that characterize human civilization today.

2.2. The invention of bow and arrows

The invention of the bow and arrow marked a significant advancement in human technology and hunting methods. This weapon system allowed early humans to hunt from a distance, increasing their safety and success rate when pursuing game. While the exact timeline of the bow and arrow's development is still debated among experts, it is generally believed to have emerged around 64,000 to 48,000 years ago.

The bow and arrow provided several advantages over earlier hunting methods:

Increased range: The bow and arrow allowed hunters to target animals from a greater distance compared to close-range weapons like spears or clubs. This meant that hunters could engage in stealthier approaches, reducing the risk of scaring away their prey or putting themselves in danger.

Improved accuracy: With practice, archers could become highly accurate in their aim, increasing the chances of a successful hunt. The arrow's aerodynamic shape and the bow's power enabled it to travel in a more predictable trajectory, making it easier to hit targets with precision.

Higher lethality: The arrow's sharp point and the bow's ability to propel it at high speeds resulted in a more lethal weapon. When an arrow struck an animal, it could penetrate deep into the body, causing significant damage to vital organs and leading to a quicker, more humane kill.

Versatility: The bow and arrow could be used in various hunting situations, from pursuing large game like deer or bison to targeting smaller animals like birds or rabbits. Additionally, with modifications like barbed points or poison, the bow and arrow could be adapted to various hunting needs.

Portability: Bows and arrows were relatively lightweight and easy to carry, making them a convenient option for hunters on the move. This portability also made it easier for early humans to travel longer distances in search of food.

The invention of the bow and arrow had a profound impact on early human societies. It increased the efficiency and success of hunting, providing a more reliable source of food and enabling populations to grow. The mastery of this technology may have also contributed to the development of more complex social structures, as successful hunters gained prestige and influence within their communities.

Furthermore, the bow and arrow's influence extended beyond hunting. As human societies grew and came into conflict with one another, the bow and arrow became an essential weapon in warfare, providing a means to engage enemies from a distance and defend against attacks. Throughout history, the bow and arrow has remained a symbol of skill, innovation, and the ingenuity of human technology.

2.3. Neolithic revolution

The Neolithic Revolution, also known as the Agricultural Revolution, was a transformative period in human history marked by the transition from hunter-gatherer societies to settled farming communities. This transition occurred around 10,000 to 12,000 years ago in different regions across the globe, including the Fertile Crescent in the Middle East, China, Mesoamerica, and the Andean region of South America. The Neolithic Revolution had far-reaching consequences, leading to significant changes in human society, culture, and technology.

Key developments during the Neolithic Revolution included following.

Domestication of plants and animals: The most significant aspect of the Neolithic Revolution was the domestication of plants and animals, which allowed early humans to control and manipulate their food sources. The cultivation of crops such as wheat, barley, rice, and maize, and the domestication of animals like sheep, goats, pigs, and cattle, provided stable and predictable food supplies, enabling human populations to grow.

Settled communities: As humans began to rely on agriculture, they established permanent settlements close to their cultivated fields. These early villages and towns enabled the development of more complex social structures, with individuals taking on specialized roles, such as farmers, artisans, and leaders.

Technological advancements: The shift to agriculture and settled life necessitated the development of new tools and technologies. Neolithic communities developed tools for farming, such as hoes, sickles, and plows, as well as pottery for storing and cooking food. They also constructed more permanent dwellings, using materials like mud-bricks and timber.

Surplus production and trade: With the reliable food supplies provided by agriculture, Neolithic communities were able to produce food surpluses. These surpluses enabled trade between communities, fostering the exchange of goods, ideas, and innovations over long distances.

Social stratification and complex societies: As agricultural communities grew larger and more complex, social stratification began to emerge. Some individuals or families accumulated more resources and power, leading to the development of social hierarchies and more complex political structures.

Emergence of writing and early states: The Neolithic Revolution eventually gave rise to early states and civilizations, which required new systems of record-keeping and communication. The invention of writing, such as cuneiform in Mesopotamia and hieroglyphics in Egypt, facilitated the management of complex societies and the development of early legal systems, literature, and historical records.

The Neolithic Revolution marked a major turning point in human history, setting the stage for the development of complex societies, advanced technologies, and the eventual rise of cities and empires. Its lasting impact can still be seen today, as the majority of the global population continues to rely on agriculture and live in settled communities.

2.4. Metallurgy and usage of metals in everyday life. The emergence of prescience

Metallurgy, the process of extracting and refining metals from their ores, played a significant role in shaping the ancient world. The use of metals in everyday life allowed for the development of more advanced tools, weapons, and infrastructure, as well as the emergence of early scientific practices. The three main ages of metallurgy are commonly known as the Copper Age (Chalcolithic), the Bronze Age, and the Iron Age.

Copper Age (Chalcolithic) - around 4500 to 3300 BCE: The Copper Age marked the first widespread use of metals, specifically copper, in human history. People in the ancient world discovered that copper, a soft and malleable metal, could be easily extracted from its ores and shaped into various tools and ornaments. Copper tools were a significant improvement over stone tools, offering better durability and cutting ability. However, the softness of copper limited its application in certain areas, such as warfare.

Bronze Age - around 3300 to 1200 BCE: The Bronze Age began when ancient civilizations discovered that by alloying copper with tin, they could produce bronze, a stronger and more durable metal than copper. Bronze tools and weapons, such as axes, knives, and spears, were more effective and long-lasting than their copper counterparts. Bronze was also used to create everyday items like vessels, jewelry, and statues. The widespread use of bronze led to the establishment of trade networks to source tin and copper, connecting different regions and fostering cultural exchange.

Iron Age - around 1200 BCE to 500 CE: The Iron Age marked a significant technological leap with the discovery of iron smelting, which allowed for the production of stronger and more versatile tools, weapons, and infrastructure. Iron was more abundant than copper and tin, making it more accessible for widespread use. The production of iron required higher temperatures and more advanced smelting techniques, leading to innovations in furnace design and the use of bellows. Iron tools and weapons, such as plows, hammers, and swords, revolutionized agriculture, craftsmanship, and warfare.

The emergence of prescience: As ancient societies developed more advanced metallurgical techniques, the foundation for early scientific practices was laid. Metallurgy, by its nature, required a deep understanding of materials and their properties, as well as the ability to manipulate and control fire and chemical processes. This led to the emergence of early chemistry, known as alchemy, which sought to understand and control the transformation of materials.

The use of metals in everyday life in the ancient world not only improved the efficiency and effectiveness of tools, weapons, and infrastructure but also contributed to the development of early scientific practices. Metallurgy was an essential driver of technological progress and social change, shaping the course of human history and paving the way for future innovations.

The term "prescience" refers to the ability to have foreknowledge or foresight of events before they happen. However, it seems that you might be referring to the

emergence of early scientific practices or proto-science, which laid the groundwork for modern scientific disciplines. These early scientific practices emerged in various ancient civilizations, including Egypt, Mesopotamia, India, China, and Greece.

In the context of the history of science and technology, the emergence of proto-science involved the development of systematic observations, experimentation, and reasoning about the natural world. These early practices evolved gradually over time, incorporating empirical knowledge, practical skills, and theoretical frameworks. Some notable examples include:

Astronomy: Ancient civilizations observed celestial bodies and developed systems to track their movements and predict astronomical events. In Mesopotamia, Babylonian astronomers created the first known star catalogs and recorded the cycles of the Moon and planets. The ancient Egyptians aligned their pyramids and temples with celestial bodies and used their knowledge of astronomy for agricultural planning.

Mathematics: The development of mathematics played a crucial role in the emergence of early scientific practices. The Sumerians and Babylonians in Mesopotamia created the first known systems of writing numbers and basic arithmetic, while the Egyptians devised methods for solving problems in geometry and land measurement. Later, the Greeks made significant advancements in mathematics, including the work of Euclid, Archimedes, and Pythagoras.

Medicine: Early civilizations developed systems of medical knowledge and practice based on empirical observations, experimentation, and theoretical frameworks. In ancient Egypt, physicians used herbs and other natural remedies to treat illnesses and performed surgical procedures. The Indian tradition of Ayurveda combined practical knowledge of herbs and treatments with a theoretical framework rooted in the balance of bodily elements. The ancient Greeks, particularly Hippocrates and Galen, made significant contributions to the understanding of human anatomy, physiology, and disease.

Philosophy and natural philosophy: The ancient Greeks laid the groundwork for the development of systematic philosophical inquiry into the nature of the world. Thinkers such as Thales, Anaximander, and Heraclitus proposed theories about the fundamental principles and elements of the universe, while Socrates, Plato, and Aristotle developed methods of logical reasoning and dialectical inquiry. These philosophical traditions provided the foundation for the emergence of natural philosophy, which sought to understand the workings of the natural world through observation, experimentation, and reason.

These early scientific practices and proto-science marked the beginning of humanity's systematic exploration of the natural world. They laid the foundation for the development of modern scientific disciplines and the scientific method, which continue to shape our understanding of the world and drive technological progress today.

Control Questions:

1. Discuss the role of human evolution in the invention of the first tools and technologies. How did early human needs and capabilities shape the development of these innovations?
2. Explain the importance of the invention of the bow and arrows in the context of ancient civilizations. How did this development impact hunting, warfare, and society in general?
3. Describe the Neolithic Revolution and its significance for human history. How did the transition from hunter-gatherer societies to agriculture-based communities transform science, technology, and civilization?
4. Outline the development of metallurgy in ancient civilizations. How did the discovery and use of metals such as bronze, iron, and gold influence technology and society?

5. Discuss the concept of "prescience" and its role in the development of ancient civilizations. How did early knowledge and understanding of the natural world contribute to the growth of science and technology?
6. Compare the scientific knowledge and technological advancements of different ancient civilizations. What factors influenced the development and dissemination of knowledge and technology among these cultures?
7. Analyze the relationship between scientific knowledge, technology, and social organization in ancient civilizations. How did advancements in science and technology shape the structure and function of these societies?
8. Evaluate the role of trade and cultural exchange in the spread of scientific knowledge and technological innovations among ancient civilizations. How did these interactions influence the development of science and technology in different regions?
9. Identify some of the key inventions and discoveries of ancient civilizations that have had a lasting impact on science and technology throughout history. What factors contributed to the success and enduring significance of these innovations?
10. Reflect on the lessons that can be learned from studying the accumulation of scientific knowledge and development of technology in ancient civilizations. How do these insights help us better understand the historical context and evolution of science and technology in human society?

Basic literature: [2]; [5]; [13].

Additional literature: [18]; [19]; [21]; [29].

CHAPTER 3. THE MAIN FEATURES OF THE DEVELOPMENT OF PRODUCTION AND TECHNOLOGY DURING THE MIDDLE AGES

- The medieval guilds and their influence on production and technology.
- Scientific and technical achievements of Central Asia and the Far East during the Middle Ages.
- Manufactory production and its evolution.
- Inventors and first machines. Evolution of natural science.

3.1. The medieval guilds and their influence on production and technology

Medieval guilds were associations of craftsmen or merchants in the same trade, formed to protect their members' interests, regulate their profession, and maintain high standards of workmanship. Guilds were influential in shaping production and technology during the Middle Ages, especially in Europe between the 11th and 16th centuries. They played a crucial role in the economic and social life of medieval towns and cities and had a lasting impact on the development of trade, industry, and technological innovation.

Some ways in which medieval guilds influenced production and technology include:

Quality control and standardization: Guilds established strict rules and regulations governing the quality of goods produced by their members. They set standards for materials, workmanship, and finished products, ensuring consistent quality and fostering a reputation for excellence. Guild members were required to undergo a rigorous apprenticeship, followed by the production of a "masterpiece" to demonstrate their skills before being admitted as a master craftsman.

Protection of trade secrets and techniques: Guilds played a crucial role in preserving and transmitting the specialized knowledge and skills of their respective trades. They protected trade secrets and techniques by limiting access to apprenticeships and masterships, ensuring that only those who had undergone proper training and demonstrated proficiency could practice the craft. This fostered a sense of professional identity and pride among guild members and helped to maintain high standards of craftsmanship.

Technological innovation: Guilds facilitated the exchange of ideas and information among craftsmen, encouraging innovation and improvements in production techniques. Members of a guild were exposed to the best practices and latest developments in their trade, fostering a competitive spirit and driving technological advancements. However, the strict regulations and secrecy surrounding guild practices could sometimes hinder innovation, as members were often discouraged from deviating from established techniques or sharing knowledge with outsiders.

Economic influence: Guilds wielded significant economic power in medieval towns and cities. They controlled production and distribution of goods within their respective trades, often holding monopolies on local markets. Guilds also played a role in setting prices and wages, ensuring fair competition and protecting the interests of their members. Their economic influence extended to the financing of public works, charitable activities, and the sponsorship of local festivals and events.

Political and social impact: Guilds often held considerable political power within medieval towns and cities. They participated in local governance, electing representatives to serve on town councils and advocating for their members' interests. Guilds also provided a social network for their members, offering mutual support, camaraderie, and opportunities for social advancement.

In summary, medieval guilds played a significant role in shaping production and technology during the Middle Ages. They established standards of quality and workmanship, protected and transmitted specialized knowledge, and fostered

technological innovation within their trades. Guilds were also influential in the economic, political, and social life of medieval towns and cities, shaping the development of trade, industry, and urban life in ways that would have lasting effects on European society.

3.2. Scientific and technical achievements of Central Asia and the Far East during the Middle Ages

During the Middle Ages, Central Asia and the Far East made significant scientific and technical achievements that had a lasting impact on the world. These regions, including Persia, India, China, and the Islamic Caliphates, were centers of learning, innovation, and cultural exchange, which contributed to their scientific and technological advancements.

Central Asia and Persia:

Mathematics: Persian mathematicians made significant contributions to the field of mathematics, particularly in algebra and trigonometry. Notably, Al-Khwarizmi, a Persian mathematician, developed algorithms and introduced the concept of algebra in his book "Al-Kitab al-mukhtasar fi hisab al-jabr wa'l-uqabala". This work laid the foundation for modern algebra.

Astronomy: Persian and Central Asian astronomers made significant advances in observational astronomy, including the development of more accurate star catalogs and the construction of advanced observatories. The Persian polymath Al-Biruni made significant contributions to the field, calculating the Earth's radius and the tilt of its axis with remarkable accuracy.

Medicine: Persian physicians, such as Ibn Sina (Avicenna), made substantial advancements in the field of medicine. Avicenna's "The Canon of Medicine" was a comprehensive medical encyclopedia that was widely used in the Islamic world and Europe for centuries. It covered various aspects of medicine, including diagnostics, treatments, and pharmacology.

India:

Mathematics: Indian mathematicians made several significant contributions during the Middle Ages, including the development of the decimal system and the concept of zero. The Indian mathematician and astronomer Aryabhata made important advancements in algebra, trigonometry, and geometry.

Astronomy: Indian astronomers made significant progress in observational astronomy, developing accurate methods for measuring celestial objects and predicting eclipses. They also devised sophisticated mathematical models to describe the motion of celestial bodies.

Medicine: The Ayurvedic system of medicine, which originated in ancient India, continued to develop during the Middle Ages. Indian physicians made advancements in surgery, pharmacology, and diagnostics, contributing to a comprehensive understanding of the human body and disease.

China:

Printing: One of the most significant technological innovations in China during the Middle Ages was the development of movable type printing by Bi Sheng in the 11th century. This advancement revolutionized the dissemination of knowledge and played a significant role in the spread of literacy and education.

Gunpowder: The invention of gunpowder in China during the 9th century had a profound impact on warfare and military technology worldwide. Gunpowder was first used in fireworks and later adapted for military use in the form of rockets, bombs, and firearms.

Navigation and Shipbuilding: Chinese advancements in navigation and shipbuilding during the Middle Ages facilitated long-distance maritime trade and exploration. The compass, an essential tool for navigation, was invented in China and later spread to other parts of the world. Chinese shipbuilding techniques, such as the use of watertight compartments and rudders, greatly improved the safety and maneuverability of ships.

Islamic Caliphates:

Translation Movement: The Islamic Golden Age witnessed a massive translation movement, which preserved and disseminated the knowledge of the ancient world. Greek, Persian, and Indian works were translated into Arabic, which then became a conduit for transmitting knowledge to Europe during the Renaissance.

Optics and Vision: The Arab scientist Alhazen made significant contributions to the understanding of optics and vision, including the development of the camera obscura and the study of light refraction. His work, "Book of Optics," laid the foundation for modern optics.

Architecture and Engineering: Islamic architecture and engineering during the Middle Ages were marked by innovative and sophisticated designs. Developments in geometry and structural engineering led to the construction of grand mosques

3.3. Manufactory production and its evolution

Manufacturing production underwent significant changes during the 13th to 16th centuries, particularly in Europe. This period marked a transition from small-scale, artisanal workshops to larger, more organized systems of production, laying the foundation for the Industrial Revolution. The evolution of manufacturing during this time can be attributed to several factors, including technological advancements, economic growth, urbanization, and the expansion of trade networks.

Technological advancements: Technological innovations played a significant role in the evolution of manufacturing during this period. Key advancements included the development of water and wind-powered mills, which increased the efficiency and scale of production in industries such as milling, textiles, and metalworking. The invention of the blast furnace in the 14th century revolutionized iron production, enabling the production of higher-quality and more durable iron goods.

Economic growth: The growth of European economies during the 13th to 16th centuries created a demand for more and diverse manufactured goods. The rise of a wealthier merchant class and an emerging consumer culture fueled the growth of various industries, including textiles, glassware, metalwork, and ceramics. This economic expansion led to the development of larger and more specialized workshops and factories to meet the growing demand for manufactured goods.

Urbanization: The growth of urban centers during this period played a crucial role in the evolution of manufacturing. Cities provided a concentrated market for manufactured goods, as well as access to skilled labor, raw materials, and transportation networks. As cities grew, so did the size and complexity of manufacturing operations, with craftsmen increasingly working together in larger workshops and factories.

Expansion of trade networks: The expansion of long-distance trade networks during the 13th to 16th centuries facilitated the exchange of goods, ideas, and technologies across different regions. This led to the diffusion of new production techniques, materials, and products, spurring innovation and competition within the manufacturing sector. The growth of international trade also created opportunities for specialization, with certain regions and cities becoming known for specific industries, such as textiles in Flanders or glassmaking in Venice.

Guilds and manufacturing organization: The influence of guilds played a significant role in shaping manufacturing during this period. Guilds were associations of craftsmen that regulated and controlled various aspects of production, including quality standards, training, and market access. Guilds helped to organize production and ensure high standards of craftsmanship, but their strict regulations and monopolistic practices could also limit innovation and competition within certain industries.

Overall, the evolution of manufacturing production during the 13th to 16th centuries laid the groundwork for the Industrial Revolution that followed. This period saw significant advancements in technology, economic growth, and the

expansion of trade networks, all of which contributed to the increasing scale and complexity of manufacturing operations. The foundation established during this period would ultimately pave the way for the mass production and mechanization of the manufacturing industry in the centuries to come.

3.4. Inventors and first machines. Evolution of natural science

During the 14th to 16th centuries, various inventors and innovations contributed to the development of early machines and technologies. These inventions laid the foundation for the later advancements during the Industrial Revolution. Here are some notable inventors and their creations during this period:

Filippo Brunelleschi (1377-1446): An Italian architect and engineer, Brunelleschi was responsible for the construction of the dome of the Florence Cathedral. He invented various machines and devices to aid in the construction, including a hoisting machine that allowed for the efficient transportation of heavy materials to the top of the dome.

Johannes Gutenberg (c. 1398-1468): A German inventor, Gutenberg is best known for his invention of the movable type printing press around 1440. This revolutionary machine allowed for the mass production of printed materials, leading to increased literacy, the spread of knowledge, and the eventual birth of the information age.

Leonardo da Vinci (1452-1519): As an Italian polymath, da Vinci contributed significantly to various fields, including engineering and mechanics. He designed numerous machines and devices, such as flying machines, water-powered mills, and a mechanical knight (a precursor to the modern robot). While many of his ideas were not realized during his lifetime, they were instrumental in inspiring later inventors and engineers.

Taqi al-Din (1526-1585): An Ottoman polymath and engineer, Taqi al-Din developed various machines and devices, including a six-cylinder pump for raising

water and a high-precision mechanical astronomical clock. He also made significant contributions to the fields of optics and astronomy.

Cornelis Drebbel (1572-1633): A Dutch inventor, Drebbel was responsible for numerous innovations, including the first navigable submarine, which he built in 1620. He also developed an automatic chicken incubator and made improvements to the telescope and the microscope.

Galileo Galilei (1564-1642): An Italian astronomer, physicist, and engineer, Galileo contributed significantly to the development of early machines and technologies. He designed various instruments, such as a military compass and a thermoscope (an early thermometer). Galileo's work laid the groundwork for the later development of the pendulum clock and other precision instruments.

These inventors and their machines played a crucial role in shaping the technological landscape during the 14th to 16th centuries. Their innovations laid the groundwork for future advancements in machinery and technology, eventually leading to the Industrial Revolution and the modern era.

The 14th to 16th centuries marked a period of significant advancements in the field of natural sciences. This era, often referred to as the Renaissance, saw a renewed interest in the classical works of ancient Greece and Rome, as well as the emergence of new ideas and discoveries. The evolution of natural sciences during this period can be attributed to several factors, including the development of new scientific methods, the contributions of individual scholars, and the increased interaction between various disciplines.

Development of new scientific methods: The Renaissance period saw the development of new scientific methodologies that shifted the focus from philosophical speculation to observation, experimentation, and mathematical analysis. This empirical approach, which emphasized the importance of direct observation and the collection of data, laid the groundwork for modern scientific inquiry.

Contributions of individual scholars: Several scholars made significant contributions to the advancement of natural sciences during the 14th to 16th centuries. Some of the most notable figures include:

Nicolaus Copernicus (1473-1543): A Polish astronomer, Copernicus proposed the heliocentric model of the solar system, which posited that the sun, rather than the Earth, was at the center of the universe. This theory challenged the long-held geocentric model and sparked a revolution in the field of astronomy.

Andreas Vesalius (1514-1564): A Flemish anatomist and physician, Vesalius is known for his groundbreaking work in human anatomy. His book "De Humani Corporis Fabrica" (On the Fabric of the Human Body) provided detailed illustrations and descriptions of the human body, challenging the accepted knowledge of the time, which was largely based on the works of the ancient Greek physician Galen.

Galileo Galilei (1564-1642): An Italian astronomer, physicist, and mathematician, Galileo made numerous contributions to the fields of physics, astronomy, and the scientific method. His observations and experiments led to the development of the laws of motion and the discovery of the four largest moons of Jupiter, among other achievements.

William Gilbert (1544-1603): An English physician and physicist, Gilbert is known for his pioneering work in the field of magnetism and electricity. His book "De Magnete" (On the Magnet) laid the foundation for the study of electromagnetism and influenced later scientists such as Michael Faraday and James Clerk Maxwell.

Increased interaction between disciplines: The Renaissance period saw an increased interaction between various fields of study, including mathematics, astronomy, physics, and medicine. This interdisciplinary approach facilitated the exchange of ideas and methods, contributing to the advancement of natural sciences.

The invention of the printing press: The invention of the movable type printing press by Johannes Gutenberg in the 15th century played a crucial role in the dissemination of scientific knowledge. The mass production of books allowed for the widespread distribution of scientific texts, leading to a greater exchange of ideas and the acceleration of scientific progress.

In conclusion, the 14th to 16th centuries marked a period of significant advancements in the field of natural sciences. The development of new scientific methods, contributions of individual scholars, increased interaction between disciplines, and the invention of the printing press all played a crucial role in shaping the evolution of natural sciences during this period. These advancements laid the groundwork for the Scientific Revolution and the subsequent development of modern science.

Control Questions:

1. Describe the medieval guild system and its influence on production and technology. How did these organizations help shape the development of various crafts and industries during the Middle Ages?
2. Discuss the scientific and technical achievements of Central Asia and the Far East during the Middle Ages. How did these advancements contribute to the overall development of technology in this period?
3. Explain the concept of manufactory production and its evolution during the Middle Ages. How did this form of production differ from earlier methods, and what impact did it have on technology and society?
4. Identify some of the most notable inventors and their inventions during the Middle Ages. How did these innovations contribute to the development of technology during this period?

5. Describe the evolution of natural science during the Middle Ages. How did the growth of scientific knowledge influence technological advancements in this era?
6. Analyze the impact of the Middle Ages on the overall trajectory of scientific and technological development. How did innovations from this period lay the foundation for future advancements?
7. Compare the development of technology in different regions during the Middle Ages. What factors contributed to variations in technological progress among these areas?
8. Assess the role of religion and the church in the development of science and technology during the Middle Ages. How did religious institutions both help and hinder technological progress in this era?
9. Evaluate the importance of trade and commerce in the dissemination of scientific knowledge and technological innovations during the Middle Ages. How did these exchanges contribute to the development of technology across regions?
10. Reflect on the lessons that can be learned from studying the development of production and technology during the Middle Ages. How do these insights help us better understand the historical context and evolution of science and technology in human society?

Basic literature: [2]; [5]; [8].

Additional literature: [4]; [20]; [24]; [25]; [29]; [32]; [35]; [39]; [43]; [44]; [47].

CHAPTER 4. DEVELOPMENT OF SCIENCE AND TECHNOLOGY DURING THE INDUSTRIAL REVOLUTION

- The industrial revolution in England. The invention of the steam engine.
- Mechanical engineering and development of metallurgy.
- Technical progress in transport and communication technology.
- Development of technical sciences.

4.1. The industrial revolution in England. The invention of the steam engine

The Industrial Revolution, which began in England during the late 18th century, was a period of rapid industrialization, urbanization, and economic growth that transformed the country and ultimately had a profound impact on the global economy. Several factors contributed to the start of the Industrial Revolution in England, including the country's access to resources, its stable political environment, and developments in technology and infrastructure.

Access to resources: England had abundant natural resources, including coal and iron ore, which were essential for the growth of the industrial sector. Coal was used to power steam engines, heat buildings, and manufacture iron and steel, while iron ore was used to produce machinery, tools, and other industrial goods.

Stable political environment: England's stable political environment provided a favorable climate for economic development. The country had a well-established system of property rights, a strong legal system, and a relatively low level of political instability, all of which encouraged investment and the growth of industry.

Developments in technology: A series of technological innovations played a crucial role in driving the Industrial Revolution in England. Some of the most significant inventions and discoveries of the period include:

The flying shuttle, invented by John Kay in 1733, which increased the speed of weaving and helped to revolutionize the textile industry.

James Hargreaves' spinning jenny, invented in 1764, which greatly increased the efficiency of yarn production.

The water frame, developed by Richard Arkwright in 1769, which used water power to drive spinning machinery, further increasing textile production.

James Watt's improvements to the steam engine in the 1770s, which made it more efficient and allowed it to be used in a wide range of industrial applications, from textile mills to mining operations.

Infrastructure improvements: Developments in transportation and infrastructure also contributed to the growth of the Industrial Revolution in England. The construction of canals and the expansion of the railway network allowed for the efficient transportation of raw materials and finished goods, both within the country and overseas. This improved access to markets and facilitated the exchange of ideas, goods, and people.

Urbanization and population growth: The growth of the industrial sector led to increased urbanization and population growth in England. As more people moved to cities to work in factories, the demand for goods and services increased, further stimulating economic growth. At the same time, improvements in agriculture and food production allowed for the population to grow and provided the necessary labor force for the expanding industrial sector.

The Industrial Revolution in England had far-reaching consequences, both domestically and globally. It led to the rise of new industries, the creation of new jobs, and significant improvements in living standards for many people. Additionally, it paved the way for the spread of industrialization to other countries, ultimately transforming the global economy and the nature of work itself.

The invention of the steam engine was a pivotal development during the Industrial Revolution, playing a significant role in the transformation of industry, transportation, and society. The steam engine is a heat engine that uses the expansion of steam to perform mechanical work, typically by driving a piston within a cylinder.

The history of the steam engine can be traced back to the 1st century AD, with the invention of the aeolipile, a simple steam-powered device, by the Greek mathematician and engineer Hero of Alexandria. However, it wasn't until the late 17th and early 18th centuries that the steam engine began to evolve into a practical and efficient machine.

Thomas Savery, an English inventor, developed an early steam-powered device in 1698, known as the "Miner's Friend" or the "Savery Engine." This engine used steam pressure to pump water out of mines, but it had limitations in terms of efficiency and safety.

Thomas Newcomen, another English inventor, improved upon Savery's design and created the first practical steam engine in 1712. The Newcomen atmospheric engine used a piston and cylinder mechanism and was initially employed for pumping water out of mines. While it was a significant improvement over Savery's engine, the Newcomen engine was still relatively inefficient in terms of fuel consumption.

James Watt, a Scottish inventor, and engineer made critical improvements to the steam engine that revolutionized its efficiency and practical applications. In the 1760s, Watt worked on an existing Newcomen engine and realized that much of the energy was wasted due to the constant heating and cooling of the cylinder. In 1769, he patented a separate condenser design that allowed the cylinder to remain hot, significantly improving the engine's efficiency.

Watt continued to refine his steam engine, introducing additional innovations such as the double-acting piston, which allowed the engine to perform work on both the upstroke and the downstroke, and the centrifugal governor, which helped to regulate the engine's speed. Watt also developed a system for converting the linear motion of the piston into rotary motion, which enabled the steam engine to be used in a wide range of industrial applications, from powering textile mills to driving various machines.

The invention and subsequent improvements of the steam engine had a profound impact on the Industrial Revolution and the world at large. Steam engines were used to power machinery, enabling large-scale production and increased efficiency in various industries, such as textiles, mining, and manufacturing. Furthermore, steam engines revolutionized transportation, leading to the development of steam-powered locomotives and ships, which drastically reduced travel times and facilitated the movement of goods and people.

In summary, the invention of the steam engine was a critical milestone during the Industrial Revolution, enabling significant advancements in industry and transportation that shaped the modern world.

4.2. Mechanical engineering and development of metallurgy

Mechanical engineering, as a distinct discipline, emerged during the 18th and 19th centuries alongside the rapid technological advancements of the Industrial Revolution. The development and refinement of machines and mechanical systems during this period laid the foundation for modern mechanical engineering. The following are some key advancements in mechanical engineering during the 18th and 19th centuries:

Steam engines: As discussed earlier, the invention and improvement of steam engines by inventors such as Thomas Newcomen, James Watt, and others had a significant impact on mechanical engineering. Steam engines were used to power a wide range of machines and vehicles, including locomotives, ships, and factory equipment. These engines also contributed to the development of thermodynamics as a scientific discipline.

Machine tools: The development of machine tools, such as lathes, milling machines, and drilling machines, was crucial to the growth of mechanical engineering. These tools enabled the precise shaping and fabrication of metal parts, which was essential for the creation and maintenance of increasingly complex machinery. Key inventors in this area include Henry Maudslay, Joseph Whitworth, and James Nasmyth.

Textile machinery: The textile industry was at the forefront of the Industrial Revolution, and the development of mechanical systems for spinning, weaving, and other processes revolutionized textile production. Some notable inventions include the spinning jenny by James Hargreaves, the water frame by Richard Arkwright, and the power loom by Edmund Cartwright.

Locomotives and railways: The development of steam-powered locomotives and the expansion of railway networks transformed transportation during the 19th century. Notable engineers, such as George Stephenson and Isambard Kingdom Brunel, contributed significantly to the design and construction of locomotives and railway infrastructure.

Mechanical power transmission: The development of systems for transmitting mechanical power, such as belts, pulleys, gears, and shafts, was crucial to the growth of industry during the 18th and 19th centuries. These systems allowed power from a single source, like a steam engine, to be distributed throughout a factory, powering multiple machines simultaneously.

Civil and mechanical engineering overlap: During the 18th and 19th centuries, there was a significant overlap between civil engineering and mechanical engineering, with many engineers working in both fields. For example, the construction of bridges, tunnels, and other infrastructure often involved the design and application of mechanical systems.

Professionalization of mechanical engineering: The establishment of professional societies and institutions, such as the Institution of Mechanical Engineers in the United Kingdom (founded in 1847), marked the

recognition of mechanical engineering as a distinct profession. These institutions helped to define and promote professional standards, as well as providing opportunities for the exchange of ideas and knowledge among engineers.

In conclusion, the 18th and 19th centuries were a critical period in the development of mechanical engineering. The advancements made during this time laid the groundwork for modern mechanical engineering and contributed significantly to the growth and success of the Industrial Revolution.

Metallurgy, the science and technology of extracting metals from their ores and refining them for practical use, experienced significant advancements during the 18th and 19th centuries. This period of rapid industrialization and technological progress led to new developments in the production and processing of various metals, which in turn had far-reaching effects on multiple industries. Some of the key advancements in metallurgy during the 18th and 19th centuries include:

Coke as a fuel source: In the early 18th century, Abraham Darby discovered that coke, a byproduct of coal, could be used as a fuel source in the production of iron. This development had a profound impact on the iron and steel industries, as coke allowed for more efficient and cost-effective iron production compared to charcoal. The widespread use of coke as a fuel source contributed to the growth of the iron industry during the Industrial Revolution.

Puddling process: In the late 18th century, English inventor Henry Cort developed the puddling process, which significantly improved the quality and efficiency of wrought iron production. Puddling involved heating pig iron in a furnace and stirring it to oxidize impurities, producing a more refined form of iron. This process allowed for the large-scale production of high-quality wrought iron, which was crucial for the construction of bridges, railways, and other infrastructure projects.

Bessemer process: In the mid-19th century, English inventor Sir Henry Bessemer developed the Bessemer process, a groundbreaking method for the mass production of steel. The process involved blowing air through molten pig

iron to remove impurities, resulting in the production of steel with greater strength and durability than wrought iron. The Bessemer process enabled the widespread use of steel in various industries, such as construction, transportation, and manufacturing, and laid the foundation for the modern steel industry.

Open hearth process: In the late 19th century, the open hearth process, also known as the Siemens-Martin process, was developed as an alternative method for steel production. This process used regenerative heating to achieve high temperatures in a furnace, allowing for the efficient production of steel from a mixture of pig iron, scrap iron, and iron ore. The open hearth process enabled greater control over the quality and composition of steel and was widely adopted in the steel industry during the late 19th and early 20th centuries.

Electrolytic refining: The development of electrolytic refining techniques in the 19th century allowed for the production of high-purity metals, such as copper, gold, and silver. The process involved passing an electric current through a solution containing dissolved metal ions, causing the metal to deposit onto a cathode. Electrolytic refining enabled the production of metals with unprecedented levels of purity, which had various applications in industries like electronics and telecommunications.

Aluminum production: The isolation of aluminum metal from its ore was a significant challenge during the 19th century. In 1886, Charles Martin Hall in the United States and Paul Héroult in France independently developed the Hall-Héroult process for extracting aluminum from its ore using electrolysis. This process made the large-scale production of aluminum possible, turning it from a rare and expensive metal into a widely available and affordable material.

In summary, the advancements in metallurgy during the 18th and 19th centuries played a crucial role in the Industrial Revolution and the development of modern industries. New processes for producing and refining metals like iron, steel, and aluminum enabled the growth of industries such as construction, transportation, and manufacturing, and had a lasting impact on the global economy and society.

4.3. Technical progress in transport and communication technology

The 18th and 19th centuries were marked by remarkable technical progress in transportation, which had significant implications for trade, economic development, and social interaction. Advances in transport technologies during this period facilitated the movement of goods and people over greater distances, at faster speeds, and with increased efficiency. Some of the most notable innovations and developments in transportation during the 18th and 19th centuries include:

Canals: The construction of canals in the 18th century provided an efficient means of transporting goods and people. Canals were man-made waterways that linked rivers, lakes, and other bodies of water, enabling the movement of cargo on barges and boats. In both Europe and the United States, extensive canal networks were built, including the Canal du Midi in France and the Erie Canal in the United States. Canals played a crucial role in the early stages of the Industrial Revolution, allowing for the efficient transportation of raw materials and finished products.

Steam-powered ships: The invention of the steam engine in the 18th century revolutionized maritime transportation. Steam-powered ships, such as the Clermont designed by Robert Fulton, allowed for faster and more reliable water transportation compared to sailing vessels. The development of steamships facilitated the growth of global trade and contributed to the expansion of European colonial empires.

Railways and locomotives: The development of steam-powered locomotives and the construction of railway networks in the 19th century dramatically transformed land transportation. Railways enabled the rapid and efficient transportation of goods and people over long distances, significantly reducing travel times and costs. The expansion of railway networks in Europe, the United States, and other regions played a vital role in the Industrial Revolution by connecting urban centers, rural areas, and resources, and stimulating economic growth.

Road improvements: The 18th and 19th centuries also witnessed significant advancements in road construction and maintenance. Engineers like John McAdam and Thomas Telford developed new techniques for building and improving roads, such as using layers of crushed stone to create a stable, durable surface. These advancements allowed for smoother, more reliable road travel and contributed to the growth of coach services, trade, and transportation.

Bicycles: The invention of the bicycle in the 19th century provided a new, efficient means of personal transportation. Early bicycles, such as the velocipede or "boneshaker," evolved into more advanced designs like the penny-farthing and the safety bicycle. Bicycles offered a relatively affordable and accessible mode of transportation, particularly in urban areas, and contributed to the development of transportation infrastructure, such as dedicated bike paths and paved roads.

Ballooning and early aviation: While the practical impact of ballooning on transportation was limited, the development of hot air balloons and gas-filled airships in the 18th and 19th centuries marked the beginning of human flight. Pioneers like the Montgolfier brothers and Henri Giffard made significant strides in the field of aviation, paving the way for future advancements in air transportation.

In summary, the technical progress in transportation during the 18th and 19th centuries played a vital role in the growth of trade, economic development, and social interaction. Innovations in transportation technologies facilitated the movement of goods and people over greater distances, enabling unprecedented levels of connectivity and contributing to the global economy's expansion.

During the 18th and 19th centuries, significant advancements in communication technology transformed the way people exchanged information and connected with each other. These innovations played a crucial role in shaping the modern world by accelerating the flow of information, promoting trade, facilitating social interactions, and enabling political and cultural exchange. Some of the most notable developments in communication technology during the 18th and 19th centuries include:

Postal systems: In the 18th century, postal systems were expanded and modernized to enable more efficient and reliable mail delivery. National postal services, like the Royal Mail in the UK and the United States Postal Service, implemented innovations such as the use of stagecoaches, mail coaches, and standardized postage rates. These improvements allowed for quicker and more dependable communication through letters and packages.

Optical telegraph: The optical telegraph, or semaphore, was an early communication system that used visual signals, typically towers with movable arms, to transmit messages over long distances. Invented by Claude Chappe in France during the late 18th century, semaphore lines were built across Europe and used primarily for military and government communication.

Electrical telegraph: The invention of the electrical telegraph in the early 19th century marked a significant breakthrough in communication technology. The electrical telegraph used electrical signals to transmit messages over long distances through a network of wires. Samuel Morse's development of Morse code and the Morse telegraph system in the 1840s allowed for rapid and efficient communication across continents. The widespread adoption of the telegraph revolutionized communication by reducing the time required to send messages over long distances from days or weeks to mere minutes.

Photography: Invented in the early 19th century, photography enabled the capture and reproduction of images, providing a new means of communication and documentation. Early photographic processes, such as the daguerreotype and

calotype, evolved into more practical and accessible methods like the wet plate collodion process and eventually, the dry plate process. Photography played a crucial role in journalism, art, and documenting historical events.

Telephone: Alexander Graham Bell's invention of the telephone in the 1870s further revolutionized communication by allowing people to speak with each other directly over long distances. The telephone's adoption and the subsequent expansion of telephone networks transformed personal and business communication, enabling real-time conversations between individuals separated by vast distances.

Transatlantic telegraph cable: The successful laying of the first permanent transatlantic telegraph cable in 1866 connected North America and Europe, enabling near-instant communication across the Atlantic Ocean. This technological feat reduced the time it took to send messages between the continents from days or weeks to mere minutes, significantly impacting international trade, diplomacy, and news reporting.

Typewriters: The invention of the typewriter in the late 19th century provided a more efficient means of producing written communication. Typewriters enabled the creation of standardized, legible documents and helped increase the speed and accuracy of written communication. Typewriters were widely adopted in offices, newsrooms, and homes, shaping the way people composed and shared written information.

In summary, the advancements in communication technology during the 18th and 19th centuries dramatically transformed the way people exchanged information and connected with each other. These innovations accelerated the flow of information, promoted trade, facilitated social interactions, and enabled political and cultural exchange, ultimately shaping the modern world.

4.4. Development of technical sciences

The 18th and 19th centuries were marked by rapid advancements in technical sciences, spurred by the spirit of the Enlightenment and the needs of the Industrial Revolution. During this period, numerous scientific discoveries, inventions, and innovations laid the foundation for many modern technologies and transformed the way people lived and worked. Some key developments in the technical sciences during the 18th and 19th centuries include:

Mechanical engineering: The field of mechanical engineering expanded significantly during the Industrial Revolution, with the development of new machines, tools, and manufacturing processes. Notable advancements include James Watt's improvements to the steam engine, the development of the spinning jenny and power loom for textile manufacturing, and the invention of machine tools such as the lathe and milling machine.

Materials science and metallurgy: The development of new materials and metallurgical processes was crucial for the growth of industry during the 18th and 19th centuries. Innovations such as the puddling process for iron production, the Bessemer process for steel production, and the introduction of new alloys like aluminum and brass enabled the construction of more robust and efficient machines, infrastructure, and consumer goods.

Civil engineering: The construction of large-scale infrastructure projects like canals, roads, railways, and bridges spurred advancements in civil engineering during the 18th and 19th centuries. Engineers like Thomas Telford, John McAdam, and Isambard Kingdom Brunel designed and built innovative structures that revolutionized transportation and trade, paving the way for modern civil engineering techniques and standards.

Electrical engineering: The development of electrical engineering as a discipline began in the 19th century, with the foundational work of scientists and inventors like Michael Faraday, James Clerk Maxwell, and Thomas Edison. Their

discoveries in electromagnetism, electric power generation, and electric lighting laid the groundwork for the widespread use of electricity in industry, communication, and everyday life.

Chemical engineering: The field of chemical engineering emerged in the 19th century, with the development of new industrial processes for the production of chemicals, materials, and pharmaceuticals. Notable advancements include the Leblanc process for the production of soda ash, the Solvay process for ammonia production, and the development of the synthetic dye industry.

Steam power and thermodynamics: The study of steam power and thermodynamics was a central focus of technical sciences during the 18th and 19th centuries, driven by the need for more efficient and powerful engines. Pioneers like Sadi Carnot, James Prescott Joule, and Rudolf Clausius developed the fundamental principles of thermodynamics, which continue to inform the design and operation of modern heat engines and power systems.

Telegraphy and communication: As mentioned previously, the development of the electrical telegraph and the telephone revolutionized communication in the 19th century. These inventions, along with advances in signal processing and information theory, laid the foundation for modern telecommunications and information technology.

The scientific method and professionalization of engineering: During the 18th and 19th centuries, the scientific method became increasingly influential in the development of technical sciences. The professionalization of engineering also took place during this period, with the establishment of engineering societies, journals, and educational institutions dedicated to the training and advancement of engineers.

In summary, the 18th and 19th centuries were a period of rapid advancement in technical sciences, driven by the needs of the Industrial Revolution and the intellectual spirit of the Enlightenment. These developments transformed the way people lived and worked, laid the foundation for many modern technologies, and continue to shape our world today.

Control Questions:

1. Explain the origins of the Industrial Revolution in England. How did economic, social, and political factors contribute to the rapid development of industry during this period?
2. Describe the invention of the steam engine and its impact on the Industrial Revolution. How did this innovation revolutionize production and transportation?
3. Analyze the growth of mechanical engineering during the Industrial Revolution. How did advancements in this field drive the development of industry and technology?
4. Discuss the development of metallurgy during the Industrial Revolution. How did innovations in metal production and processing shape the course of industrialization?
5. Examine the technical progress in transport during the Industrial Revolution. How did new transportation methods like railways and steamships contribute to the growth of industry and trade?
6. Explore the advancements in communication technology during the Industrial Revolution. How did innovations like the telegraph and the telephone revolutionize communication and impact society?
7. Describe the development of technical sciences during the Industrial Revolution. How did the growth of scientific knowledge influence the course of industrialization?
8. Assess the role of government and private institutions in promoting the development of science and technology during the Industrial Revolution. How did these entities shape the trajectory of innovation during this period?
9. Compare the impact of the Industrial Revolution on different sectors of the economy, such as agriculture, manufacturing, and services. How did technological advancements transform these industries?

10. Reflect on the social, economic, and environmental consequences of the Industrial Revolution. How did rapid industrialization and technological progress impact living standards, working conditions, and the environment?

Basic literature: [2]; [5]; [13].

Additional literature: [1]; [3]; [5]; [7]; [42]; [48]; [50]; [54].

CHAPTER 5. NEW SCIENTIFIC INVENTIONS DURING THE LAST THIRD OF THE 19TH - EARLY 20TH CENTURY

- The development of mathematics and astronomy.
- Fundamental discoveries in physics.
- Chemistry, geology, and mechanics during the period of Modernity.
- The emergence and development of new kinds of transportation and communication.

5.1. The development of mathematics and astronomy

The period between 1800 and 1915 was marked by significant developments and innovations in mathematics. Many important concepts, theories, and methods emerged during this time, influencing various branches of mathematics and setting the stage for further advancements in the 20th century. Some key developments in mathematics during the 1800-1915 period include:

Non-Euclidean Geometry: The development of non-Euclidean geometry in the 19th century challenged the long-standing assumptions of Euclidean geometry. Pioneered by mathematicians such as Nikolai Lobachevsky, János Bolyai, and Carl Friedrich Gauss, non-Euclidean geometry laid the groundwork for modern geometry and its applications in fields like physics and engineering.

Number Theory: Number theory saw significant progress during this period, with major contributions from mathematicians such as Carl Friedrich Gauss, Peter Gustav Lejeune Dirichlet, and Bernhard Riemann. Gauss's *Disquisitiones Arithmeticae* was a foundational work in number theory, and Riemann's introduction of the Riemann zeta function led to important developments in the distribution of prime numbers.

Group Theory: The concept of group theory emerged in the early 19th century, primarily through the work of Évariste Galois and Augustin-Louis Cauchy. Group theory provided a powerful framework for understanding the symmetries and structures of mathematical objects, with applications in various fields like algebra, geometry, and physics.

Real Analysis and Calculus: The foundations of real analysis and calculus were solidified during this period by mathematicians such as Augustin-Louis Cauchy, Karl Weierstrass, and Georg Cantor. Their rigorous treatment of concepts like limits, continuity, and convergence laid the groundwork for modern analysis and its applications in various branches of mathematics and science.

Complex Analysis: Complex analysis, which deals with functions of complex variables, saw significant advancements during this period. Bernhard Riemann, Augustin-Louis Cauchy, and Karl Weierstrass made important contributions to the field, developing key concepts such as analytic continuation, contour integration, and the theory of residues.

Set Theory: Georg Cantor's work on set theory in the late 19th century introduced a new framework for understanding the nature of infinity and laid the foundation for modern set theory. Cantor's ideas faced initial opposition but eventually gained widespread acceptance and became an essential tool for mathematicians in various fields.

Topology: The field of topology, which studies the properties of spaces that are preserved under continuous deformations, emerged during the late 19th and early 20th centuries. Key contributors to the development of topology include Henri Poincaré, Felix Klein, and Georg Cantor. Topology has since become a fundamental area of mathematics with applications in various disciplines.

Mathematical Physics: The 19th and early 20th centuries saw a close relationship between mathematics and physics, with many mathematicians contributing to the development of mathematical models and methods for understanding physical phenomena. Key figures in mathematical physics during this period include James Clerk Maxwell, Lord Kelvin, Henri Poincaré, and Albert Einstein.

Probability and Statistics: The fields of probability and statistics also saw significant advancements during this period. Key developments include the work of Pierre-Simon Laplace on the theory of probability, Adolphe Quetelet's work on social statistics and the concept of the "average man," and Francis Galton's work on regression and correlation.

In summary, the period between 1800 and 1915 was marked by significant advancements in mathematics, with the development of new concepts, theories, and methods that continue to influence various branches of mathematics today.

The period between 1800 and 1915 witnessed considerable advancements in the field of astronomy. New discoveries, technological innovations, and emerging theories expanded human understanding of the universe during this time. Some of the key developments in astronomy during the 1800-1915 period include:

Discovery of new celestial bodies: The early 19th century saw the discovery of several new celestial bodies in our solar system. The first asteroid, Ceres, was discovered by Giuseppe Piazzi in 1801. This was followed by the discovery of many other asteroids throughout the century. In 1846, Urbain Le Verrier and John Couch Adams independently predicted the existence of a new planet, Neptune, which was subsequently observed by Johann Gottfried Galle.

Stellar spectroscopy: The development of spectroscopy in the mid-19th century enabled astronomers to study the chemical composition of stars by analyzing the light they emit. Gustav Kirchhoff and Robert Bunsen's work on spectroscopy laid the foundation for this field, and astronomers such as William Huggins and Angelo Secchi made significant contributions by classifying stars based on their spectral characteristics.

Astrophotography: The invention of photography in the early 19th century led to its application in astronomy, known as astrophotography. This technique allowed for the capture of more detailed and accurate images of celestial objects, significantly advancing astronomical research. Pioneers in this field include John William Draper, who took the first photograph of the Moon, and Henry Draper, who took the first photograph of a stellar spectrum.

Development of large telescopes: The 19th and early 20th centuries saw the construction of several large telescopes, which significantly improved observational capabilities. Notable examples include the Leviathan of Parsonstown, built by William Parsons in 1845, and the 100-inch Hooker Telescope at the Mount Wilson Observatory, completed in 1917.

Theoretical astrophysics: The emerging field of theoretical astrophysics during the late 19th and early 20th centuries sought to explain the physical processes occurring in celestial objects using mathematical models and physical laws. Key figures in this field include James Clerk Maxwell, who developed a theory of electromagnetism that explained the behavior of light, and Lord Kelvin and Hermann von Helmholtz, who proposed theories on the source of the Sun's energy.

Stellar evolution and classification: During this period, astronomers developed a better understanding of the life cycles and types of stars. Ejnar Hertzsprung and Henry Norris Russell independently developed the Hertzsprung-Russell (H-R) diagram, which relates the luminosity of stars to their spectral type or temperature. This diagram remains a fundamental tool in understanding stellar evolution and classification.

Discovery of the Cepheid variable stars: In 1908, Henrietta Swan Leavitt discovered a relationship between the period and luminosity of Cepheid variable stars, which allowed astronomers to measure the distance to these stars and, consequently, the size of the Milky Way galaxy. This discovery laid the groundwork for the development of the cosmic distance scale and the understanding of the scale of the universe.

Einstein's theory of relativity: Although not directly related to observational astronomy, Albert Einstein's development of the theory of relativity in the early 20th century had profound implications for the understanding of the universe. The theory, which describes the fundamental relationship between space, time, and matter, has numerous applications in modern astronomy and has shaped our current understanding of the cosmos.

In summary, the period between 1800 and 1915 was marked by significant advancements in astronomy, including the discovery of new celestial bodies, the development of new observational techniques and instruments.

5.2. Fundamental discoveries in physics

The period between 1800 and 1915 witnessed a series of groundbreaking discoveries in physics that would shape the scientific understanding of the universe and pave the way for future advancements. Some of the most influential discoveries and developments in physics during this time include:

Electromagnetism: Hans Christian Ørsted's 1820 discovery of the relationship between electricity and magnetism marked the beginning of the study of electromagnetism. André-Marie Ampère, Michael Faraday, and other physicists further developed this field, ultimately leading to James Clerk Maxwell's formulation of the unified theory of electromagnetism in the 1860s. Maxwell's equations, which describe the behavior of electric and magnetic fields, remain fundamental to our understanding of electromagnetism today.

Thermodynamics: The 19th century saw the development of the laws of thermodynamics, which govern the behavior of energy and heat in physical systems. Key figures in this field include Sadi Carnot, who laid the groundwork for the study of thermodynamics with his work on heat engines, and Rudolf Clausius and William Thomson (Lord Kelvin), who formulated the first and second laws of thermodynamics. These laws provided a framework for understanding the conservation of energy and the direction of energy flow in physical systems.

Kinetic theory of gases: The kinetic theory of gases, which describes the behavior of gases in terms of the motion of their constituent particles, was developed in the mid-19th century. Key contributions were made by James Clerk Maxwell, Ludwig Boltzmann, and Josiah Willard Gibbs. The kinetic theory of gases provided insights into the relationships between temperature, pressure, and volume in gases and led to the development of statistical mechanics.

Quantum theory: The early 20th century saw the emergence of quantum theory, which fundamentally changed our understanding of the behavior of particles at the atomic and subatomic scales. Max Planck's work on black-body radiation in 1900 introduced the concept of quantized energy levels, and Albert Einstein's explanation of the photoelectric effect in 1905 further solidified the idea that energy is quantized in discrete units called quanta.

Special relativity: In 1905, Albert Einstein published his theory of special relativity, which describes the behavior of objects moving at speeds close to the speed of light. Special relativity introduced the concepts of time dilation, length contraction, and the equivalence of mass and energy ($E=mc^2$), fundamentally changing our understanding of space and time.

Atomic structure: The understanding of atomic structure advanced significantly during this period. J.J. Thomson's discovery of the electron in 1897 marked the beginning of modern atomic theory. Ernest Rutherford's gold foil experiment in 1911 led to the proposal of the nuclear model of the atom, with a small, dense nucleus containing protons surrounded by orbiting electrons.

Radioactivity: The discovery of radioactivity in 1896 by Henri Becquerel and the subsequent work of Marie and Pierre Curie on radioactive elements like radium and polonium significantly expanded our knowledge of atomic processes. These discoveries laid the foundation for the study of nuclear physics and the eventual development of nuclear power and weapons.

X-rays: In 1895, Wilhelm Conrad Röntgen discovered X-rays, a form of high-energy electromagnetic radiation. This discovery revolutionized medical diagnostics and led to further exploration of the properties of electromagnetic radiation.

In summary, the period between 1800 and 1915 saw numerous groundbreaking discoveries in physics that laid the foundation for modern scientific understanding. These discoveries spanned various fields, including electromagnetism, thermodynamics, quantum theory, and atomic structure, and continue to shape our understanding of the physical world today.

5.3. Chemistry, geology, and mechanics during the period of Modernity

The period between 1800 and 1915 was marked by significant advancements and discoveries in the fields of chemistry, geology, and mechanics. These developments laid the groundwork for modern scientific understanding and continue to influence these fields today.

Chemistry:

Atomic theory: John Dalton, an English chemist, proposed his atomic theory in 1803, which stated that all matter is made up of indivisible and indestructible atoms. This theory provided a foundation for the understanding of chemical reactions and the behavior of elements.

Periodic table: Dmitri Mendeleev, a Russian chemist, formulated the periodic table in 1869. Mendeleev's table organized elements based on their atomic weights

and properties, allowing for the prediction of undiscovered elements and providing a systematic framework for the study of chemistry.

Structural chemistry: The understanding of chemical structures and bonding advanced significantly during this period. Friedrich August Kekulé von Stradonitz, and Archibald Scott Couper independently proposed the concept of chemical structure, which explained how atoms are arranged in molecules.

Stereochemistry: Jacobus Henricus van 't Hoff and Joseph Le Bel independently developed the concept of stereochemistry in the 1870s, providing an understanding of the three-dimensional arrangement of atoms in molecules and its effect on chemical properties.

Radiochemistry: The discoveries of radioactivity and radioactive elements by Henri Becquerel and Marie and Pierre Curie during the late 19th and early 20th centuries led to the development of radiochemistry, which studies the behavior of radioactive substances and their applications.

Geology:

Stratigraphy and the Geological Time Scale: Early 19th-century geologists, such as William Smith, Georges Cuvier, and Alexandre Brongniart, developed the principles of stratigraphy, which involves studying rock layers to reconstruct Earth's geological history. This work laid the foundation for the creation of the Geological Time Scale, which organizes Earth's history into distinct time periods based on geological and paleontological evidence.

Uniformitarianism: The principle of uniformitarianism, first proposed by James Hutton and later popularized by Charles Lyell in his influential book "Principles of Geology" (1830-1833), suggested that geological processes occurring in the present could be used to explain the geological features observed in the past. This idea challenged the prevailing catastrophism theory and provided a framework for understanding the slow, continuous processes that shape Earth's surface.

Ice Age Theory: In the mid-19th century, Swiss scientist Louis Agassiz proposed the theory that Earth had experienced multiple ice ages, during which large portions of the planet were covered in ice. This theory, supported by evidence such as glacial deposits and characteristic landforms, significantly influenced the understanding of Earth's climate history and geological processes.

Plate Tectonics: Although the theory of plate tectonics was not fully developed until the mid-20th century, early evidence for continental drift and the idea that continents had once been connected began to emerge during the late 19th and early 20th centuries. Geologists such as Alfred Wegener, who proposed the theory of continental drift in 1912, laid the groundwork for the eventual development of the plate tectonics theory.

Mechanics:

Development of Classical Mechanics: In the early 19th century, mathematicians and physicists, such as Joseph Louis Lagrange and William Rowan Hamilton, expanded on the principles of classical mechanics laid down by Isaac Newton. They developed new mathematical formulations, such as Lagrangian and Hamiltonian mechanics, which provided alternative ways to describe the motion of particles and systems.

Elasticity and Solid Mechanics: The study of the deformation and motion of solid materials, known as solid mechanics, advanced significantly during the 19th century. Contributions from scientists like Augustin-Louis Cauchy, who developed the theory of elasticity, and Thomas Young, who introduced Young's modulus as a measure of a material's stiffness, led to a better understanding of the behavior of materials under stress and strain.

Fluid Mechanics: The 19th century saw significant advancements in the understanding of fluid behavior and the development of mathematical models to describe fluid motion. Key contributors in this field include Claude-Louis Navier and George Gabriel Stokes, who independently developed the Navier-Stokes equations, which describe the motion of viscous fluid substances.

Statistical Mechanics: In the late 19th and early 20th centuries, physicists like James Clerk Maxwell, Ludwig Boltzmann, and Josiah Willard Gibbs developed the principles of statistical mechanics, which uses statistical methods to describe the behavior of a large number of particles in a system. This approach helped bridge the gap between microscopic laws of physics and macroscopic thermodynamic properties of materials.

These advancements in geology and mechanics during the period between 1800 and 1915 laid the foundation for our modern understanding of Earth's processes and the behavior of physical systems, shaping the fields of Earth science and engineering for years to come.

5.4. The emergence and development of new kinds of transportation and communication

Between 1870 and 1914, the world experienced a rapid emergence and development of new forms of transportation and communication. These innovations revolutionized the way people and goods moved and how information was transmitted, significantly impacting global economic growth and social interaction. Some of the most significant advancements during this period include:

Transportation:

The development of railroads, which played a pivotal role in the rapid industrialization and economic growth of many countries. This era witnessed several advancements in railway technology, expansion of railway networks, and improvements in train operations.

Expansion of railway networks: The late 19th and early 20th centuries saw a dramatic expansion of railway networks across Europe, North America, and other parts of the world. This expansion was driven by the need for faster, more efficient transportation of goods and people to support industrialization and economic growth. Countries like the United States, Great Britain, Germany, and Russia invested heavily in constructing new railway lines, connecting cities, towns, and rural areas, and enabling better access to resources and markets.

Advancements in railway technology: The period also saw several technological advancements in the railway industry. The development of more powerful and efficient steam locomotives allowed trains to travel at faster speeds and carry heavier loads. Railway tracks and bridges were improved to support the increasing weight and speed of trains, while signaling systems and other safety measures were also enhanced to reduce the risk of accidents.

Improvement in train operations: Operational efficiency was a key focus during this period, with railway companies adopting new management techniques, such as time-tabling, to improve punctuality and reduce downtime. In addition, companies started to offer more comfortable passenger services, with better-designed carriages and amenities like dining cars and sleeping compartments.

Economic impact: The expansion and improvement of railroads in this era had a profound impact on the global economy. Railways facilitated the movement of goods, people, and ideas, enabling the growth of industries, urbanization, and the spread of new technologies. Railroads also played a critical role in the development of international trade, as they provided a more efficient and cost-effective means of transporting goods over long distances.

Social impact: The growth of railroads in this period had significant social implications as well. For instance, the availability of faster and more accessible transportation options led to increased mobility for people, allowing them to travel further and more frequently for work or leisure. This, in turn, contributed to the

growth of tourism and the formation of new social and cultural connections between different regions.

Influence on urban development: The expansion of railway networks in the late 19th and early 20th centuries played a crucial role in shaping urban development. Cities and towns grew around railway stations, with new neighborhoods and industries emerging in areas with good rail connections. Railways also led to the creation of suburbs, as people sought to live away from the congested urban centers while still having access to employment opportunities and amenities in the city.

In summary, the period between 1870 and 1915 was a transformative era for railroads, marked by rapid expansion, technological advancements, and improvements in operations. The growth of the railway industry had far-reaching economic, social, and urban development impacts, driving industrialization and fostering greater global interconnectedness.

The period between 1850 and 1900 marked the early stages of the development of automobiles. While the first practical automobile wouldn't appear until the late 19th century, the foundations for the invention and evolution of the automobile were being laid during this time. Key developments and events in this period include:

Steam-powered vehicles: In the early to mid-19th century, steam-powered vehicles were the primary focus for inventors and engineers. These vehicles were large, heavy, and not very practical for everyday use. However, they did pave the way for future innovations and showed the potential of using an engine to power personal transportation.

Internal combustion engine: A crucial step in the development of the automobile was the invention of the internal combustion engine. In 1860, French engineer Étienne Lenoir developed the first internal combustion engine that used a mixture of coal gas and air. His invention, called the "Hippomobile," was a significant milestone, but it was inefficient and not yet suitable for powering automobiles.

Nikolaus Otto's four-stroke engine: In 1876, German engineer Nikolaus Otto invented the four-stroke internal combustion engine, which is also known as the Otto cycle. Otto's engine was more efficient and practical than Lenoir's design and set the stage for the development of modern gasoline engines.

Karl Benz and the first gasoline-powered automobile: In 1885, German engineer Karl Benz built the first gasoline-powered automobile, known as the Benz Patent-Motorwagen. It was a three-wheeled vehicle powered by a single-cylinder engine, and it is considered the first practical automobile. Benz received a patent for his invention in 1886, marking the official birth of the automobile era.

Gottlieb Daimler and Wilhelm Maybach: German inventors Gottlieb Daimler and Wilhelm Maybach also made significant contributions to the development of automobiles during this period. In 1885, they built a four-wheeled vehicle with a high-speed internal combustion engine. Their vehicle, called the "Cannstatt-Daimler," featured a number of innovations, such as the first use of a carburetor to mix fuel and air. Daimler also patented the first motorcycle in 1885.

Early electric vehicles: In the late 19th century, electric vehicles began to emerge as an alternative to gasoline-powered cars. Electric cars were quieter, cleaner, and easier to operate than their gasoline counterparts, but they suffered from limited range and long recharging times. Thomas Edison even worked on improving battery technology for electric vehicles, but ultimately, gasoline-powered cars would dominate the market.

In summary, the period between 1850 and 1900 saw the early development of automobiles, with inventors and engineers experimenting with steam-powered vehicles, internal combustion engines, and electric vehicles. The late 19th century marked the birth of the automobile era, with Karl Benz's gasoline-powered Patent-Motorwagen and innovations from Gottlieb Daimler and Wilhelm Maybach laying the groundwork for the future of personal transportation.

The period between 1850 and 1900 was marked by significant developments and experiments in aviation, leading up to the Wright Brothers' first powered flight in 1903. Here are some key events and inventions that occurred during this time:

Early gliders: Throughout the 19th century, many inventors and engineers experimented with gliders, unpowered aircraft that could achieve sustained flight by exploiting the lift generated by air currents. Sir George Cayley, an English engineer and aviation pioneer, designed and built gliders in the early 1800s, laying the foundation for future developments in aviation.

Balloons and airships: Balloons had been around since the 18th century, but they saw significant advancements in the 19th century. Balloons filled with lighter-than-air gases, such as hydrogen or helium, were used for aerial reconnaissance, transportation, and even mail delivery. Airships, also known as dirigibles, were developed as steerable versions of balloons, incorporating engines for propulsion and a rigid or semi-rigid frame for structural support. Count Ferdinand von Zeppelin's development of the rigid airship in the late 1800s was a significant milestone in aviation history.

Otto Lilienthal's gliding experiments: German aviation pioneer Otto Lilienthal conducted extensive research on the principles of flight, focusing on the study of bird flight and wing design. Between 1891 and 1896, Lilienthal carried out more than 2,000 gliding flights using various glider designs. His work greatly influenced the Wright Brothers and other aviation pioneers, and he is often referred to as the "Father of Modern Aviation."

Octave Chanute's contributions: Octave Chanute, a French-American civil engineer, played a crucial role in the development of aviation by bringing together various aviation pioneers and sharing their ideas and research. He published "Progress in Flying Machines" in 1894, which summarized the existing knowledge on aerodynamics, gliders, and other aviation-related topics. Chanute also designed and tested several gliders of his own.

Samuel Langley's aerodrome: American astronomer and aviation pioneer Samuel Langley successfully flew a series of steam-powered model aircraft called "Aerodromes" in the 1890s. Langley's experiments demonstrated the feasibility of powered flight and attracted considerable attention from the scientific community and the public.

Gustave Whitehead's claims: Gustave Whitehead, a German-American inventor, claimed to have achieved powered flight in 1901, two years before the Wright Brothers. While some contemporary reports support Whitehead's claims, there is ongoing debate among historians and aviation experts about the veracity of these claims, and the Wright Brothers are still widely recognized as the inventors of the first successful powered airplane.

The period between 1850 and 1900 saw significant developments in aviation, with pioneers like Otto Lilienthal, Octave Chanute, and Samuel Langley conducting experiments and research that would pave the way for the Wright Brothers and the era of powered flight.

The period between 1850 and 1900 was marked by significant advancements in steamship technology and an increased use of steamships for transportation, trade, and military applications. Here are some key developments and milestones during this time:

Expansion of transatlantic steamship travel: In the mid-19th century, steamship companies like the Cunard Line and Inman Line expanded their transatlantic services, providing regular and reliable travel between Europe and North America. Steamships like the RMS Britannia and the SS Great Western greatly reduced travel time compared to sailing ships, making it possible to cross the Atlantic in as little as 10-14 days.

Technological advancements: Steamship technology saw considerable improvements in the second half of the 19th century. Innovations such as the compound steam engine, which used high-pressure steam more efficiently, and the introduction of steel hulls allowed for larger, faster, and more efficient ships.

Passenger travel: The growing middle class and the increased availability of affordable travel options led to a boom in passenger travel during this period. Steamships like the RMS Oceanic and the RMS Majestic were built to accommodate the rising demand for transatlantic travel, offering luxurious accommodations and various classes of service.

Commercial trade: Steamships played a crucial role in global trade and transportation, as they were faster, more reliable, and capable of carrying larger cargo loads than sailing ships. Steamships facilitated the growth of international trade networks and the movement of goods between countries, stimulating economic growth and globalization.

The Suez Canal: The opening of the Suez Canal in 1869 had a significant impact on steamship travel and trade. The canal provided a shorter route between Europe and Asia, reducing the travel distance by thousands of miles and making steamships even more efficient and economical for global trade.

Military applications: The advancements in steamship technology led to the development of steam-powered warships, which were faster, more maneuverable, and better armed than sailing ships. Steam-powered ironclads, like the HMS Warrior and the USS Monitor, revolutionized naval warfare and played significant roles in conflicts such as the American Civil War and the various colonial conflicts of the late 19th century.

Exploration and scientific research: Steamships also played a crucial role in the exploration of the world's oceans and remote regions. Ships like the HMS Challenger, which undertook the first global oceanographic survey between 1872 and 1876, helped advance scientific knowledge of the world's seas and marine life.

In summary, the period between 1850 and 1900 saw substantial advancements in steamship technology, leading to faster, more efficient, and more reliable ships. This period marked a significant expansion of global trade, passenger travel, and military applications, as well as the exploration and study of the world's oceans.

In the sphere of communication the telegraph was a groundbreaking invention in the 19th century, revolutionizing communication by allowing rapid transmission of messages over long distances. Between 1800 and 1915, the telegraph underwent significant development and expansion, playing a crucial role in shaping modern society.

Early experiments: The concept of the electric telegraph can be traced back to the late 18th and early 19th centuries, with inventors like Alessandro Volta, Samuel Thomas von Sömmering, and Sir Francis Ronalds making early contributions to the field. However, it wasn't until the 1830s and 1840s that practical telegraph systems began to emerge.

Morse code and the first telegraph line: In 1837, American inventor Samuel Morse, along with his assistant Alfred Vail, developed the Morse code, a system of dots and dashes representing letters and numbers that could be transmitted electronically. In 1844, Morse successfully sent the first telegraph message using Morse code from Washington, D.C., to Baltimore, Maryland, demonstrating the potential of the telegraph for long-distance communication.

Rapid expansion of telegraph networks: Following the success of Morse's demonstration, telegraph lines were quickly constructed across the United States and Europe. By the 1850s, telegraph networks connected major cities and facilitated instant communication between governments, businesses, and individuals.

Transatlantic telegraph cable: One of the most significant achievements of this period was the successful laying of the first transatlantic telegraph cable in 1858, connecting North America and Europe. Although the first cable failed after a few weeks, subsequent attempts were more successful, and by 1866 a reliable connection had been established. This greatly reduced communication time between continents, from weeks or months to mere minutes.

Telegraph and the media: The telegraph had a significant impact on the media, enabling newspapers to receive and publish news from around the world much faster than before. This led to the creation of news agencies like Reuters, Havas, and the Associated Press, which gathered and distributed news via telegraph.

Telegraph in warfare: The telegraph played a crucial role in military communication, allowing commanders to send orders and receive updates from the battlefield in real-time. This was evident in conflicts like the American Civil War and the Crimean War, where telegraph lines were used to coordinate troop movements and relay vital information.

Western Union and the rise of telegrams: Western Union, founded in 1851, became the dominant telegraph company in the United States, constructing a vast network of telegraph lines and offices. The company popularized the use of telegrams, which became an essential method of communication for both personal and business purposes.

Decline of the telegraph: By the early 20th century, the telegraph faced increasing competition from the telephone, which allowed for more natural and direct communication. Although the telegraph remained in use for specialized applications such as stock market ticker tape machines and international communication, its importance began to diminish as the telephone became more widespread.

In summary, between 1800 and 1915, the telegraph revolutionized communication by allowing rapid transmission of messages over long distances. The development and expansion of telegraph networks transformed various aspects of society, including the media, warfare, and personal communication.

The telephone, invented by Alexander Graham Bell in 1876, transformed communication by enabling people to speak directly with each other over long distances. Between 1870 and 1915, the telephone underwent significant development and growth, becoming an indispensable tool for businesses and households alike.

Invention and early development: Alexander Graham Bell was awarded the patent for the telephone in 1876, and soon after, he and his partners formed the Bell Telephone Company. The first telephones were relatively crude, using a single device for both speaking and listening. However, they quickly evolved into more user-friendly designs, with separate earpieces and mouthpieces.

Expansion of telephone networks: In the early years, telephone networks were limited and primarily served businesses and affluent individuals who could afford the cost of installation and service. However, by the 1890s, telephone networks began to expand rapidly in urban areas, with new telephone exchanges being built to accommodate the growing demand for connections.

Technological innovations: Several key innovations contributed to the growth of the telephone during this period. The introduction of long-distance lines allowed for cross-country communication, while the invention of the rotary dial in 1896 by Almon Strowger improved the ease and efficiency of making calls. Additionally, the development of switchboards and the use of operators enabled more efficient call routing and management.

The rise of telephone companies: The Bell Telephone Company initially held a monopoly on the telephone industry, but the expiration of key patents in the 1890s led to the emergence of competing companies, known as "independents". These companies began to build their networks and offer services, leading to increased competition and more affordable pricing for consumers.

Impact on business: The telephone quickly became an essential tool for businesses, facilitating instant communication between offices, suppliers, and customers. The growth of the telephone industry also created numerous job opportunities, particularly for women, who made up the majority of telephone operators.

Residential adoption: As telephone networks expanded and prices decreased, more households began to adopt telephone service. By the early 20th century, the telephone had become a common fixture in middle-class homes, allowing families to stay in touch with friends and relatives across the country.

Government regulation: As the telephone industry grew, it became subject to increasing government regulation. In the United States, the Mann-Elkins Act of 1910 placed telephone companies under the jurisdiction of the Interstate Commerce Commission (ICC), allowing for more oversight and regulation of rates and services.

Impact on society: The widespread adoption of the telephone had a profound impact on society, changing the way people communicated and conducted business. The telephone also played a role in emergency services, with the first 911 emergency call system being introduced in the United States in 1911.

In summary, between 1870 and 1915, the telephone underwent significant growth and development, becoming an essential communication tool for businesses and households alike. Technological innovations, network expansion, and increased competition helped make the telephone more accessible and affordable, while government regulation sought to ensure fair pricing and service. The telephone's impact on society was profound, changing the way people communicated and conducted business. These advancements in transportation and communication between 1870 and 1915 revolutionized the movement of people, goods, and information, driving economic growth and fostering a more interconnected world.

Control Questions:

1. What were some notable developments in mathematics during the late 19th and early 20th centuries, and who were the key mathematicians involved in these advancements?
2. Describe the key astronomical discoveries made during the last third of the 19th century and the early 20th century. How did these discoveries influence our understanding of the universe?
3. Identify three major discoveries in physics during this period and explain their significance in shaping modern physics.
4. How did the periodic table transform our understanding of chemistry during the late 19th and early 20th centuries? Who was responsible for its development?
5. Briefly discuss the advancements made in the fields of geology and mechanics during this period. How did these advancements contribute to the growth of modern science?
6. Explain the significance of the invention of the internal combustion engine in the development of transportation during this period.

7. What were the major innovations in transportation during the late 19th and early 20th centuries, and how did they impact society and industry?
8. Describe the development of communication technology during this period, focusing on the telegraph and the telephone. How did these inventions revolutionize communication and contribute to the growth of global connectivity?
9. How did the advent of new kinds of transportation and communication during this period impact global trade and economic development?
10. In what ways did the scientific and technological advancements of the late 19th and early 20th centuries contribute to shaping the modern world?

Basic literature: [5]; [12]; [17].

Additional literature: [2]; [5]; [6]; [10]; [11]; [16]; [27]; [28]; [40].

CHAPTER 6. DEVELOPMENT OF TECHNOLOGY AT THE BEGINNING OF THE 20th CENTURY

- Electricity is the basis of industrial development.
- Application of new technologies in the metallurgical, machine-building and chemical industries.
- Transport and construction.
- New equipment on the fields of the First World War.

6.1. Electricity is the basis of industrial development

The period between 1870 and 1920 marked a significant turning point in industrial development, largely due to the widespread adoption and utilization of electricity. This newfound ability to harness and distribute electrical power led to transformative changes in industry, transportation, communication, and everyday life. Some of the most notable ways electricity served as the basis for industrial development during this time include:

Electrification of factories: The adoption of electric motors in factories revolutionized industrial production. Electric motors replaced steam engines and waterwheels, allowing for more flexible and efficient factory layouts, increased productivity, and a safer working environment. Factories could now be built anywhere, no longer needing to be near a water source or coal supply to generate power.

Electric lighting: The invention of the incandescent light bulb by Thomas Edison in 1879 (and other inventors such as Sir Hiram Maxim and Sir Joseph Swan) enabled the widespread use of electric lighting in factories, homes, and public spaces. Electric lighting allowed for longer working hours, increased productivity, and improved working conditions. Additionally, it contributed to the growth of cities and urbanization, as streets could now be lit at night, enhancing public safety and commerce.

Electric transportation: The development and implementation of electric transportation systems, such as streetcars, trams, and electric railways, provided faster, cleaner, and more efficient means of moving people and goods in urban areas. This helped to alleviate congestion, reduce dependence on horses, and improve the overall quality of life in cities. Electrification also played a role in the development of electric-powered elevators, which enabled the construction of taller buildings and shaped the skylines of modern cities.

Electric communication: The expansion of telegraph and telephone networks, as well as the invention of radio, relied on electricity to transmit information quickly and efficiently over long distances. These advances in communication technologies facilitated global connectivity, reshaped business practices, and transformed the way people interacted with one another.

Household appliances: The introduction of electric household appliances, such as washing machines, refrigerators, vacuum cleaners, and sewing machines, began to emerge during this period. These innovations transformed domestic life, reducing labor-intensive tasks and improving the quality of life for millions of people.

Development of electrical engineering: The growing demand for electricity and electrical systems led to the emergence of electrical engineering as a distinct discipline. Pioneers such as Nikola Tesla, George Westinghouse, and Charles Proteus Steinmetz made significant contributions to the development of alternating current (AC) systems, power generation, and transmission infrastructure, which formed the backbone of modern electrical grids.

Electric power generation and distribution: The construction of large-scale power plants and distribution networks facilitated the generation and transmission of electricity to homes, businesses, and factories. Innovations in power generation, such as hydroelectric dams and large-scale generators, allowed for more efficient and reliable production of electricity.

In summary, electricity was indeed the basis of industrial development between 1870 and 1920. It facilitated significant advancements in manufacturing, transportation, communication, and everyday life, ultimately shaping the modern industrialized world we know today.

The Current War, also known as the War of Currents, was a significant event in the history of science and technology that took place during the late 19th century. The war was a competition between two of the greatest inventors of the time, Thomas Edison and George Westinghouse, over the future of electricity and power distribution.

The origins of the war can be traced back to the late 1870s, when Thomas Edison developed the first practical incandescent light bulb. Edison saw electricity as the key to the future, and he was determined to create a system for generating and distributing it that would transform the way people lived and worked.

Edison's vision for electricity was based on the use of direct current (DC) power, which he saw as the most efficient and reliable way to generate and distribute electricity. However, George Westinghouse had a different vision. Westinghouse believed that alternating current (AC) power was the key to the future of electricity, as it could be generated more efficiently and transmitted over greater distances.

The battle between DC and AC power quickly became known as the War of Currents, with Edison and Westinghouse fighting for dominance in the growing market for electricity. Edison was determined to prove that DC power was superior, and he went to great lengths to discredit AC power and the companies that were developing it.

One of Edison's most notorious tactics was the use of public demonstrations to showcase the dangers of AC power. In 1888, Edison's company, Edison Electric Light Company, used AC power to electrocute animals as part of a public demonstration, in an attempt to show that AC power was dangerous and deadly. However, the demonstrations backfired, as they only served to draw attention to the benefits of AC power and the dangers of Edison's tactics.

Despite Edison's efforts, Westinghouse continued to develop and promote AC power, and he eventually won the battle for dominance in the growing market for electricity. The success of AC power was due in part to the development of the transformer, which made it possible to transmit electricity over long distances with minimal loss of power.

The War of Currents had a significant impact on the future of electricity and power distribution. The success of AC power led to the development of new technologies and industries, including the development of the electric motor and the creation of the modern power grid. The legacy of the War of Currents can still be seen today, with AC power remaining the dominant form of power distribution in most parts of the world

6.2. Application of new technologies in the metallurgical, machine-building and chemical industries

The period between 1890 and 1920 was marked by the application of new technologies across various industries, including metallurgy, machine-building, and the chemical industry. These advancements played a crucial role in shaping the course of industrialization, economic growth, and modernization.

Metallurgical Industry and some notable examples of technological innovations during this time include:

The Bessemer process, developed by British inventor Sir Henry Bessemer in the 1850s, revolutionized the steelmaking industry by providing a cost-effective and efficient method for producing large quantities of steel from pig iron. The process

helped to fuel the rapid industrialization of the 19th century and made steel the primary construction material for many infrastructures, including railways, bridges, and buildings.

The Bessemer process is based on the principle of blowing air through molten pig iron to remove impurities and convert it into steel. A step-by-step description of the Bessemer process:

- **Charging the converter:** The process starts with loading pig iron into a large, pear-shaped vessel called a Bessemer converter. The converter is lined with refractory material that can withstand high temperatures.
- **Blowing air:** Once the pig iron is molten, air is forced through the molten metal using tuyeres, which are small nozzles located at the bottom of the converter. The air blast oxidizes the impurities present in the pig iron, such as silicon, manganese, and carbon, which are then removed as slag or gas.
- **Formation of slag:** The oxidized impurities combine with the limestone or other flux materials, which are added to the converter. The fluxes help to form a liquid slag, which floats on top of the molten metal and is periodically removed.
- **Removal of carbon:** The oxidation of carbon in the pig iron is a critical aspect of the Bessemer process. As the carbon reacts with oxygen, it forms carbon dioxide, which escapes as gas. The removal of carbon reduces the brittleness of the metal, turning it into steel.
- **End of the blow:** When most of the impurities have been removed, and the carbon content has been reduced to the desired level, the air blow is stopped. This usually takes around 15-20 minutes. At this point, the molten steel is still in the converter.
- **Adding alloys:** To further refine the steel and provide specific properties (such as increased strength or corrosion resistance), alloying elements like manganese, chromium, or nickel may be added to the molten steel.
- **Tapping the steel:** The finished steel is then poured, or "tapped", into molds or ladles, where it is allowed to solidify before being shaped into various forms, such as bars, plates, or rails.

The Bessemer process was eventually replaced by more advanced steelmaking techniques, such as the open-hearth process and, later, the basic oxygen process, which offer better control over the steel's composition and properties. However, the Bessemer process played a crucial role in the mass production of steel and contributed to the growth of modern industries.

Open Hearth Furnace: Developed in the late 19th century, the open-hearth process allowed for the production of steel in larger quantities and with greater control over the final product's composition. This method improved the quality and versatility of steel and contributed to the growth of the steel industry.

Electric Arc Furnace: Invented in the early 20th century, the electric arc furnace offered a more efficient and cleaner method of steel production. It used electric arcs to heat and melt scrap metal and other raw materials, enabling the recycling of steel and reducing dependence on traditional blast furnaces.

Machine-building Industry and some notable examples of technological innovations during this time include:

Assembly line production is a manufacturing process that revolutionized the way goods were produced, dramatically increasing efficiency and lowering costs. It was popularized by Henry Ford in the early 20th century when he implemented it in the production of the Ford Model T automobile. The assembly line concept is based on the division of labor and the sequential arrangement of tasks, where each worker or machine is responsible for a specific part of the production process.

The main principles of assembly line production include:

- **Division of labor:** The production process is broken down into smaller, specialized tasks. Each worker or machine focuses on a specific task, allowing for increased efficiency and expertise.
- **Standardization of parts:** Assembly lines rely on the standardization of parts, ensuring that each component is interchangeable and can fit seamlessly into the final product. This standardization helps to streamline production and reduce the likelihood of errors.

- Sequential arrangement: The production process is organized in a linear or sequential manner, with each task being completed in a specific order. As the product moves down the assembly line, each worker or machine adds a component or performs a specific operation.
- Continuous movement: The assembly line is designed to keep products moving through the production process continuously, minimizing delays and increasing overall efficiency.
- Automation: Many modern assembly lines utilize automation, incorporating machines and robots to perform tasks more efficiently and accurately than human workers. Automation can significantly increase production speed and reduce labor costs.

The assembly line production method led to a significant reduction in production time and costs, enabling manufacturers to produce goods more affordably and in greater quantities. As a result, products became more accessible to a wider range of consumers. The adoption of assembly lines across various industries contributed to the rapid industrialization and economic growth experienced during the 20th century. Today, assembly lines are used in the production of a wide range of goods, from automobiles and electronics to food and pharmaceuticals.

Development of Precision Tools and Machines: The advancements in machine tools, such as milling machines, lathes, and grinding machines, enabled the production of high-precision components. This increased the efficiency and quality of machine-building, paving the way for more sophisticated and reliable machinery across various industries.

The application of electric motors during the period of 1870-1915 marked a significant transformation in industrial processes, transportation, and household appliances. The emergence of electric motors led to increased efficiency, reduced operational costs, and cleaner energy compared to the previous reliance on steam engines.

Electric motors were used to power machinery in factories, replacing steam engines and water wheels. This change allowed for greater flexibility in factory layouts, as electric motors could be easily installed and operated wherever needed. Factories also became cleaner and quieter as the need for coal-fired boilers diminished.

The development of electric motors led to innovations in transportation, such as electric trams, streetcars, and trains. These systems offered a cleaner, quieter, and more efficient alternative to steam-powered transportation. Electric elevators also became more prevalent, enabling the construction of taller buildings.

The introduction of electric motors facilitated the development of various household appliances, such as sewing machines, washing machines, vacuum cleaners, and electric fans. These appliances made daily chores more manageable and improved the quality of life for many individuals.

Electric motors played a vital role in power generation, particularly in the form of generators or dynamos. These devices were used to convert mechanical energy into electrical energy, providing electricity to power various applications, from industrial processes to lighting in homes and public spaces.

The development of electric motors supported advances in communication technology during this period. For example, electric motors were used in telegraph systems to power the transmission of messages over long distances.

Overall, the widespread application of electric motors during the period of 1870-1915 revolutionized many aspects of daily life and industry. The increased efficiency, reduced costs, and cleaner energy offered by electric motors contributed to the rapid industrialization and economic growth experienced during this time.

Chemical Industry and some notable examples of technological innovations during this time include:

Haber-Bosch Process: Invented in the early 20th century, the Haber-Bosch process allowed for the industrial-scale production of ammonia by combining nitrogen and hydrogen under high pressure and temperature. This

development had a profound impact on agriculture, as ammonia is a key ingredient in the production of nitrogen-based fertilizers that contributed to increased crop yields and global food production.

The development of synthetic dyes between 1870 and 1915 had a significant impact on various industries, including textiles, printing, and photography. Before the advent of synthetic dyes, natural dyes derived from plants, animals, and minerals were used, but these dyes were often expensive, difficult to produce, and limited in color range.

The revolution in synthetic dyes began in 1856 when an 18-year-old British chemist named William Henry Perkin accidentally discovered the first synthetic dye, called mauveine or Perkin's mauve, while attempting to synthesize quinine. This discovery opened the door to the development of a wide range of synthetic dyes based on aniline and other coal-tar derivatives.

Several important synthetic dyes were developed during the period of 1870-1915, including:

- Alizarin (1869): German chemists Carl Graebe and Carl Liebermann synthesized alizarin, a red dye derived from the madder plant, marking the first time a natural dye had been successfully synthesized.
- Congo Red (1884): Developed by German chemist Paul Böttiger, Congo Red was the first direct dye that could be applied to fabric without the need for a mordant (a substance that helps fix the dye to the fabric). It was initially used for dyeing cotton, but its use expanded to other fabrics.
- Methylene Blue (1876): Heinrich Caro, a German chemist, discovered methylene blue, which became an essential dye for the textile industry. It also played a significant role in medical research, particularly in staining cells for microscopic examination.

- **Synthetic Indigo (1897):** Adolf von Baeyer, a German chemist, successfully synthesized indigo, a blue dye derived from the *Indigofera* plant. The development of synthetic indigo had a profound impact on the dye industry, as it was cheaper and more consistent in quality compared to natural indigo.

The development of synthetic dyes during the period of 1870-1915 had several significant effects. Synthetic dyes greatly expanded the available color range, allowing for the production of vibrant and diverse textiles, papers, and other colored products.

Synthetic dyes were less expensive and more readily available than natural dyes, making them accessible to a wider range of consumers and industries. The demand for synthetic dyes stimulated the growth of the dye and chemical industries, particularly in Germany, which became the global leader in dye production and research. The production and use of synthetic dyes also had negative environmental consequences, including water pollution and toxic waste from dye manufacturing facilities.

Overall, the development of synthetic dyes between 1870 and 1915 revolutionized the dye industry and had a profound impact on multiple sectors, including textiles, printing, and photography. However, it also led to environmental challenges that continue to be addressed today.

Electrochemistry, the study of chemical reactions involving the transfer of electrons, experienced significant advancements between 1870 and 1915. During this period, many fundamental concepts and technologies were developed, laying the foundation for modern electrochemical applications. Some of the key developments include:

- **Laws of Electrolysis (1834, 1857):** Michael Faraday, a British scientist, established the quantitative relationship between electricity and chemical reactions in his laws of electrolysis. Although formulated before 1870, Faraday's laws continued to guide electrochemical research during this period.

- **Electrochemical Series (1884):** The electrochemical series, which arranges elements based on their standard electrode potentials, was introduced by the Swedish chemist Svante Arrhenius. This series helps predict the outcomes of electrochemical reactions and the feasibility of various redox reactions.
- **Ostwald's Dilution Law (1888):** Wilhelm Ostwald, a German chemist, formulated the dilution law for weak electrolytes, providing insights into the behavior of ions in solution and the degree of dissociation.
- **Nernst Equation (1889):** Walther Nernst, a German physical chemist, developed the Nernst equation, which relates the voltage of an electrochemical cell to the concentrations of the reacting species. This equation has broad applications in electrochemistry, including determining equilibrium constants, solubility products, and the standard electrode potentials of half-cells.
- **Discovery of Superconductivity (1911):** Heike Kamerlingh Onnes, a Dutch physicist, discovered superconductivity – the phenomenon of zero electrical resistance – in mercury at very low temperatures. This groundbreaking discovery paved the way for further research into the properties and potential applications of superconducting materials.
- **Development of the Lead-Acid Battery (1859, 1881):** French physicist Gaston Planté invented the lead-acid battery in 1859, but it was not until 1881 that another French scientist, Camille Alphonse Faure, improved its design and made it more practical for widespread use. The lead-acid battery became the first rechargeable battery, widely used in automobiles, telecommunication systems, and various other applications.
- **Edison's Alkaline Storage Battery (1901):** Thomas Edison developed the alkaline storage battery as an alternative to the lead-acid battery. Although it never became as popular as the lead-acid battery, Edison's invention found some applications in electric vehicles, mining equipment, and railway signaling systems.

These developments in electrochemistry during 1870-1915 laid the groundwork for a better understanding of chemical reactions involving electron transfer, and the practical applications of these principles in energy storage, industrial processes, and various other fields.

In conclusion, the application of new technologies across the metallurgical, machine-building, and chemical industries during 1890-1920 played a vital role in shaping industrial development. These innovations contributed to increased production, improved efficiency, and greater economic growth, setting the stage for continued advancements in the 20th century and beyond.

6.3. Transport and construction

The period between 1900 and 1920 was marked by significant advancements in both transport and construction industries, driven by technological innovations, economic growth, and urbanization. These developments transformed the way people and goods moved and shaped the built environment, leaving a lasting impact on societies worldwide.

The period from 1870 to 1915 was a time of significant development for automobiles. This era witnessed the emergence of the modern automobile and the establishment of the automotive industry. Key milestones and advancements during this time include:

- **Benz Patent Motorwagen (1885-1886):** German inventor Karl Benz developed the Benz Patent Motorwagen, widely regarded as the first true automobile. It was a three-wheeled vehicle powered by a single-cylinder, four-stroke gasoline engine. Benz received a patent for his invention in 1886.
- **Daimler's Motorized Carriage (1886):** Almost simultaneously, another German engineer, Gottlieb Daimler, built a four-wheeled motorized carriage powered by a gasoline engine. Daimler's engine featured a high-speed design that would become the basis for many future automobile engines.

- Panhard et Levassor (1891): French automaker Panhard et Levassor introduced the first production cars with a modern layout, featuring a front-mounted engine and rear-wheel drive. This design would become the standard configuration for most automobiles for many decades.
- First Automobile Race (1894): Organized by the French newspaper Le Petit Journal, the Paris-Rouen race was the first-ever automobile competition, attracting a variety of steam-powered, gasoline-powered, and electric vehicles.
- Ford Model T (1908): American automaker Henry Ford introduced the Model T, an affordable and reliable automobile that revolutionized transportation and industry. The Model T was produced on the first moving assembly line, which significantly reduced production costs and made automobiles more accessible to the general public.
- Electric Starter (1911): Charles Kettering invented the electric self-starter, replacing the hand crank and making it much easier to start gasoline-powered automobiles. This invention contributed to the decline of electric vehicles, as one of the main advantages of electric cars at the time was their ease of starting compared to gasoline-powered cars.

These developments between 1870 and 1915 laid the foundation for the modern automobile industry and transformed personal transportation. The innovations of this period enabled the mass production of automobiles, making them more accessible and changing the way people lived, worked, and traveled.

The period between 1870 and 1915 was a time of significant growth and innovation for railways. Railroads continued to expand across the globe, improving transportation, trade, and communication.

The completion of the First Transcontinental Railroad in the United States connected the East and West coasts, revolutionizing transportation, and facilitating the movement of goods and people across the country. This achievement paved the way for further railroad expansion throughout the world.

Expansion of Rail Networks: During this period, rail networks expanded significantly in various countries, including the United States, Canada, Europe, and Russia. The Canadian Pacific Railway, completed in 1885, linked the eastern and western parts of Canada. In Russia, the Trans-Siberian Railway, completed in 1916, connected Moscow to the Pacific coast, becoming the longest railway line in the world.

The period saw numerous technological innovations in rail transport. The use of steel rails, air brakes, and automatic couplers enhanced railway safety and efficiency. The introduction of electric and diesel locomotives began to replace steam-powered locomotives, offering cleaner and more efficient alternatives.

With the expansion of railways, coordinating train schedules became increasingly complex. To address this issue, the concept of standard time zones was introduced in the 1880s. Sir Sandford Fleming, a Canadian railway engineer, proposed dividing the world into 24 time zones, each one hour apart. The idea was quickly adopted by railway companies and eventually became the global standard.

The first electric-powered railway lines emerged during this period. The Volk's Electric Railway in England, which opened in 1883, was the first public electric railway. By the early 20th century, several countries began implementing electric-powered railways, particularly in urban areas.

The famous luxury train service, the Orient Express, began operating in 1883. It initially ran between Paris and Istanbul, offering passengers an unparalleled travel experience with luxurious accommodations, fine dining, and exceptional service.

As cities grew and industrialized, the need for efficient urban transportation increased. The development of streetcars, trams, and subway systems helped to address this demand. The first underground railway, the London Underground, opened in 1863, and by the early 20th century, several other cities, including New York, Paris, and Berlin, had developed their own subway systems.

These developments in railways during 1870-1915 contributed to the rapid industrialization, urbanization, and globalization that characterized this era. Railways played a crucial role in shaping modern society by facilitating the movement of people, goods, and ideas across vast distances.

The period between 1870 and 1915 witnessed significant advancements in aviation, with the development of the first powered, controlled, and sustained heavier-than-air flights. Key milestones and innovations in aviation during this time include:

- **Balloons and Airships:** Before the invention of airplanes, balloons and airships were the primary means of air travel. Balloons had been around since the 18th century, but airships, such as the Zeppelin, emerged in the late 19th century. These rigid, dirigible airships were powered by engines and could be controlled in flight, unlike balloons.
- **Otto Lilienthal:** The German aviation pioneer Otto Lilienthal made important contributions to the understanding of aerodynamics and the development of gliders. Between 1891 and 1896, Lilienthal conducted over 2,000 glider flights, proving the viability of heavier-than-air flight and inspiring future aviation pioneers.
- **Samuel Langley:** American inventor and scientist Samuel Langley built a series of steam-powered, unmanned aircraft called "Aerodromes" in the late 1890s. Although his attempts at a manned flight were unsuccessful, Langley's work laid the groundwork for future powered aircraft development.
- **Wright Brothers:** Orville and Wilbur Wright are credited with inventing the first successful powered, controlled, and sustained heavier-than-air aircraft. On December 17, 1903, the Wright Flyer, piloted by Orville, took off in Kitty Hawk, North Carolina, covering a distance of 120 feet (36.5 meters) in 12 seconds. The brothers continued to refine their designs, making significant advancements in aircraft control systems and stability.

- **Glenn Curtiss:** American aviation pioneer Glenn Curtiss developed the first practical seaplane in 1911, which could take off and land on water. He also contributed to the development of ailerons, which allowed pilots to control an aircraft's roll, making flight more stable and easier to control.
- **Louis Blériot:** French aviator Louis Blériot became the first person to fly across the English Channel in a heavier-than-air aircraft. On July 25, 1909, Blériot completed the historic 22-mile (35.4-kilometer) flight in his Blériot XI monoplane, further demonstrating the potential of powered aviation.
- **Early Military Aviation:** During this period, governments began to recognize the potential military applications of aviation. In 1909, the U.S. Army purchased its first airplane, the Wright Military Flyer. The First Balkan War (1912-1913) saw the first use of airplanes for reconnaissance, while the Italo-Turkish War (1911-1912) marked the first instance of aerial bombing.

The period between 1870 and 1915 was a time of rapid progress in aviation, marked by numerous breakthroughs and innovations. These early developments laid the foundation for the modern aviation industry, which would continue to evolve rapidly throughout the 20th century.

The period between 1870 and 1915 was a significant era for the shipping industry, witnessing several major advancements and innovations that transformed maritime transport. Some key developments during this time include:

- **Iron and Steel Hulls:** Wooden-hulled ships gave way to iron and steel-hulled vessels, which were more durable and could carry heavier loads. The use of steel in shipbuilding also enabled the construction of larger ships, which could travel longer distances and transport more cargo.
- **Steam Engines:** The adoption of steam engines in the shipping industry led to a significant increase in speed and efficiency. Steamships could maintain a more consistent speed and were less dependent on wind conditions compared to sailing vessels. This allowed for more reliable scheduling and faster travel times.

- **Screw Propellers:** The introduction of screw propellers revolutionized ship propulsion, replacing the traditional paddle wheels. Propellers were more efficient and allowed ships to achieve higher speeds. The combination of screw propellers and steam engines marked a new era of maritime transport.
- **Ocean Liners:** The growth of international trade and passenger travel led to the development of large, luxurious ocean liners. Ships like the RMS Titanic, RMS Lusitania, and RMS Mauretania became symbols of this era, offering comfortable and fast transatlantic crossings. The competition among shipping lines to build the fastest and most luxurious liners was fierce.
- **Refrigerated Ships:** The invention of refrigerated ships (reefers) allowed perishable goods, such as meat and produce, to be transported over long distances without spoiling. This innovation revolutionized the global food trade and enabled the growth of international markets for fresh produce.
- **Bulk Carriers:** The introduction of bulk carriers during this period allowed for the efficient transportation of large quantities of loose cargo, such as coal, grain, and ore. These ships greatly facilitated the expansion of global trade and the movement of raw materials.
- **Suez Canal:** The opening of the Suez Canal in 1869 significantly reduced travel times between Europe and Asia, bypassing the need to sail around Africa. This greatly increased the efficiency of maritime trade and had a profound impact on global shipping routes.
- **Advances in Navigation:** Improvements in navigation techniques and technology, such as the introduction of wireless telegraphy (Marconi system) for ship-to-shore communication, made shipping safer and more efficient. Ships could now communicate with each other and receive updates on weather conditions and navigational hazards, reducing the risk of accidents.

The developments in the shipping industry between 1870 and 1915 laid the groundwork for the modern maritime transport system, which would continue to evolve throughout the 20th century and beyond.

Development of construction industry and technologies was also the driver of the periode. The period between 1870 and 1915 saw the rise of skyscrapers, which were made possible due to several technological advancements and innovations in architecture, construction methods, and materials.

The Bessemer Process, developed in the 1850s, allowed for the mass production of steel, which was stronger and more flexible than iron. This made it an ideal material for constructing tall buildings, as it could support the weight of multiple stories and withstand strong winds.

The invention of the safety elevator by Elisha Otis in 1852 revolutionized vertical transportation, making it possible to quickly and safely move people and goods between floors in tall buildings. Elevators were a crucial development that made the construction of high-rise buildings feasible, as they eliminated the need for long, impractical staircases.

The development of load-bearing steel frames, also known as the "skeleton" construction method, was a major breakthrough in the construction of tall buildings. This method involves using a grid of steel columns and beams to support the building's weight, instead of relying on the walls to bear the load. This allowed for taller, more flexible structures and larger windows, which brought more natural light into the buildings.

The Chicago School of Architecture emerged in the late 19th century, led by architects such as William Le Baron Jenney, Louis Sullivan, and Daniel Burnham. This movement pioneered the use of steel-frame construction and emphasized the importance of function and efficiency in building design. The Home Insurance Building in Chicago, completed in 1885 and designed by William Le Baron Jenney, is often considered the first true skyscraper, standing at ten stories tall.

New York City also saw a rapid rise in the construction of skyscrapers during this period. The Flatiron Building, completed in 1902, and the Woolworth Building, completed in 1913, were iconic examples of skyscrapers built during this time. The Woolworth Building, at 60 stories, was the tallest building in the world when it was completed.

As buildings grew taller, concerns about fire safety increased. To address these concerns, architects and engineers developed new methods to prevent the spread of fires, such as installing fireproof materials, designing fire-resistant stairwells, and incorporating standpipes and sprinkler systems.

As cities became more crowded and skyscrapers began to dominate the skyline, concerns arose about the impact of tall buildings on natural light and air circulation. This led to the development of zoning laws in cities like New York, which regulated the height and shape of buildings to ensure that sunlight and air could still reach the streets below.

The period between 1870 and 1915 marked a transformative era in the history of architecture and urban planning, as the rise of skyscrapers forever changed the way cities were designed and built.

The widespread adoption of reinforced concrete as a construction material allowed for more durable, fire-resistant, and versatile structures. The technique of using steel reinforcement bars within concrete provided added strength and flexibility, enabling the construction of more complex and innovative architectural designs.

Large-scale infrastructure projects, such as the construction of the Panama Canal, the Trans-Siberian Railway, and the New York City subway system, showcased the capabilities of modern construction techniques and engineering feats. These projects played a vital role in connecting people and promoting economic growth.

Rapid urbanization during this period necessitated the development of urban planning and sanitation systems. The introduction of modern sewer systems, water supply networks, and electrical grids improved living conditions in growing cities, while the emergence of urban planning principles guided the design and layout of streets, parks, and public spaces.

In summary, the advancements in transport and construction between 1900 and 1920 revolutionized the way people and goods moved and shaped the built environment. These developments laid the foundation for the modern transportation networks and urban landscapes we see today, reflecting the transformative power of technology and innovation during this era.

6.4. Military equipment during the First World War

The First World War, which lasted from 1914 to 1918, saw significant advancements and changes in military equipment and tactics. The industrial and technological innovations of the time contributed to the development of new weapons and vehicles, which, in turn, influenced the course of the war.

The machine gun emerged as one of the most devastating weapons during the First World War. The Maxim gun, Vickers gun, and the German Maschinengewehr 08 (MG08) were some of the most widely used machine guns, capable of firing hundreds of rounds per minute. These guns led to a shift in infantry tactics and contributed to the trench warfare that characterized the conflict.

Artillery played a central role in World War I and was responsible for a large proportion of casualties on both sides. The war witnessed advancements in artillery technology, tactics, and organization, which led to more effective and deadly firepower on the battlefield.

- **Field Artillery:** Field artillery refers to mobile guns and howitzers designed to provide direct or indirect fire support to infantry and other units on the battlefield. Examples of field artillery include the British 18-pounder field gun, the French

75mm field gun, and the German 7.7 cm Feldkanone 96 neuer Art (FK 96 n.A.). These guns were typically moved by horses or, in some cases, by motorized vehicles.

- **Heavy Artillery:** Heavy artillery was used to engage targets at longer ranges, with larger calibers and higher explosive payloads. The German 42 cm Big Bertha and the British 9.2-inch howitzer were examples of heavy artillery guns used in World War I. These weapons often required specialized transport and large crews to operate and maintain them.
- **Siege Artillery:** Siege artillery was intended for the destruction of fortified positions and included massive guns and mortars capable of firing heavy shells over great distances. The German 21 cm Mörser 10 and the Austrian 30.5 cm Mörser M.11 were examples of siege artillery used during the conflict.
- **Trench Mortars:** Trench mortars were smaller, portable artillery pieces designed to lob shells at high angles to provide close support to infantry in the trenches. Examples include the British Stokes mortar and the German Granatenwerfer 16. These weapons were often used to target enemy trenches, dugouts, and strongpoints.

Advancements in Artillery Technology:

- **High-Explosive Shells:** The introduction of high-explosive shells greatly increased the destructive power of artillery. These shells were filled with powerful explosives like TNT or amatol, which produced a more significant blast and fragmentation effect than older black powder-filled shells.
- **Shrapnel Shells:** Shrapnel shells were designed to burst in mid-air, releasing a cloud of metal balls and fragments that would rain down on enemy troops. These shells were particularly effective against infantry in open terrain and were widely used during the early stages of the war.

- **Indirect Fire:** The development of indirect fire techniques allowed artillery to engage targets beyond the line of sight, using spotters or observation balloons to provide targeting information. This enabled guns to be positioned in safer, concealed locations and greatly increased their effectiveness on the battlefield.
- **Ranging and Targeting:** Improvements in artillery ranging and targeting, such as the use of meteorological data, more accurate maps, and advances in optics, allowed for more precise and effective fire. This led to more efficient use of artillery resources and increased the lethality of bombardments.
- **Counter-Battery Fire:** The use of counter-battery fire, or targeting enemy artillery positions, became an essential tactic during World War I. Advances in sound ranging and flash spotting enabled more accurate identification of enemy gun positions, allowing for more effective counter-battery fire.
- **Artillery Barrages:** Artillery barrages were used to support infantry attacks by creating a curtain of fire ahead of advancing troops, forcing enemy soldiers to take cover and disrupting their defenses. The creeping barrage, in which the curtain of fire moved forward at a controlled pace, was a particularly effective tactic developed during the war.

Chemical warfare was introduced during the First World War, with both sides employing various types of poison gases such as chlorine, phosgene, and mustard gas. These gases caused numerous casualties and suffering among soldiers and forced the development of gas masks and other protective measures.

Tanks were first introduced during World War I as a response to the stalemate of trench warfare. These armored vehicles were designed to break through enemy lines, cross difficult terrain, and provide support for infantry. Early tanks faced numerous challenges, including mechanical unreliability and vulnerability to enemy fire, but they paved the way for the evolution of armored warfare in subsequent conflicts.

- **British Mark I:** The Mark I, developed by the British, was the first tank used in combat. Introduced in the Battle of the Somme in 1916, the Mark I had a distinctive rhomboid shape designed to cross trenches and navigate rough terrain. It was armed with machine guns and either two 6-pounder cannons or additional machine guns. The Mark I was slow, with a top speed of about 3.7 mph (6 km/h), and mechanically unreliable, but it demonstrated the potential of armored vehicles on the battlefield.
- **French FT-17:** The French FT-17, first deployed in 1918, was a small, light tank with a rotating turret. It was faster and more maneuverable than the British Mark I, with a top speed of around 5 mph (8 km/h). The FT-17 was armed with a 37mm cannon or a machine gun and had a crew of two. Its design influenced many future tank developments, particularly in terms of its turret configuration and mobility.
- **German A7V:** Germany's first tank, the A7V, entered service in 1918. It was a large, box-shaped vehicle with a crew of up to 18, armed with a 57mm cannon and multiple machine guns. The A7V was cumbersome and mechanically unreliable, with a top speed of about 9 mph (15 km/h). Germany produced only 20 A7V tanks during the war, relying primarily on captured British and French tanks for their armored forces.

Tank Tactics and Development:

- **Combined Arms:** Tanks were initially employed as standalone weapons to break through enemy lines, but their effectiveness was limited without infantry support. As the war progressed, the concept of combined arms emerged, which involved the coordinated use of tanks, infantry, and artillery to overcome enemy defenses.
- **Creeping Barrage:** Tanks were often used in conjunction with creeping barrages, where artillery fire was carefully timed to move ahead of advancing infantry and tanks. This tactic provided cover for the attacking forces and suppressed enemy defenses, making it easier for tanks to break through.

- **Tank-versus-Tank Combat:** As more tanks were introduced to the battlefield, the first instances of tank-versus-tank combat occurred. These engagements highlighted the importance of tank armor, firepower, and mobility in determining the outcome of armored battles.
- **Tank Design:** The experiences of World War I led to a greater understanding of the strengths and weaknesses of tank design. Key features such as increased armor protection, more reliable engines, better suspension systems, and improved firepower would be incorporated into future tank designs.
- **Impact on Warfare:** The introduction of tanks during World War I marked a significant shift in the nature of warfare. Although early tanks were plagued by mechanical issues and limited by their slow speed, they demonstrated the potential for armored vehicles to break the deadlock of trench warfare. The lessons learned from the development and deployment of tanks in World War I would inform the design and tactics of armored warfare in subsequent conflicts, including World War II and beyond.

Aviation played an increasingly important role during World War I as both a reconnaissance and combat tool. At the beginning of the conflict, aircraft were primarily used for observation and reconnaissance purposes, but as the war progressed, they evolved into fighters, bombers, and ground-attack platforms. The development of aviation technology and tactics during this period laid the groundwork for modern airpower.

At the start of the war, airplanes were used mainly for reconnaissance, scouting enemy positions, and directing artillery fire. Observation balloons also played a vital role in gathering intelligence on enemy troop movements and positions. As the importance of aerial reconnaissance became apparent, both sides sought to disrupt enemy intelligence gathering by attacking observation aircraft and balloons.

To protect reconnaissance aircraft and gain control of the skies, fighter planes were developed. These fast, agile, and heavily armed aircraft engaged in dogfights with enemy planes, with the objective of shooting them down. Some notable fighter planes of World War I include the British Sopwith Camel, the French SPAD S.VII, and the German Fokker Dr.I.

As the war continued, the use of aircraft for bombing missions increased. Early bombers were often repurposed reconnaissance planes or larger multi-engine aircraft, capable of carrying small bomb loads. These planes targeted enemy infrastructure, such as railroads, factories, and military installations, in an effort to weaken the enemy's war effort. Examples of early bombers include the German Gotha G.IV and the British Handley Page Type O.

Toward the end of the war, aircraft began to be used for close air support and ground-attack missions. These planes were equipped with machine guns and small bomb loads to engage enemy troops, vehicles, and fortifications. The British Sopwith Salamander and the French Breguet 14 were examples of ground-attack aircraft from this period.

World War I saw numerous advancements in aviation technology, including more powerful and reliable engines, synchronized machine guns, which allowed pilots to fire through their propellers without damaging them, and improved airframes for increased performance and durability. Other innovations, such as radio communication, parachutes, and aerial photography, were also developed and refined during the war.

As aviation technology evolved, so did tactics and organization. The establishment of fighter squadrons, the use of large formations for bomber raids, and the development of ground-attack tactics all emerged during this period. The concept of air superiority, the notion that control of the skies is a critical factor in determining the outcome of battles and campaigns, became increasingly important.

World War I saw the emergence of famous fighter pilots, known as aces, who gained notoriety for their skill and number of enemy aircraft shot down. Some of the most famous aces from this period include the German Manfred von Richthofen, known as the Red Baron, the French René Fonck, and the British Edward Mannoock.

During World War I, naval warfare played a crucial role in shaping the outcome of the conflict. The navies of the major powers, particularly the British Royal Navy and the German Imperial Navy, were engaged in a variety of operations, including blockades, naval battles, and submarine warfare. The war at sea had a significant impact on global trade, military strategy, and the development of naval technology.

One of the key naval strategies employed during the war was the use of blockades. The British Royal Navy implemented a blockade of Germany, preventing the import of critical resources such as food and raw materials. This blockade severely impacted the German economy and contributed to food shortages and civil unrest in the country. In response, Germany attempted to counter the blockade by using submarines, known as U-boats, to target British and Allied shipping.

Several notable naval battles occurred during World War I, including the Battle of Heligoland Bight, the Battle of Dogger Bank, and the Battle of Jutland. The largest and most significant of these engagements was the Battle of Jutland, fought between the British Royal Navy's Grand Fleet and the German High Seas Fleet in May 1916. While the battle was tactically inconclusive, it confirmed British naval dominance and maintained the effectiveness of the blockade against Germany.

Submarine warfare, particularly the use of German U-boats, was a significant aspect of naval combat during World War I. German submarines targeted Allied merchant and military vessels in an effort to disrupt shipping and weaken the British blockade. This unrestricted submarine warfare led to significant losses of merchant ships and strained relations between Germany and neutral countries, including the United States. The sinking of the British passenger liner *Lusitania* by a German U-boat in 1915, which resulted in the deaths of 1,198 passengers, including 128 Americans, was a key factor that contributed to the United States' eventual entry into the war.

World War I saw the development and implementation of various new naval technologies. Dreadnought battleships, characterized by their heavy armor, large size, and powerful, long-range guns, became the centerpiece of many navies during this period. The war also saw the widespread use of submarines, which revolutionized naval warfare with their stealth capabilities and underwater attacks. Additionally, the conflict saw the emergence of naval aviation, with aircraft carriers, seaplanes, and airships being utilized for reconnaissance, bombing, and anti-submarine warfare.

Mines were extensively used during World War I as a means of disrupting enemy shipping and protecting friendly waters. Both sides laid extensive minefields, which led to the development of minesweeping techniques and technologies. In response to the threat posed by German U-boats, the Allies developed new anti-submarine tactics and technologies, including the use of depth charges, hydrophones (early underwater microphones), and convoy systems to protect merchant shipping.

Overall, naval warfare during World War I was characterized by blockades, large-scale naval battles, and the extensive use of submarines and new naval technologies. The war at sea significantly influenced the outcome of the conflict, as the British blockade contributed to the weakening of the German war effort, while the unrestricted submarine warfare campaign played a key role in the United States' entry into the war. The lessons learned from this conflict would shape the development of naval strategy and technology in the years leading up to World War II.

Trench warfare necessitated the development of specialized equipment such as trench mortars, periscopes, wire cutters, and camouflage. Soldiers often used improvised weapons like clubs, bayonets, and trench knives for close combat in the confined spaces of the trenches.

The First World War saw the widespread use of new communication technologies such as field telephones, wireless radios, and signal flares. These devices improved coordination between troops and allowed for more effective command and control during battles.

In conclusion, the First World War marked a turning point in military equipment and tactics, with the introduction of new weapons, vehicles, and technologies that would shape future conflicts. The innovations of this period had far-reaching consequences, both on and off the battlefield, and altered the course of warfare in the years to come.

Control Questions:

1. Explain how electricity became the basis of industrial development in the early 20th century. What were some of the key innovations in electrical technology during this period?

2. Describe the new technologies that were applied to the metallurgical industry during the early 20th century, and discuss their impact on industrial production.
3. How did the machine-building industry evolve during the early 20th century? What technological advancements played a crucial role in this development?
4. What were the major innovations in the chemical industry in the early 20th century, and how did they contribute to the growth of the industry?
5. Discuss the impact of electricity on the development of transportation and construction during this period. How did new electric-powered technologies revolutionize these sectors?
6. Describe the key advancements in transportation during the early 20th century. What impact did these advancements have on global trade and travel?
7. How did new construction techniques and materials transform the built environment in the early 20th century?
8. Explain the role of technological advancements in shaping the tactics and strategies employed during the First World War.
9. Discuss the development and application of new military equipment, such as machine guns, artillery, and tanks, during the First World War. How did these technologies change the nature of warfare?
10. How did the rapid technological advancements of the early 20th century contribute to the global political and economic landscape of the time?

Basic literature: [2]; [5]; [6]; [10]; [12]; [16].

Additional literature: [14]; [30]; [33]; [36]; [45]; [46]; [49]; [51]; [53].

CHAPTER 7. WORLD SCIENCE AND TECHNOLOGY IN 1920s-1940s

- Development of electric power, metallurgy, chemical industry and mining in the 20s-40s of the 20th century.
- Mechanical engineering in the interwar period and during the Second World War.
- Creation of jet aircraft and rocket technology.
- Electronics is a step into the future. The beginning of the atomic era.

7.1. Development of electric power, metallurgy, chemical industry and mining in the 20s-40s of the 20th century

The period between 1920 and 1945 saw significant advancements in the generation, distribution, and utilization of electric power. This period witnessed a rapid expansion of electrical infrastructure, as well as innovations in electric power generation technologies and the development of new appliances and devices that relied on electricity. These advancements revolutionized industries, transformed urban landscapes, and improved the daily lives of millions of people worldwide.

The expansion of electrical infrastructure between 1920 and 1945 was a crucial period for the growth of electricity as a primary energy source for industry, transportation, and everyday life. During this time, significant advancements were made in the generation, transmission, and distribution of electricity, leading to increased availability, reliability, and affordability of electric power. Here are some key developments in the expansion of electrical infrastructure during this period:

- Rural electrification: In the 1920s and 1930s, electricity was primarily available in urban areas, leaving rural communities underserved. In the United States, the Rural Electrification Administration (REA) was established in 1935 as part of the New Deal to bring electricity to rural areas. The REA provided loans and technical assistance to establish rural electric cooperatives, which played a crucial role in expanding the electrical infrastructure in rural America.

- Growth of power plants: The number and capacity of power plants increased during this period to meet the growing demand for electricity. Power plants became larger and more efficient, utilizing new technologies such as steam turbines and hydroelectric dams. Additionally, the first large-scale nuclear power plant was built in 1944, although it was initially used for military purposes.
- High-voltage transmission lines: The development of high-voltage transmission lines allowed electricity to be transmitted over long distances with minimal losses. This enabled power plants to be located further from population centers, taking advantage of economies of scale and reducing the overall cost of electricity.
- Regional power grids: The interconnection of power plants and transmission lines led to the development of regional power grids. These grids allowed for the efficient distribution of electricity and improved the reliability of the electrical system by sharing power among multiple plants and reducing the impact of localized outages.
- Electrification of transportation: The expansion of electrical infrastructure contributed to the growth of electric railways, trams, and trolleybuses in cities around the world. These electric transportation systems helped to reduce urban air pollution and congestion.
- Household electrification: As the electrical infrastructure expanded, electricity became more accessible and affordable for households. This led to a boom in the adoption of electrical appliances such as refrigerators, washing machines, and vacuum cleaners, which transformed domestic life and improved living standards.
- Industrial electrification: The expansion of electrical infrastructure also enabled the widespread adoption of electric motors in factories, replacing steam engines and other less efficient power sources. This led to increased productivity, greater flexibility in factory layout, and improved working conditions.

The period between 1920 and 1945 was a time of rapid growth and transformation for the electrical infrastructure, which laid the foundation for the modern electrical grid and the widespread use of electricity in all aspects of life.

During the period from 1920 to 1945, significant advances were made in power generation technologies. These developments helped increase the efficiency, reliability, and capacity of power generation systems, ultimately contributing to the widespread availability of electricity.

In the early 20th century, steam turbines became the dominant technology for electricity generation in large power plants. Steam turbines offered higher efficiency and greater power output than reciprocating steam engines, leading to their widespread adoption. Improvements in turbine design and materials during this period allowed for increased efficiency and higher operating temperatures and pressures.

The construction of large hydroelectric dams accelerated during this period, providing a clean and renewable source of electricity. Notable projects include the Hoover Dam in the United States, completed in 1936, and the Dnieper Hydroelectric Station in the Soviet Union, completed in 1932. Hydroelectric power became an important component of the global energy mix, and advances in dam construction and turbine design increased the efficiency and capacity of hydroelectric power plants.

The Hoover Dam is a massive concrete arch-gravity dam that was constructed in the 1930s on the Colorado River, on the border between Arizona and Nevada. The dam was a significant engineering achievement, and it has played a significant role in the development of the western United States, providing hydroelectric power and irrigation to millions of people.

The construction of the Hoover Dam began in 1931, and it was completed in 1935. The project was a massive undertaking, requiring the construction of a massive concrete dam that would be able to withstand the extreme conditions of the Colorado River. The dam was designed to be 726 feet high, with a base thickness of 660 feet

and a top thickness of 45 feet. It was constructed using more than 3 million cubic yards of concrete, which was transported to the site by a fleet of trucks and cable cars.

The construction of the Hoover Dam was a significant engineering achievement, requiring the use of new and innovative construction techniques. The dam was constructed using a process known as slip-forming, in which a massive, continuous pour of concrete was used to create the structure. This process allowed the dam to be constructed quickly and efficiently, and it has since been used in the construction of other large concrete structures, such as high-rise buildings and bridges.

The Hoover Dam was designed to serve multiple purposes, including the generation of hydroelectric power and the irrigation of farmland in the surrounding area. The dam was also designed to control the flow of the Colorado River, which had been known to cause devastating floods in the past. The creation of Lake Mead, the reservoir created by the Hoover Dam, has also become a major recreational destination, attracting millions of visitors each year.

The Hoover Dam played a significant role in the development of the western United States, providing a source of hydroelectric power and irrigation to millions of people. The hydroelectric power generated by the dam was used to power the growth of the cities in the surrounding area, including Los Angeles, Las Vegas, and Phoenix. The irrigation provided by the dam allowed farmers in the surrounding area to grow crops more efficiently, which played a significant role in the development of the agricultural industry in the region.

In recent years, the Hoover Dam has faced significant challenges, including a decline in water levels in Lake Mead due to a prolonged drought. The dam has also faced concerns over its safety and efficiency, with some experts calling for the construction of a new dam or the use of alternative methods of generating hydroelectric power. Despite these challenges, the Hoover Dam remains a significant engineering achievement and a symbol of American innovation and progress.

During this period, power plants using coal, oil, and natural gas became more efficient and reliable. Developments in boiler design, combustion control, and pollution reduction technologies helped improve the performance and environmental impact of fossil fuel power plants.

Although gas turbines were primarily developed for aviation during this period, their potential for electricity generation was also recognized. Gas turbines offered high power-to-weight ratios and the ability to quickly respond to changes in demand. The first gas turbine for power generation was built by Brown Boveri (now ABB) in Switzerland in 1939.

Advances in power generation technologies were accompanied by efforts to bring electricity to rural areas. The Rural Electrification Administration (REA) in the United States, for example, provided funding and technical assistance for the construction of small, decentralized power plants in rural areas, often using locally available fuels such as wood or agricultural waste.

These advances in power generation technologies during the 1920-1945 period played a significant role in shaping the modern energy landscape, leading to the widespread availability of electricity and enabling the electrification of transportation, industry, and households.

Between 1920 and 1945, numerous innovations in electrical appliances and devices took place, transforming everyday life and contributing to the modernization of households, industry, and communication. Here are some key innovations from this period:

- Refrigerators: In the 1920s, electric refrigerators began to replace iceboxes in households. This innovation allowed for more efficient food preservation and storage, reducing food spoilage and waste.
- Vacuum cleaners: The first practical electric vacuum cleaners were introduced in the 1920s, making household cleaning more efficient and convenient. As vacuum cleaner technology improved, they became more affordable and widely adopted.

- Washing machines: Electric washing machines were introduced during this period, greatly reducing the time and effort required for laundry. Early models were quite basic, but by the 1930s, more advanced models with agitators and automatic timers became available.
- Radios: The first commercial radio stations began broadcasting in the 1920s, and the mass production of affordable radio receivers soon followed. Radios became a common household item, providing news, entertainment, and information to millions of people.
- Televisions: Although television technology was developed in the 1920s, it was not until the late 1940s that commercial television broadcasting began. The first television sets became available for sale to the public in the late 1930s but were not widely adopted until after World War II.
- Electric toasters: The first pop-up electric toasters were invented in the 1920s. This innovation allowed for more convenient and safer toasting compared to using open flames or stovetops.
- Electric irons: The 1920s also saw the introduction of electric irons, which made ironing clothes faster and more efficient. The electric iron replaced earlier irons heated by coal or gas.
- Electric fans: Fans had existed before the 1920s, but the introduction of electric fans made them more efficient, reliable, and convenient. They became a popular way to cool homes and offices during warm months.
- Electric lighting: The widespread adoption of electric lighting in homes, businesses, and public spaces continued during this period, replacing gas and kerosene lamps. Developments in electric lighting included the introduction of more efficient bulbs and the expansion of electrical grids to supply power.
- Electric typewriters: The first electric typewriters were introduced in the 1920s and 1930s, improving typing speed and reducing the physical effort required compared to manual typewriters.

- **Phonographs:** While phonographs were invented in the late 19th century, the development of electric phonographs and amplifiers in the 1920s allowed for higher-quality sound reproduction and greater convenience.

These innovations in electrical appliances and devices from 1920 to 1945 had a profound impact on daily life, making tasks more efficient, improving the quality of life, and enabling new forms of communication and entertainment.

The period between 1920 and 1945 saw the emergence of electric transportation options, including electric trains, streetcars, and trolleybuses. These new forms of transportation were quieter, cleaner, and more efficient than their steam or internal combustion engine counterparts, leading to their widespread adoption in many cities.

In summary, the period from 1920 to 1945 marked a significant phase in the development of electric power. The expansion of electrical infrastructure brought electricity to more people, advances in power generation technologies improved efficiency and capacity, and new appliances and devices revolutionized daily life and industry. This era laid the foundation for the widespread use of electricity that continues to shape our modern world.

7.2. Mechanical engineering in the interwar period and during the Second World War

The interwar period (1918-1939) and the Second World War (1939-1945) saw significant developments and innovations in mechanical engineering. These advancements were driven by the need to rebuild economies after the First World War, the desire for technological progress, and the demands of wartime production.

During the interwar period and the Second World War, the automotive industry underwent significant transformations and innovations that reshaped transportation and manufacturing processes. Here are some key aspects of the automotive industry during this time:

The concept of mass production and the use of assembly lines, pioneered by Henry Ford and the Ford Motor Company, revolutionized the automotive industry. The introduction of the Ford Model T in 1908 made automobiles more affordable for the general public. The assembly line production method increased efficiency and output, enabling manufacturers to meet growing demand and reduce production costs. By the 1920s, assembly lines were widely adopted throughout the industry, and automobile ownership became increasingly common.

The interwar period saw numerous innovations in automotive technology that improved vehicle performance, reliability, and comfort. Engineers developed more efficient internal combustion engines, better suspension systems, and more robust body construction methods. Innovations in materials, such as the introduction of stainless steel, also contributed to the development of lighter and more durable vehicles.

As automobile ownership grew, the need for better and more extensive road networks became apparent. Governments invested in the construction of highways, bridges, and tunnels to accommodate the increasing number of vehicles. The development of these infrastructure projects further contributed to advancements in civil and mechanical engineering.

The interwar period also saw the growth of commercial vehicles and public transportation systems. Trucks and buses became increasingly important for transporting goods and people over long distances, reducing reliance on trains and horse-drawn vehicles. Advancements in diesel engine technology made commercial vehicles more efficient and powerful, while improvements in suspension and braking systems made them safer and more comfortable for passengers.

As cars became more widespread, their design and styling evolved to reflect changing tastes and consumer preferences. Streamlined shapes and aerodynamic features became popular in the 1930s, influenced by the art deco movement and the growing importance of aerodynamics in aviation. The introduction of closed, all-steel body construction in the 1920s and 1930s also enabled more sophisticated and attractive vehicle designs.

The Second World War had a profound impact on the automotive industry. Many automobile manufacturers were repurposed to produce military vehicles, such as tanks, trucks, and jeeps. Production of consumer automobiles was halted or significantly reduced in many countries to conserve resources and focus on the war effort. Post-war, the industry had to rebuild and retool, which eventually led to a boom in automobile production and demand during the 1950s and 1960s.

In summary, the interwar period and the Second World War saw significant changes and innovations in the automotive industry. These developments in mass production, technology, infrastructure, commercial vehicles, and design shaped the industry and laid the foundation for its continued growth and evolution in the post-war era.

The interwar period (1918-1939) was a time of remarkable innovation and advancement in aviation. The experiences and lessons learned from the First World War, along with significant investments in research and development, led to rapid progress in aircraft design and performance. Some key aspects of aviation during the interwar period include:

The interwar period saw the emergence of commercial aviation as a viable means of transportation. Airlines were established to transport passengers, mail, and cargo over long distances. Innovations in aircraft design, such as all-metal construction, more efficient engines, and retractable landing gear, enabled larger, faster, and more comfortable planes. Examples of iconic interwar passenger aircraft include the Ford Trimotor, Douglas DC-3, and the Boeing 247.

The interwar period was also a time of air races and record-setting flights, which captured the public's imagination and pushed the limits of aviation technology. Aviators like Charles Lindbergh, Amelia Earhart, and Howard Hughes became international celebrities due to their daring and groundbreaking flights. Races like the Schneider Trophy and the Bendix Trophy spurred innovations in aircraft design, engine technology, and aerodynamics.

Military aviation advanced rapidly during the interwar period, with new aircraft designs and technologies emerging to meet the changing needs of warfare. Monoplanes replaced biplanes as the dominant aircraft design, offering greater speed and maneuverability. All-metal construction, enclosed cockpits, and retractable landing gear became standard features on many military aircraft. The development of faster and more powerful engines allowed for increased range, payload capacity, and performance.

The interwar period saw the development of new air power doctrines and strategies. Military theorists like Giulio Douhet, Billy Mitchell, and Hugh Trenchard advocated for the strategic use of air power to achieve decisive results in warfare. The concept of strategic bombing, in which an enemy's industrial and civilian infrastructure is targeted, emerged as a dominant theme in air power theory.

The development of more efficient and powerful aircraft engines played a crucial role in the progress of aviation during the interwar period. The introduction of air-cooled radial engines, such as the Pratt & Whitney R-1340 Wasp and the Wright R-1820 Cyclone, offered greater reliability and performance compared to earlier liquid-cooled inline engines. Additionally, the development of superchargers allowed engines to maintain power at higher altitudes, enabling aircraft to fly faster and farther.

The interwar period saw a greater emphasis on aerodynamics and streamlining in aircraft design, leading to more efficient and higher-performing planes. Innovations such as the cantilever wing, which eliminated the need for external bracing wires and struts, reduced drag and improved structural efficiency. The

NACA (National Advisory Committee for Aeronautics, the predecessor of NASA) conducted extensive research into airfoils, wing shapes, and other aerodynamic features, which greatly benefited the aviation industry.

In summary, the interwar period was a time of rapid innovation and progress in aviation. Developments in commercial aviation, air races, military aviation, air power doctrines, aircraft engines, and aerodynamics all contributed to the remarkable advancements witnessed during this time, laying the foundation for the further evolution of aviation in the decades to follow.

The interwar period and the years following the Second World War saw considerable advancements in production techniques and industrial automation. These innovations played a crucial role in shaping the modern industrial landscape, driving efficiency, increasing output, and reducing costs. Here are some significant developments in production techniques and industrial automation during this time:

While the concept of the assembly line dates back to the early 20th century with Henry Ford's Model T production, the method continued to evolve and expand during the interwar period. This method of breaking down the manufacturing process into small, repetitive tasks, and moving the product from one workstation to another allowed for increased efficiency and productivity. Other industries, such as consumer goods and electronics, adopted assembly line production techniques to meet growing demand.

The standardization of parts and processes became increasingly important during this time, as it allowed for more efficient production and easier maintenance. The use of interchangeable parts meant that manufacturers could produce components at a larger scale and assemble products more quickly. This approach also facilitated the repair and replacement of worn or damaged parts, reducing downtime and maintenance costs.

Industries such as chemical, steel, and oil refining began to adopt continuous production processes, wherein raw materials were continuously fed into the system, and finished products were extracted without interruption. This method increased efficiency by eliminating the need for starting and stopping production between batches, reducing waste, and lowering energy consumption.

The concept of quality control and statistical process control (SPC) emerged in the 1920s and 1930s, driven by the work of Walter A. Shewhart and W. Edwards Deming. The use of statistical methods to monitor and control production processes allowed manufacturers to identify and eliminate sources of variation, improving product quality and reducing waste.

The interwar period and the years following the Second World War saw the first steps towards industrial automation, with the development of simple automated devices and control systems. Relay logic, pneumatic and hydraulic controls, and early electronic devices began to replace manual tasks and decision-making in manufacturing processes. These early automation technologies increased efficiency, reduced human error, and contributed to safer working conditions.

Numerical Control and Computer-Aided Manufacturing: In the late 1940s and early 1950s, the concept of numerical control (NC) emerged, allowing for the precise control of machine tools using coded instructions. The development of NC machines paved the way for computer-aided manufacturing (CAM), which combined computer programming with manufacturing processes to enable more efficient and accurate production.

These innovations, which include assembly line production, standardization, continuous production processes, quality control, early industrial automation, numerical control, and the foundations of robotics, played a critical role in shaping the modern industrial landscape and transforming manufacturing processes around the world.

In summary, the interwar period and the Second World War saw substantial advancements in mechanical engineering, driven by the demands of rebuilding economies, technological progress, and wartime production. These developments in automotive, aviation, armaments, production techniques, and computing and control systems had a lasting impact on the field of mechanical engineering and continue to shape the modern world.

7.3. Creation of jet aircraft and rocket technology

The creation of jet aircraft marked a significant milestone in aviation history, revolutionizing air travel and military aviation. Jet engines, which generate thrust by expelling high-speed exhaust gases, allowed for higher speeds, altitudes, and overall performance compared to traditional piston-engine aircraft. The development of jet aircraft took place primarily during and after World War II.

In the 1920s and 1930s, several engineers and inventors were working on concepts for jet propulsion. Notable figures included Frank Whittle in the United Kingdom and Hans von Ohain in Germany. Both developed their own designs for jet engines, with Whittle receiving a patent for his turbojet engine concept in 1930 and von Ohain working on a similar design independently.

The first successful flight of a jet-powered aircraft occurred in Germany in 1939. The aircraft, Heinkel He 178, was designed by the Heinkel Flugzeugwerke company and used a Heinkel-Hirth HeS 3 turbojet engine developed by Hans von Ohain. The He 178 demonstrated the feasibility of jet propulsion, but it did not enter mass production.

The rapid advancements in jet engine technology during World War II led to the development of several operational jet aircraft. The most famous of these was the German Messerschmitt Me 262, which became the world's first operational jet-powered fighter aircraft. The British Gloster Meteor, which entered service in 1944, was the Allies' first jet fighter and the only one to see combat during the war.

The Messerschmitt Me 262, also known as the Schwalbe (Swallow), was the world's first operational jet-powered fighter aircraft. It was designed and manufactured in Germany during World War II, with its first test flight occurring in 1941. However, it wasn't until 1944 that the Me 262 saw widespread deployment in the German Luftwaffe.

The Me 262 was powered by two Jumo 004 turbojet engines, which allowed the aircraft to achieve top speeds of approximately 540 mph (870 km/h) – significantly faster than the propeller-driven fighter planes of the time. Its armament consisted of four 30mm MK 108 cannons mounted in the nose, which provided formidable firepower against both air and ground targets.

While the Me 262 demonstrated a clear advantage in terms of speed, it had its share of drawbacks. The jet engines were relatively unreliable, with short service lives, and were prone to flameouts during rapid acceleration or deceleration. Additionally, the Me 262 was vulnerable during takeoff and landing due to its slower speeds, making it an easy target for Allied fighters.

The introduction of the Me 262 came too late to have a decisive impact on the outcome of World War II. Its production was hampered by a combination of factors, including shortages of strategic materials, bombing of manufacturing facilities, and a shifting focus on defensive measures rather than offensive weaponry. Furthermore, the relatively small number of Me 262s produced and their late arrival in the conflict limited their overall effect on the air war.

Despite its limitations, the Messerschmitt Me 262 was a groundbreaking aircraft that paved the way for future jet-powered fighters. Its design and technology influenced the development of post-war aircraft, such as the American F-86 Sabre and the Soviet MiG-15, setting the stage for the jet age in military aviation.

The Gloster Meteor was the first operational jet-powered fighter aircraft in the British Royal Air Force (RAF) and the Allies' first operational jet fighter during World War II. Designed and produced by the Gloster Aircraft Company, the Meteor made its maiden flight in 1943 and entered service with the RAF in 1944.

The Meteor was powered by two Rolls-Royce Derwent turbojet engines, which allowed the aircraft to reach a top speed of around 600 mph (965 km/h). Its armament typically consisted of four 20mm Hispano Mk.V cannons mounted in the nose, providing it with significant firepower for both air-to-air and ground-attack roles.

Though the Meteor was not deployed in combat against the German Messerschmitt Me 262, it did see limited action during the final stages of World War II. The primary role of the Meteor during the war was to intercept and destroy German V-1 flying bombs, which it performed effectively.

In the years following World War II, the Gloster Meteor underwent several upgrades and modifications, resulting in numerous variants being produced. These included the Meteor F.8, which was the definitive and most-produced version, as well as the Meteor T.7 trainer and the Meteor NF night fighter series.

The Meteor was eventually replaced by more advanced jet fighters, such as the Hawker Hunter and the English Electric Lightning. However, the aircraft had a long service life, with some variants remaining in operation until the 1980s in various air forces around the world.

The Gloster Meteor's development and service marked a significant milestone in the evolution of jet-powered aviation, playing a crucial role in the transition from piston-engine to jet-engine aircraft in the post-war era.

After World War II, jet aircraft development continued at a rapid pace, with nations around the world recognizing the potential of jet propulsion. The United States developed its first operational jet fighter, the Lockheed P-80 Shooting Star, followed by more advanced models such as the North American F-86 Sabre and the McDonnell F-4 Phantom II. The Soviet Union also made significant strides in jet aircraft development, with aircraft like the Mikoyan-Gurevich MiG-15 and MiG-21 becoming iconic symbols of the Cold War era.

The introduction of jet aircraft to civil aviation was another significant milestone. The British-made de Havilland Comet became the world's first commercial jet airliner when it entered service in 1952. The Boeing 707, which first flew in 1957, became one of the most successful early commercial jetliners, setting the standard for future aircraft design and shaping the modern air travel industry.

The pursuit of ever-faster aircraft led to the development of supersonic jet aircraft, capable of breaking the sound barrier and flying at speeds greater than Mach 1. The Bell X-1, piloted by Chuck Yeager in 1947, became the first aircraft to exceed the speed of sound in level flight. This milestone spurred the development of military supersonic jet aircraft, such as the North American F-100 Super Sabre and the Soviet MiG-19. In the realm of civil aviation, the Anglo-French Concorde and the Soviet Tupolev Tu-144 became the first and only supersonic commercial jet airliners, although their operational life was limited due to economic and environmental factors.

The creation of jet aircraft revolutionized aviation, enabling higher speeds, greater altitudes, and increased overall performance compared to propeller-driven aircraft. The development of jet engines during World War II and the subsequent advancements in both military and civil aviation have had a lasting impact on the aerospace industry and the way people travel today.

The development of rocket technology between 1900 and 1945 was marked by numerous significant advancements, driven primarily by the needs of warfare and the pursuit of space exploration. The following are some key milestones in the creation of rocket technology during this period:

In the early 20th century, several visionaries laid the groundwork for modern rocketry. Russian scientist Konstantin Tsiolkovsky published his work on the theoretical aspects of space travel, including the use of rockets for propulsion. American engineer Robert H. Goddard made significant contributions to rocket technology, successfully launching the world's first liquid-fueled rocket in 1926. Hermann Oberth, a German physicist and engineer, also published important works on the potential of rocketry for space travel.

During the interwar period, rocketry enthusiasts in various countries formed clubs and societies dedicated to the development of rocket technology. In Germany, the Verein für Raumschiffahrt (VfR - Society for Space Travel) was established in 1927. Its members, including Wernher von Braun, conducted experiments with liquid-fueled rockets. The American Interplanetary Society (later renamed the American Rocket Society) and the British Interplanetary Society were also founded during this time, promoting research and development in rocket technology.

The onset of World War II accelerated the development of rocket technology for military purposes. The German V-2 rocket, designed by Wernher von Braun and his team, became the world's first long-range guided ballistic missile. The V-2 was used to bombard targets in Europe, primarily London and Antwerp, causing significant destruction and loss of life. The rocket's advanced technology laid the foundation for post-war advancements in both military and civilian rocketry.

The V-2 rocket, also known as the A4, was a German long-range ballistic missile developed during World War II under the direction of Wernher von Braun. It was the world's first long-range guided ballistic missile and the first human-made object to achieve sub-orbital spaceflight. The V-2, short for "Vergeltungswaffe 2" (Retribution Weapon 2), was designed to carry a 1-ton warhead and had an operational range of approximately 200 miles (320 km).

The development of the V-2 began in the early 1930s at the German Army's Kummersdorf research facility. In 1937, the development program was moved to Peenemünde, where the first successful test flight took place in October 1942. The

V-2 was powered by a liquid-propellant rocket engine that used a mixture of liquid oxygen and ethyl alcohol as fuel, allowing the missile to reach speeds of up to 3,580 miles per hour (5,760 km/h) and an altitude of around 55 miles (88 km) at its peak.

The V-2 became operational in September 1944 and was primarily used to target cities in Belgium, France, and the United Kingdom. Over 3,000 V-2 rockets were launched by the German military, causing thousands of casualties and significant damage to infrastructure. However, the V-2 was not a decisive weapon in the war due to its relatively low accuracy, high cost, and limited production numbers.

Following the end of World War II, the United States and the Soviet Union both seized V-2 rockets, production facilities, and technical personnel, including Wernher von Braun, as part of Operation Paperclip and Operation Osoaviakhim. The V-2 became the basis for various early American and Soviet rockets, including the American Redstone rocket and the Soviet R-1 and R-2.

The V-2 rocket played a significant role in the development of post-war rocket technology and laid the groundwork for the space race between the United States and the Soviet Union. Its legacy can be seen in the design of modern rockets and the early development of both nations' space programs.

After World War II, the United States and the Soviet Union seized the opportunity to obtain German rocket technology and expertise. Operation Paperclip, a secret U.S. program, brought Wernher von Braun and many of his colleagues to the United States, where they would go on to play a central role in developing American rocket technology. The Soviet Union also captured German rocket scientists and technology, which would contribute to their early successes in the Space Race.

The technological advancements made during the 1900-1945 period laid the foundation for the development of various rocket and missile systems in the post-war era. These included the American Redstone rocket family, which was used for various purposes, including launching the first U.S. satellite, Explorer 1, and propelling the Mercury-Redstone spacecraft carrying the first American astronaut,

Alan Shepard, into space. The Soviet Union developed the R-1 and R-2 missiles, which were based on the V-2 design, and later the R-7, which would become the world's first intercontinental ballistic missile (ICBM) and launch vehicle for Sputnik, the first artificial satellite.

The 1900-1945 period was a critical time in the development of rocket technology, with significant advancements made in both theoretical and practical aspects. The contributions of early pioneers, along with the accelerated development during World War II, laid the foundation for the rapid progress in rocketry and space exploration that would follow in the second half of the 20th century.

7.4. Electronics is a step into the future. The beginning of the atomic era

The period between 1920 and 1945 witnessed significant advancements in electronics, driven by the development of new materials, components, and technologies. These advancements contributed to various industries, such as communication, entertainment, and military applications. Some of the notable milestones in electronics during this period include:

Vacuum tubes were crucial components in early electronic devices, enabling the amplification and control of electrical signals. The invention of the tetrode (1926) and the pentode (1929) tubes provided improved performance and reduced unwanted oscillations compared to earlier triode designs.

The Golden Age of Radio occurred during the 1920s and 1930s, as radio broadcasting became an increasingly popular form of mass communication and entertainment. The development of new electronic components, such as vacuum tubes, made it possible to create more powerful and reliable radio transmitters and receivers.

The first television broadcasts were made in the 1920s and 1930s, using mechanical systems. However, electronic television systems, such as those developed by Philo Farnsworth (1927) and Vladimir Zworykin (1933), demonstrated

the potential for higher-quality images and eventually replaced mechanical systems. The first regular electronic television broadcasts began in the United States in 1939.

The development of radar technology in the 1930s and 1940s was a critical advancement for both military and civilian applications. Radar systems use radio waves to detect and locate objects, providing essential information for navigation, air traffic control, and military purposes, such as early warning systems and targeting during World War II.

Early electronic computers were developed during the 1940s, with notable examples including the British Colossus (1943), used for codebreaking during World War II, and the American Electronic Numerical Integrator and Computer (ENIAC, 1945), a general-purpose computer designed to perform complex calculations. These machines used vacuum tubes to perform logic operations and store data, paving the way for modern digital computers.

The development of magnetic recording technology, such as magnetic tape and wire recorders, allowed for the storage and playback of audio and data signals. This technology was used for various applications, including audio recording, data storage, and even the development of the first digital computers.

These advancements in electronics during the 1920-1945 period laid the foundation for the rapid progress in technology that would follow in the second half of the 20th century. The transition from vacuum tubes to semiconductors, along with the development of new components and technologies, enabled the miniaturization and increased functionality of electronic devices, revolutionizing communication, entertainment, and computing.

The atomic era began in the early 20th century, with groundbreaking discoveries in nuclear physics that would eventually lead to the development of nuclear weapons and nuclear power. Here are some key events and milestones in the development of the atomic era between 1920 and 1945:

- Discovery of the atomic nucleus (1911): Ernest Rutherford's gold foil experiment led to the discovery of the atomic nucleus, which provided a foundation for understanding the structure of the atom and the forces that hold it together.
- Rutherford's model of the atom (1911): Rutherford proposed a model of the atom where electrons orbit a central, positively charged nucleus, resembling a miniature solar system. This model, although later refined, helped to advance the understanding of atomic structure.
- Bohr's model of the atom (1913): Niels Bohr proposed a model in which electrons occupy specific energy levels or orbits around the nucleus. This model explained the behavior of electrons and the nature of atomic spectra, which furthered the understanding of atomic structure and the behavior of electrons.
- Discovery of isotopes (1913): Frederick Soddy discovered that atoms of the same element can have different masses due to varying numbers of neutrons in their nuclei. This concept of isotopes provided essential insights into nuclear reactions and atomic structure.
- Discovery of artificial radioactivity (1934): Irène Joliot-Curie and Frédéric Joliot discovered artificial radioactivity by bombarding stable elements with alpha particles, resulting in the production of new radioactive isotopes. This discovery expanded the understanding of nuclear reactions and laid the groundwork for future nuclear technologies.
- Discovery of nuclear fission (1938): Lise Meitner and Otto Hahn, along with Fritz Strassmann, discovered nuclear fission, the process by which atomic nuclei split into smaller nuclei, releasing a large amount of energy. This discovery would eventually lead to the development of nuclear weapons and nuclear power.

The Manhattan Project was a top-secret research and development effort during World War II, aimed at producing the world's first atomic bomb. Initiated by the United States in collaboration with the United Kingdom and Canada, the project brought together some of the most brilliant scientific minds of the time, including J. Robert Oppenheimer, Enrico Fermi, and Leo Szilard, among others.

Concerned about the possibility of Nazi Germany developing nuclear weapons, a group of scientists led by Albert Einstein and Leo Szilard sent a letter to President Franklin D. Roosevelt in 1939, urging him to support research into atomic energy. This led to the establishment of the Uranium Committee, which later evolved into the Manhattan Project.

The project was led by General Leslie R. Groves of the U.S. Army Corps of Engineers, who oversaw the construction and management of the project sites. J. Robert Oppenheimer was appointed as the scientific director, responsible for coordinating the scientific research and development efforts.

The Manhattan Project involved several facilities across the United States, each with specific roles in the development of the atomic bomb. Key sites included:

- Los Alamos, New Mexico: The main research and development site, where scientists designed and built the atomic bombs.
- Oak Ridge, Tennessee: A facility for uranium enrichment, using the electromagnetic separation and gaseous diffusion methods.
- Hanford, Washington: A site for plutonium production, housing the world's first large-scale nuclear reactors.

The project led to numerous scientific and technological advancements, including the development of methods for uranium enrichment and plutonium production. The creation of the first controlled nuclear chain reaction, led by Enrico Fermi at the University of Chicago's Metallurgical Laboratory. The design and construction of two types of atomic bombs: the uranium-based "Little Boy" and the plutonium-based "Fat Man."

On July 16, 1945, the first successful test of a nuclear weapon took place at the Trinity test site in New Mexico. The test, codenamed "Trinity," confirmed the functionality of the plutonium-based bomb and demonstrated the immense destructive power of atomic weapons.

In August 1945, the United States dropped atomic bombs on the Japanese cities of Hiroshima and Nagasaki, leading to the deaths of over 100,000 people and the eventual surrender of Japan, effectively ending World War II.

The Manhattan Project marked the beginning of the nuclear age and had a profound impact on science, technology, international relations, and global security. The project's success initiated a nuclear arms race during the Cold War, while also paving the way for the development of nuclear power as a source of energy. It also raised ethical questions and debates about the use of nuclear weapons and their consequences for humanity and the environment.

Another focus of the Manhattan Project and nuclear research was the creation of the first nuclear reactor. The Chicago Pile was the world's first artificial nuclear reactor, and it was constructed by a team of scientists at the University of Chicago under the direction of Enrico Fermi. The development of the Chicago Pile was a significant milestone in the history of science and technology, and it paved the way for the development of nuclear power and the atomic bomb.

The Chicago Pile was constructed in 1942, during the height of World War II. The project was sponsored by the United States government, which was interested in developing a new source of energy and potential weapon. Enrico Fermi was chosen to lead the project due to his extensive experience in nuclear physics and his reputation as a world-renowned scientist.

The construction of the Chicago Pile was a significant challenge, as it required the creation of a controlled nuclear chain reaction. The scientists working on the project had to design a system that would allow them to control the release of energy from the nuclear reaction, as well as a method for shielding themselves and the surrounding environment from the dangerous levels of radiation produced by the reactor.

The Chicago Pile was constructed using graphite blocks, which were arranged in a circular pattern to create a sphere. Inside the sphere, scientists placed uranium pellets, which were used as fuel for the reactor. The scientists then used a series of control rods to regulate the amount of fuel being consumed by the reactor, and they monitored the energy output using a series of detectors.

On December 2, 1942, the Chicago Pile achieved its first controlled nuclear chain reaction. This was a significant achievement, as it demonstrated for the first time that it was possible to produce energy through nuclear reactions. The success of the Chicago Pile also led to the development of nuclear power, which has since become a major source of energy around the world.

The success of the Chicago Pile also played a significant role in the development of the atomic bomb. The knowledge gained from the Chicago Pile was used by scientists working on the Manhattan Project to develop the first atomic bomb, which was tested in New Mexico in 1945. The development of the atomic bomb had a significant impact on the outcome of World War II, and it also led to the beginning of the nuclear arms race between the United States and the Soviet Union.

In the years since the construction of the Chicago Pile, there have been significant advancements in the field of nuclear power. Nuclear power has become a major source of energy around the world, with many countries relying on nuclear power to meet their energy needs. There have also been significant advancements in the safety and efficiency of nuclear power, with new reactor designs and safety protocols being developed to reduce the risk of accidents and improve the overall efficiency of nuclear power.

In conclusion, the Chicago Pile was a significant milestone in the history of science and technology, and it paved the way for the development of nuclear power and the atomic bomb. The construction of the Chicago Pile was a significant challenge, but it demonstrated for the first time that it was possible to produce energy through nuclear reactions. The success of the Chicago Pile also played a significant role in the development of the atomic bomb, which had a significant impact on the

outcome of World War II. The knowledge gained from the Chicago Pile has since been used to develop new and improved forms of nuclear power, and it continues to play a significant role in the energy production and national security of many countries around the world.

In general, in the 1920s and 1940s, the development of technology took place on the basis of the growing role of physical, mathematical and natural sciences, especially mathematics. At the same time, the successes of physics were determined by the development of technology, and this relationship accelerated scientific and technological progress.

Control Questions:

1. Describe the major developments in electric power generation and distribution during the 1920-1940s. How did these advancements impact society and industry during this period?
2. Discuss the key innovations and trends in metallurgy, chemical industry, and mining during the 1920-1940s. What factors contributed to the growth of these industries?
3. How did mechanical engineering evolve in the interwar period and during the Second World War? What were some of the most significant inventions and advancements in this field?
4. Explain the role of mechanical engineering in the development and production of military equipment during the Second World War.
5. Discuss the creation of jet aircraft during this period, including the key technological advancements and milestones. How did these innovations change the face of aviation?
6. Describe the development of rocket technology in the 1920-1940s. How did this technology evolve from early experiments to practical applications in both military and space exploration contexts?

7. Explain the emergence of electronics during this period and its impact on various industries and sectors. What were some of the most important inventions and discoveries in the field of electronics during the 1920-1940s?
8. Discuss the beginning of the atomic era, including the key scientific breakthroughs and technological advancements that laid the foundation for nuclear power and weaponry.
9. How did the development of electronics and atomic technology pave the way for future advancements in science and technology in the latter half of the 20th century?
10. Reflect on the broader societal, economic, and political implications of the rapid technological advancements in science and technology during the 1920-1940s.

Basic literature: [1]; [2]; [3]; [4]; [5]; [14]; [15]; [16].

Additional literature: [14]; [34]; [45]; [46]; [52]; [55]; [56].

CHAPTER 8. DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN THE SECOND HALF OF THE 20th – AT THE BEGINNING OF THE 21st CENTURY

- Electric power engineering and electrical systems.
- Metallurgy, chemical technologies and mechanical engineering.
- Transport development. Aviation and cosmonautics.
- Electronics, communication and computer systems.

8.1. Electricity and electrical systems

The period between 1945 and 2022 saw significant advancements in electricity and electrical systems, leading to the widespread adoption and integration of electrical technologies in various aspects of daily life, industry, and infrastructure. Some of the key developments during this time include:

Expansion of power grids: The post-World War II era saw a massive expansion of electrical power grids around the world, connecting urban and rural areas and ensuring the reliable supply of electricity to homes, businesses, and industries. This facilitated economic growth, development, and the overall improvement of living standards.

Nuclear power has undergone substantial developments since its inception in the 1940s. From its beginnings in nuclear weapons research to its current status as a significant source of electricity, nuclear power has evolved in response to changing needs and priorities.

Birth of nuclear power Following the development and use of atomic bombs during World War II, the focus shifted to peaceful applications of nuclear energy. The United States launched the "Atoms for Peace" program in 1953, which aimed to promote the peaceful use of nuclear technology and share knowledge with other nations.

Early nuclear power plants The first commercial nuclear power plant, the Shippingport Atomic Power Station in the United States, became operational in 1958. Other countries, such as the United Kingdom, France, and the Soviet Union, also began building and operating nuclear power plants during this period.

Expansion and growing concerns The 1970s saw a rapid expansion of nuclear power as an energy source, with many new reactors being constructed worldwide. However, concerns about nuclear safety and waste disposal started to emerge. The 1979 Three Mile Island accident in the United States heightened these concerns and led to increased regulation and oversight of the industry.

Slowdown and reassessment The growth of nuclear power slowed in the 1980s due to increasing costs, public opposition, and the 1986 Chernobyl disaster in the Soviet Union. The Chernobyl accident, which caused significant environmental and health impacts, further raised questions about the safety of nuclear power.

The Chernobyl disaster was a catastrophic nuclear accident that occurred on April 26, 1986, at the No. 4 reactor in the Chernobyl Nuclear Power Plant, near the city of Pripyat in the north of the Ukrainian SSR in the Soviet Union. It is considered the worst nuclear disaster in history and is one of only two nuclear energy accidents rated at seven, the maximum severity, on the International Nuclear Event Scale (the other being the Fukushima disaster in 2011).

The accident occurred during a late-night safety test simulating a station blackout power-failure, during which safety systems were deliberately turned off. A combination of inherent reactor design flaws, specifically related to the RBMK reactor type, and operator errors led to a sudden and uncontrollable power surge. The explosion and subsequent fires released large amounts of radioactive particles into the atmosphere, which spread over much of Western USSR and Europe.

Approximately 50 emergency workers and plant personnel died due to acute radiation syndrome in the immediate aftermath of the explosion, and thousands of first responders, known as liquidators, were exposed to high levels of radiation during the cleanup efforts. The long-term health effects of the disaster are still being studied, but it is estimated that the accident may have caused thousands of additional cancer deaths over time.

The nearby city of Pripyat, which housed the plant's workers and their families, was evacuated the day after the disaster, and the 30-kilometer (18.6-mile) exclusion zone around the power plant was established. The zone, which includes parts of modern-day Ukraine and Belarus, remains mostly uninhabited due to ongoing radiation hazards.

The Chernobyl disaster had significant social, political, and economic consequences for the Soviet Union and sparked a global reevaluation of the safety and viability of nuclear power. The disaster highlighted the need for improved reactor designs, better safety protocols, and more transparent communication during nuclear accidents. In the decades since the accident, the site has been the subject of extensive remediation efforts, including the construction of a massive containment structure known as the New Safe Confinement, which was completed in 2016 to replace the aging "sarcophagus" built shortly after the disaster.

Focus on safety and efficiency In response to safety concerns, the nuclear industry focused on improving reactor designs and safety measures. Advanced reactor designs, such as the Generation III and III+ reactors, offered enhanced safety features and better efficiency. During this period, several countries, including Germany and Sweden, decided to phase out nuclear power, while others, like France, continued to rely heavily on it.

Nuclear renaissance and Fukushima disaster The early 2010s saw a renewed interest in nuclear power, with several countries announcing plans to build new reactors. However, the 2011 Fukushima Daiichi nuclear disaster in Japan brought safety concerns back to the forefront and led to the shutdown of several reactors, particularly in Japan and Germany.

New technologies and the role of nuclear power in climate change mitigation As concerns about climate change and the need for low-carbon energy sources grow, nuclear power has been considered as a potential solution. The development of small modular reactors (SMRs) and advanced reactor designs, such as Generation IV reactors, promises increased safety, efficiency, and flexibility. However, public acceptance, high costs, and concerns about nuclear waste and proliferation remain challenges to the expansion of nuclear power.

A nuclear power plant operates on the principle of nuclear fission, which involves the splitting of heavy atomic nuclei, releasing a large amount of energy in the form of heat. This heat is then used to produce steam, which powers turbines connected to generators that produce electricity. Here is a step-by-step explanation of the operation of a typical pressurized water reactor (PWR), the most common type of nuclear power plant:

- **Nuclear fuel:** Nuclear power plants use enriched uranium fuel, typically in the form of uranium dioxide pellets that are arranged in long, cylindrical fuel rods. These rods are bundled together to form fuel assemblies, which are placed inside the reactor core.
- **Nuclear fission:** When a slow-moving neutron is absorbed by a uranium-235 nucleus, the nucleus becomes unstable and undergoes fission, splitting into two smaller nuclei (fission products), additional neutrons, and a large amount of energy in the form of heat. The released neutrons can then initiate a chain reaction by causing further fission events in other uranium-235 nuclei.

- **Control of the fission process:** To control the rate of fission and maintain a stable chain reaction, control rods made of materials that absorb neutrons (e.g., boron or cadmium) are inserted into or withdrawn from the reactor core. When the control rods are inserted into the core, they absorb more neutrons, reducing the rate of fission. Conversely, withdrawing the control rods increases the rate of fission.
- **Heat transfer and coolant:** The heat generated by the fission process is transferred to a coolant, typically water, that flows through the reactor core. In a PWR, the water is pressurized to prevent it from boiling, even at high temperatures. This pressurized water absorbs the heat from the reactor core and transfers it to a steam generator.
- **Steam generation:** In the steam generator, the pressurized water from the reactor core flows through tubes, transferring heat to a separate water loop, which turns into steam. This design keeps the radioactive materials within the primary coolant loop, isolated from the secondary loop that produces steam.
- **Power generation:** The high-pressure steam from the steam generator is directed to a turbine, where it expands and drives the turbine blades. The turbine is connected to an electrical generator, which produces electricity as it spins. After passing through the turbine, the steam is condensed back into water and returned to the steam generator to be reheated, forming a closed loop.
- **Cooling system:** The heat absorbed by the steam in the condenser is transferred to a cooling system, which can be either a body of water (e.g., a river or ocean) or a cooling tower, where the heat is released into the atmosphere. This ensures that the steam condenses back into water, which can be reused in the steam generator.
- **Radioactive waste management:** Spent fuel assemblies, which contain radioactive fission products and transuranic elements, are removed from the reactor core and stored in cooling pools or dry casks until they can be transported to a long-term storage facility or reprocessed.

In summary, the development of nuclear power from 1945 to 2022 has seen significant advancements in technology, alongside growing concerns about safety and environmental impacts. The future of nuclear power will likely depend on its ability to address these concerns while providing a reliable and low-carbon energy source in the face of climate change.

High-voltage direct current (HVDC) transmission technology has seen significant advancements between 1945 and 2020, driven by the need to transmit large amounts of electricity over long distances with minimal losses. This technology has become crucial for integrating renewable energy sources into the grid, connecting remote generation sites to demand centers, and enhancing power grid stability.

Early advancements (1940s-1960s): The first commercial HVDC transmission link was the 100 kV, 20 MW Gotland line in Sweden, commissioned in 1954, which connected the mainland to the island of Gotland. The success of this project spurred further development of HVDC technology, with advancements in thyristor valves and control systems leading to improved reliability and efficiency.

Expansion and increased capacity (1970s-1980s): During this period, HVDC transmission lines were increasingly deployed around the world. Technological advancements led to higher voltage levels and capacities, enabling longer transmission distances. Notable projects from this period include the 500 kV, 2,000 MW Pacific Intertie in the United States and the 600 kV, 3,100 MW Inga-Shaba transmission line in the Democratic Republic of Congo.

Transition to Voltage Source Converters (1990s-2000s): Voltage Source Converter (VSC) technology emerged as an alternative to the traditional Line Commutated Converter (LCC) systems. VSCs use Insulated Gate Bipolar Transistors (IGBTs) and offer better control of active and reactive power, making them suitable for applications like connecting offshore wind farms or supporting weak grids. The first commercial VSC-HVDC link, the Hellsjön-Alebo project in Sweden, was commissioned in 1997.

Advancements in converter technology and grid integration (2010s-2020): During this period, HVDC technology saw continuous improvements in converter efficiency, capacity, and voltage levels. Multi-terminal HVDC systems emerged, allowing for more flexible grid interconnections. HVDC transmission lines played a key role in integrating large-scale renewable energy sources, such as offshore wind farms in the North Sea, and in interconnecting regional grids to enhance stability and security of supply.

In summary, the development of HVDC transmission from 1945 to 2020 has been marked by significant technological advancements and a growing recognition of its importance in the global energy landscape. The technology has evolved to meet the needs of an increasingly interconnected and decarbonized energy system, and its role is expected to expand further as countries continue to transition towards renewable energy sources.

The 21st century has seen the development and implementation of smart grid technologies that leverage digital communication, data analytics, and automation to optimize the generation, distribution, and consumption of electricity. Smart grids offer improved efficiency, reliability, and sustainability, while also supporting the integration of distributed energy resources and electric vehicles.

The growth of renewable energy sources and the need for grid stability have spurred advances in energy storage technologies, such as batteries and pumped hydro storage. These systems help balance supply and demand, store excess energy produced during periods of low demand, and provide backup power during outages.

The rise of electric vehicles (EVs) has been one of the most notable developments in recent years. The advancements in battery technology, charging infrastructure, and government policies have contributed to the increasing adoption of EVs, which are seen as a critical component in reducing greenhouse gas emissions and combatting climate change.

Improvements in energy efficiency have been a key focus during this period. Technological innovations in lighting, appliances, and industrial processes have contributed to significant reductions in energy consumption and associated emissions.

Green energy has been an integral part of the world's technological advancements since the 1980s. The environmental concerns and the need to shift from fossil fuels have been the driving forces behind the research and development of green energy. In the early 1980s, wind turbines and solar panels began to appear on rooftops and in remote areas. However, it was not until the late 1990s and early 2000s that green energy sources began to make a significant contribution to the energy mix. During this period, the cost of green energy started to decline, making it more competitive with fossil fuels. In the last decade, the world has seen a rapid increase in the use of green energy, with wind and solar power leading the way. Technological advancements have also made energy storage more efficient, leading to the development of electric cars and other forms of transport. The shift to green energy is a continuous process, and it is expected to continue as the world works towards reducing carbon emissions and combating climate change.

The development of solar power has been one of the most significant advancements in green energy in recent years. Since the 1980s, researchers and scientists have been working to improve the efficiency and cost-effectiveness of solar power. The first solar panels were expensive, bulky, and produced very little power. However, with the development of thin-film solar cells, the cost of solar panels has decreased significantly. In the early 2000s, there was a significant increase in the use of solar power for residential and commercial use. In the last decade, utility-scale solar power plants have been developed, which can generate large amounts of electricity to power entire cities. The development of energy storage systems has also made solar power more practical by allowing excess energy to be stored and used when the sun is not shining. Additionally, advancements in solar technology have enabled solar panels to be integrated into building materials such as roofing tiles and

windows. With these advancements, the future of solar power looks bright, and it is expected to continue to be a significant source of renewable energy in the coming years.

The development of wind power has also been a significant advancement in green energy over the years. In the 1980s, the first wind turbines were developed and used primarily for remote power applications. However, as the technology improved and costs decreased, wind power started to become a more significant source of energy. In the late 1990s and early 2000s, wind turbines became more efficient, and their capacity increased significantly. As a result, wind power became competitive with fossil fuels in terms of cost. In recent years, wind power has seen significant growth, particularly in Europe and China. In 2020, wind power accounted for nearly 8% of the total electricity generation in the United States. Advances in wind turbine technology have also made wind power more practical in more locations, including offshore wind farms. Additionally, wind power can now be combined with energy storage systems to provide a more reliable and consistent source of energy. With further research and development, wind power is expected to continue to grow and become a significant contributor to the world's energy mix.

Bioenergy is another form of green energy that has seen significant development over the years. Bioenergy involves using organic matter such as wood, agricultural waste, and even animal waste to generate energy. In the early 2000s, the use of bioenergy for electricity generation and heating became more widespread. The development of advanced biofuels made from algae, waste oil, and other sources also increased. In recent years, there has been a significant push towards using bioenergy for transportation, particularly through the use of biofuels in vehicles. The development of bioenergy has also created opportunities for rural communities to produce their own energy, using locally available resources. However, bioenergy has also been the subject of controversy, as the production of some biofuels can lead to deforestation and other environmental issues.

As a result, there is a need to develop sustainable bioenergy sources that minimize the impact on the environment. Despite these challenges, bioenergy is expected to continue to be an important component of the world's energy mix in the coming years. The use of geothermal energy involves harnessing the heat from the earth to generate electricity or heat buildings. In the early 2000s, geothermal power plants were built in several countries, including the United States, Iceland, and the Philippines. These plants use the earth's natural heat to generate electricity, which is then distributed to homes and businesses. Advances in technology have made it possible to extract heat from deeper and hotter areas, making geothermal energy more efficient and cost-effective. In recent years, there has been a push towards using geothermal energy for heating and cooling buildings. Geothermal heat pumps, which use the constant temperature of the earth to heat or cool a building, have become more popular in residential and commercial applications. There has also been research into using geothermal energy to produce hydrogen, which could be used as a clean fuel for transportation. While the development of geothermal energy has been slower compared to other forms of green energy, it is expected to become more widely used in the coming years as technology improves and the need for sustainable energy sources increases.

According to the International Energy Agency (IEA), electricity from renewable sources accounted for 28% of global electricity generation in 2020. The IEA also reported that renewable energy sources, including hydropower, wind, solar, and bioenergy, were responsible for 90% of new electricity capacity added globally in 2020. Additionally, the United Nations reported that renewable energy accounted for over 72% of all new power capacity additions in the United States in 2020. In the European Union, renewable energy sources accounted for 38% of electricity generation in 2020. These statistics indicate that renewable energy sources are playing an increasingly significant role in the world's electricity generation, and the trend is expected to continue in the coming years as countries work towards reducing carbon emissions and combating climate change.

According to the Ukrainian State Agency for Energy Efficiency and Energy Saving, the share of electricity generated from renewable sources in Ukraine has been steadily increasing over the years. In 2020, renewable energy sources accounted for about 6% of Ukraine's electricity generation, which is a significant increase from the 2.5% in 2019. The agency also reported that as of 2020, the country's total installed capacity of renewable energy sources was approximately 5.5 GW, which includes 3.7 GW of wind power and 1.6 GW of solar power. Ukraine has set a target to increase its share of renewable energy in electricity generation to 25% by 2035. To achieve this goal, the country is investing in the development of wind and solar power, and also promoting the use of biomass and biogas for electricity generation. These statistics indicate that Ukraine is making progress towards increasing its use of renewable energy, which is crucial for reducing carbon emissions and promoting sustainable energy practices.

In summary, the period between 1945 and 2022 has been marked by tremendous advancements in electricity and electrical systems. These developments have shaped the modern world, providing the foundation for economic growth and improvements in living standards, while also driving the transition towards more sustainable and environmentally-friendly energy sources.

8.2. Metallurgy, chemical technologies and mechanical engineering

Metallurgy and chemical technologies have experienced significant advancements since 1945, leading to the development of new materials, improved production methods, and innovative applications across various industries. Here are some key developments in metallurgy and chemical technologies during this period:

The development of new materials, such as high-strength steels, aluminum alloys, titanium alloys, and composite materials, has revolutionized industries like aerospace, automotive, and construction. These materials offer superior performance characteristics, such as strength, corrosion resistance, and lightweight properties, enabling more efficient and sustainable designs.

Powder metallurgy techniques have evolved considerably, allowing for the production of complex shapes and the development of materials with unique properties, such as metal matrix composites, metal foams, and nanocrystalline materials. These advancements have found applications in various industries, including aerospace, automotive, and electronics.

Also known as 3D printing, additive manufacturing has emerged as a transformative technology in metallurgy, enabling the production of complex metal parts with minimal material waste. The technology has been particularly impactful in industries like aerospace, where it enables the production of lightweight and intricate components.

The development of high-performance plastics and polymers, such as polyamides, polyethylene, and polycarbonates, has led to their widespread use across various industries. These materials offer a combination of strength, lightweight properties, and chemical resistance, making them suitable for applications in automotive, aerospace, electronics, and medical devices.

Innovations in the petrochemical industry have led to the development of new processes and catalysts for producing chemicals, plastics, and synthetic fibers. This has enabled the production of a wide range of materials and products with diverse properties and applications.

Environmental concerns and the desire for more sustainable industrial practices have driven the development of green chemistry. This field focuses on reducing waste, minimizing energy consumption, and using renewable feedstocks to create environmentally-friendly chemical processes and products.

The emergence of nanotechnology has had a profound impact on both metallurgy and chemical industries. The manipulation of materials at the nanoscale has enabled the development of new materials with unique properties, such as carbon nanotubes and graphene, as well as novel applications in areas like electronics, energy storage, and medicine.

The intersection of biology and chemistry has led to significant advancements in biotechnology. This includes the development of biodegradable plastics, biofuels, and biomaterials, as well as the use of enzymes and microorganisms for various industrial processes.

In summary, the period from 1945 to 2022 has seen remarkable progress in metallurgy and chemical technologies. These advancements have transformed industries, enabled new applications, and driven the development of more sustainable and environmentally-friendly materials and processes.

In the field of mechanical engineering, there has been a significant focus on the development of advanced technologies and systems, such as robotics and automation. Robotics and automation have played a significant role in improving efficiency and reducing costs in a wide range of industries, including manufacturing and logistics. The use of advanced sensors and algorithms has also led to significant improvements in machine learning and artificial intelligence, which are being used to create smarter and more efficient machines.

The use of digital technology has also had a significant impact on metallurgy, chemical technologies, and mechanical engineering. The development of big data and the Internet of Things (IoT) has allowed for real-time monitoring and analysis of materials, processes, and machines, which can lead to improvements in efficiency, safety, and overall product quality. Digital technology is also being used to develop new systems for product design and development, with the use of virtual reality and other technologies allowing for more accurate and efficient product development and testing.

In the field of metallurgy, there has also been a significant focus on the development of 3D printing, which allows for the creation of complex metal parts and components. 3D printing has the potential to revolutionize the way that metal parts and components are produced, with significant benefits in terms of efficiency and cost-effectiveness.

In the field of chemical technologies, there has been a significant focus on the development of renewable energy sources, such as hydrogen fuel cells and solar power. These technologies are expected to play a significant role in reducing carbon emissions and improving the sustainability of the chemical industry.

In the field of mechanical engineering, there has been a significant focus on the development of electric and hybrid-electric machines, such as cars and airplanes. These machines offer significant environmental benefits and improved efficiency, and they have become increasingly popular with consumers. Major players such as Tesla and Boeing have invested heavily in the development of electric and hybrid-electric machines, and the technology is expected to continue to improve in the coming years.

In conclusion, the fields of metallurgy, chemical technologies, and mechanical engineering have all undergone significant changes in the last decades, with advancements in technology and engineering that have led to improvements in efficiency, safety, and environmental impact. The use of advanced materials, new manufacturing and processing techniques, and digital technology has all played a significant role in the development of these fields, and these advancements are expected to continue to drive innovation and progress in the years to come.

8.3. Transport development. Aviation and cosmonautics

Transport development between 1945 and 2022 has seen tremendous advancements across various modes of transportation, including road, rail, air, and maritime transport. These developments have facilitated global trade, enhanced connectivity, and improved mobility for people worldwide. Some of the most notable advancements in transport during this period include:

Since 1945, the automotive industry has seen numerous technological advancements and innovations, which have led to significant improvements in vehicle performance, safety, efficiency, and environmental impact. Here are some key developments in the automobile sector:

Engines have become more fuel-efficient, powerful, and reliable over the years. Advancements such as fuel injection systems, turbocharging, variable valve timing, and direct gasoline injection have allowed for better performance and lower emissions. Diesel engines have also undergone significant improvements, with common rail systems, turbocharging, and exhaust gas recirculation reducing emissions and enhancing efficiency.

The use of lightweight materials, such as aluminum, high-strength steel, and composites, has become more widespread, reducing vehicle weight and improving fuel efficiency. New manufacturing techniques, like 3D printing, have also allowed for the creation of complex, lightweight components that were previously unachievable.

Modern vehicles are equipped with numerous safety features, such as airbags, anti-lock braking systems (ABS), electronic stability control (ESC), and traction control systems, which have significantly improved road safety. Advanced driver assistance systems (ADAS), like adaptive cruise control, lane departure warning, blind-spot monitoring, and forward collision warning, have further enhanced vehicle safety.

The emergence of electric vehicles, powered by batteries or fuel cells, has been a game-changer for the automotive industry. EVs produce zero tailpipe emissions, making them environmentally friendly alternatives to internal combustion engine (ICE) vehicles. Improvements in battery technology, such as higher energy density and faster charging capabilities, have made EVs more practical and appealing to consumers.

The development of autonomous vehicles has the potential to revolutionize personal mobility and transportation. Autonomous driving technologies rely on a combination of sensors, cameras, radar, and lidar to navigate and make decisions on the road. While fully autonomous vehicles are not yet commercially available, many vehicles already have semi-autonomous features, like self-parking and adaptive cruise control.

Modern vehicles are increasingly becoming connected to the internet, enabling features like remote diagnostics, over-the-air software updates, and integration with smartphone apps. Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication systems are also being developed, which will enable real-time data sharing between vehicles and infrastructure, improving traffic management and safety.

In addition to electric vehicles, the automotive industry has also explored other alternative fuels, such as biofuels, natural gas, and hydrogen. These alternatives can help reduce dependence on fossil fuels and lower greenhouse gas emissions.

The rise of ride-sharing services like Uber and Lyft has had a significant impact on personal mobility and the automotive industry. These services have led to a shift in consumer preferences, with some people choosing to use shared mobility services instead of owning a vehicle.

High-speed rail (HSR) is a type of passenger rail transportation that operates at much faster speeds than traditional rail systems. The first high-speed rail systems emerged in the mid-20th century, with Japan's Shinkansen (also known as the "bullet train") being one of the most iconic examples, beginning operation in 1964. Since then, HSR has expanded to numerous countries worldwide, including France, Germany, Spain, Italy, China, South Korea, and Turkey.

Here are some key aspects of high-speed rail:

- **Speed:** High-speed trains typically operate at speeds above 155 mph (250 km/h) on dedicated tracks, while some trains, like France's TGV and China's CRH, can reach speeds over 186 mph (300 km/h) or even 217 mph (350 km/h). These high speeds significantly reduce travel times, making HSR an attractive alternative to air travel and traditional rail for medium-distance trips.
- **Infrastructure:** High-speed rail systems require dedicated tracks, usually built with high-quality materials and engineered to allow for smooth and efficient operation at high speeds. This often involves constructing straighter and more gently curving tracks, installing advanced signaling systems, and utilizing noise and vibration reduction measures.
- **Rolling stock:** HSR trains are aerodynamically designed to reduce air resistance and increase energy efficiency. They are typically electrically powered, using overhead catenary systems or, in some cases, underfloor power supply systems. These trains are equipped with advanced suspension and braking systems, which enable high-speed travel while maintaining passenger comfort and safety.
- **Economic impact:** High-speed rail can have significant economic benefits, both in terms of job creation during construction and operation and by connecting major cities and economic centers more efficiently. HSR can boost tourism, increase business productivity, and spur regional development by providing fast and convenient transportation options.

- **Environmental impact:** HSR is generally considered to be a more environmentally friendly mode of transportation than air travel and road transportation, as it produces fewer greenhouse gas emissions per passenger mile. Electric HSR trains produce no direct emissions, and when powered by renewable energy sources, their overall environmental impact can be even lower.
- **Safety:** High-speed rail has an impressive safety record, with very few accidents in its history. This is attributed to the use of dedicated tracks, advanced signaling systems, and stringent maintenance standards.
- **Challenges:** High-speed rail projects can face several challenges, including high construction costs, land acquisition issues, and political opposition. Moreover, HSR can sometimes struggle to compete with low-cost airlines and well-developed highway networks in certain markets.

As countries around the world continue to invest in high-speed rail infrastructure, HSR is likely to play an increasingly significant role in regional and intercity transportation, offering a fast, safe, and environmentally friendly alternative to other modes of transport.

Since the end of World War II, aviation has experienced remarkable advancements in technology, design, and safety. The post-1945 period saw the emergence of new aircraft types, propulsion systems, and materials, which revolutionized air travel and the aerospace industry. Here are some notable developments in aviation from 1945 to 2022:

The widespread adoption of jet engines, which provided greater speed, range, and efficiency compared to piston engines, revolutionized commercial and military aviation. The de Havilland Comet (1952) was the world's first jet-powered commercial airliner, followed by the Boeing 707 (1958) and Douglas DC-8 (1959), which helped establish long-haul jet travel.

The breaking of the sound barrier by Chuck Yeager in the Bell X-1 (1947) led to the development of supersonic aircraft. The most famous examples include the Concorde (1969), a commercial airliner that could travel at over twice the speed of sound, and military aircraft like the F-4 Phantom II (1958), F-14 Tomcat (1970), and F-15 Eagle (1972).

The introduction of wide-body aircraft, such as the Boeing 747 (1969), made long-haul air travel more comfortable and affordable. The 747 was followed by other wide-body designs like the McDonnell Douglas DC-10 (1970), Lockheed L-1011 Tristar (1970), Airbus A300 (1972), and Boeing 777 (1994).

Advances in computing and electronics led to the development of sophisticated avionics systems, such as fly-by-wire controls, glass cockpits, and advanced navigation and communication systems. These innovations greatly improved aircraft performance, reliability, and safety.

The use of lightweight materials, such as aluminum alloys, titanium, and composite materials, enabled the construction of lighter and more fuel-efficient aircraft. Aerodynamic improvements, like winglets and laminar flow control, also contributed to better performance and reduced fuel consumption.

The advent of satellite-based navigation systems, such as GPS, and improvements in air traffic control technologies have made flying safer and more efficient. Modern air traffic management systems, like NextGen in the US and SESAR in Europe, aim to further improve airspace utilization, reduce delays, and minimize environmental impacts.

The rise of low-cost carriers, such as Southwest Airlines in the US and Ryanair in Europe, has transformed the aviation industry by offering affordable air travel to millions of passengers. This has led to increased competition, which has driven further innovation and efficiency improvements in the sector.

The development of UAVs and drones has revolutionized aviation, particularly in the fields of surveillance, reconnaissance, and cargo transport. These aircraft, which can be remotely piloted or autonomous, have been adopted by both military and civilian sectors.

Research and development efforts are underway to create electric and hybrid aircraft, with the goal of reducing emissions, noise pollution, and fuel consumption. Examples of such aircraft include the Eviation Alice, an all-electric regional aircraft, and the Zunum Aero, a hybrid-electric regional aircraft.

Companies like Boom Supersonic and Aerion Supersonic are working on developing next-generation supersonic commercial aircraft, while NASA and other organizations are researching hypersonic travel, which could lead to speeds exceeding Mach 5.

The Concorde was a supersonic passenger aircraft that was developed and manufactured by the British Aircraft Corporation (BAC) and Aérospatiale, a French company. It was a symbol of advanced aviation technology and cooperation between the United Kingdom and France. The Concorde first flew in 1969 and entered commercial service in 1976. It was retired in 2003 after 27 years of service.

The Concorde had a unique delta-wing configuration and a slender, streamlined fuselage designed for high-speed flight. It was powered by four Rolls-Royce/Snecma Olympus 593 turbojet engines, which enabled the aircraft to reach speeds of up to Mach 2.04 (over 2,180 km/h or 1,354 mph) and cruise at an altitude of around 60,000 feet. This allowed the Concorde to cross the Atlantic in just under 3.5 hours, significantly reducing travel times compared to conventional subsonic airliners.

A total of 20 Concorde were built, including prototype, pre-production, and production aircraft. The Concorde primarily served transatlantic routes between London and New York, and Paris and New York, operated by British Airways and Air France. The aircraft was known for its luxurious amenities and distinctive experience, often catering to wealthy passengers and celebrities.

Despite its technological achievements, the Concorde faced several challenges that ultimately contributed to its retirement:

- High operating costs: The Concorde was expensive to operate due to its high fuel consumption, extensive maintenance requirements, and low passenger capacity (typically around 100 passengers per flight).
- Noise and environmental concerns: The Concorde's sonic boom and loud engine noise led to numerous noise complaints, resulting in restrictions on supersonic flight over land. Additionally, the aircraft's high fuel consumption and emissions raised environmental concerns.
- Limited market: The high ticket prices and limited route options (primarily transatlantic flights) meant that the Concorde primarily catered to a niche market of wealthy passengers, limiting its commercial viability.
- The Air France Flight 4590 accident: In July 2000, an Air France Concorde crashed shortly after takeoff from Paris Charles de Gaulle Airport, killing all 109 passengers and crew onboard, as well as four people on the ground. Although the accident was not directly attributed to a design flaw in the Concorde, it raised safety concerns and contributed to the decline in passenger confidence.
- Economic downturn and declining demand: The early 2000s saw a downturn in the global economy and a decline in air travel demand following the September 11, 2001 attacks. This further reduced the already limited market for the Concorde's high-priced, luxury service.

In 2003, both British Airways and Air France decided to retire their Concorde fleets, marking the end of an era in commercial supersonic aviation. Although no longer in service, the Concorde remains an iconic symbol of aviation history and technological innovation.

The Antonov An-225 Mriya was a strategic airlift cargo aircraft designed and built by the Antonov Design Bureau in the Soviet Union during the 1980s. The name "Mriya" (Мрія) means "dream" or "inspiration" in Ukrainian. The An-225 was the heaviest and largest cargo aircraft ever built, with a maximum takeoff weight of 640 metric tons (1,410,958 lb) and a wingspan of 88.4 meters (290 ft).

Originally developed to transport the Buran space shuttle, the An-225 was designed to carry large, heavy, and bulky cargo externally on its fuselage. After the cancellation of the Soviet space program, the aircraft found new life as a commercial cargo transporter. The An-225 has been used to carry a variety of oversized and heavy loads, including large industrial equipment, relief supplies, and military vehicles.

The An-225 was powered by six Ivchenko-Progress D-18T turbofan engines, providing enough thrust to lift the massive aircraft and its cargo. It had a range of up to 15,400 kilometers (9,570 miles) when carrying a reduced payload, allowing for intercontinental flights.

Only one An-225 was completed and remained operational until February 2022 while being destroyed during the Russian invasion of Ukraine. It was a unique and highly sought-after aircraft for specialized cargo transportation. The second An-225 airframe was left unfinished after the collapse of the Soviet Union but has been the subject of several attempts to complete its construction and bring it into service.

The An-225's impressive size, payload capacity, and unique capabilities have made it a symbol of engineering excellence and have earned it a place in aviation history.

Maritime transport has undergone significant changes since 1945, as new technologies, ship designs, and management practices have transformed the shipping industry.

The introduction of standardized shipping containers in the 1950s revolutionized the shipping industry, enabling faster and more efficient loading and

unloading of cargo. The use of containers significantly reduced transportation costs and led to the growth of global trade. Today, container ships are the backbone of international trade, transporting millions of TEUs (twenty-foot equivalent units) every year.

Ship sizes have increased dramatically since the mid-20th century, with the development of larger and more efficient vessels, such as bulk carriers, tankers, and container ships. Larger ships can carry more cargo, resulting in lower transportation costs per unit. Examples of large ships include the Very Large Crude Carrier (VLCC), Ultra Large Container Vessel (ULCV), and Panamax-class vessels.

The shipping industry has also seen the development of specialized vessels designed for specific types of cargo or operations, such as Roll-on/Roll-off (Ro-Ro) ships for transporting vehicles, liquefied natural gas (LNG) carriers for transporting natural gas, and heavy-lift ships for transporting oversized cargo. These specialized ships help to meet the diverse needs of the global economy.

The shipping industry has benefited from numerous technological advancements, including improvements in navigation systems, satellite communication, and ship propulsion. For example, the use of GPS and Electronic Chart Display and Information Systems (ECDIS) has greatly improved navigation safety and efficiency. Ship propulsion has also evolved, with the development of more efficient diesel engines, as well as alternative propulsion systems like LNG, hybrid, and battery-powered systems.

The International Maritime Organization (IMO) and other regulatory bodies have introduced increasingly strict environmental regulations to address concerns about air and water pollution, as well as greenhouse gas emissions from ships. These regulations have spurred the development of cleaner technologies and fuels, such as low-sulfur fuel, LNG, and scrubbers, which help to reduce the environmental impact of shipping.

Ports have become larger and more advanced to accommodate the growth in maritime trade and the increasing size of ships. Many ports have implemented

automation and digital technologies to improve efficiency and reduce the time ships spend in port. For example, the use of automated cranes, self-driving vehicles, and digital platforms for tracking and managing cargo can help to streamline port operations.

The shipping industry has made significant strides in improving safety and security, through the adoption of international conventions, such as the International Convention for the Safety of Life at Sea (SOLAS) and the International Ship and Port Facility Security (ISPS) Code. These regulations, along with advancements in ship design and technology, have contributed to a decline in shipping accidents and incidents of piracy.

The shipping industry is increasingly adopting digital technologies, such as the Internet of Things (IoT), blockchain, and artificial intelligence (AI), to improve efficiency, reduce costs, and enhance competitiveness. These technologies enable better tracking of cargo, more efficient route planning, predictive maintenance, and improved decision-making.

In summary, maritime transport has experienced significant advancements since 1945, driven by innovations in ship design, technology, and management practices. As the industry continues to evolve, it will likely see further improvements in efficiency, sustainability, and safety.

Public transportation has undergone considerable advancements since 1945, with innovations in technology, infrastructure, and planning, leading to improved efficiency, accessibility, and sustainability.

The construction of MRT systems, such as subways and metros, has dramatically improved urban transportation in many cities around the world. These systems provide fast, efficient, and high-capacity transportation options that help reduce congestion and reliance on private vehicles.

The resurgence of LRT and trams in many cities has provided a convenient and environmentally friendly transportation option, especially in medium-density areas where MRT systems may not be economically viable. LRT and trams often integrate well with other transportation modes, such as buses and bicycles, promoting multimodal transportation.

BRT systems combine the efficiency and speed of rail systems with the flexibility and lower cost of bus systems. These systems typically feature dedicated bus lanes, advanced signaling systems, and off-board fare collection, resulting in faster and more reliable service compared to traditional bus systems.

The adoption of electric and hybrid buses in public transportation fleets has increased significantly in recent years, driven by concerns about air quality and greenhouse gas emissions. These buses produce lower emissions and often have lower operating costs compared to conventional diesel buses.

Many cities have implemented integrated ticketing systems that allow passengers to use a single ticket or card to travel on multiple modes of public transportation. These systems simplify fare collection, reduce waiting times, and encourage the use of public transportation.

Advances in information technology have enabled public transportation agencies to provide real-time information on vehicle locations, arrival times, and service disruptions. Passengers can access this information through mobile applications, digital displays at stations, or websites, making it easier to plan and navigate their journeys.

Public transportation systems have become more accessible for people with disabilities through the implementation of various measures, such as low-floor buses and trains, wheelchair ramps, tactile paving, and audible signals at stations and stops.

Urban planners and transportation agencies have increasingly recognized the importance of public transportation in promoting sustainable development. As a result, many cities have prioritized public transportation in their urban planning and transportation policies, aiming to reduce reliance on private cars and promote more sustainable modes of travel.

Advances in autonomous vehicle technology have the potential to transform public transportation by reducing the need for human drivers, improving safety, and optimizing vehicle routing. In addition, connected vehicle technology enables communication between vehicles and infrastructure, which can help improve the efficiency and safety of public transportation systems.

Overall, public transportation has seen significant advancements since 1945, leading to improved efficiency, accessibility, and sustainability. As technology continues to evolve, further innovations are likely to shape the future of public transportation, making it an even more attractive and environmentally friendly alternative to private car use.

The development and expansion of transportation infrastructure, including highways, bridges, tunnels, airports, and seaports, have played a crucial role in supporting the growth of global trade, tourism, and regional connectivity. Technological advancements in materials, engineering, and construction techniques have enabled the construction of more efficient and durable infrastructure.

In summary, the period between 1945 and 2022 has witnessed remarkable advancements in transportation across various modes. These developments have had profound impacts on global connectivity, trade, and mobility, and continue to shape the future of transportation as we strive for more sustainable, efficient, and accessible systems.

Space exploration between 1945 and 1980 saw significant milestones and achievements, marking the beginning of the Space Age. During this period, the United States and the Soviet Union were engaged in a fierce competition known as the Space Race, which led to rapid advancements in space technology and exploration. Here are some key events and achievements from this period:

- **Sputnik 1 (1957):** The Soviet Union launched Sputnik 1, the world's first artificial satellite, on October 4, 1957. This event marked the beginning of the Space Age and ignited the Space Race between the United States and the Soviet Union.
- **Explorer 1 (1958):** In response to the launch of Sputnik, the United States successfully launched its first satellite, Explorer 1, on January 31, 1958. Explorer 1 made significant scientific discoveries, including the detection of the Van Allen radiation belts surrounding Earth.
- **Luna Program (1959-1976):** The Soviet Union's Luna Program was a series of robotic spacecraft missions aimed at exploring the Moon. Luna 2 became the first human-made object to impact the Moon in 1959, and Luna 3 returned the first images of the Moon's far side in the same year.
- **Yuri Gagarin (1961):** Soviet cosmonaut Yuri Gagarin became the first human to journey into outer space and orbit the Earth on April 12, 1961, aboard the Vostok 1 spacecraft.
- **Project Mercury (1958-1963):** The United States launched its first human spaceflight program, Project Mercury, with the goal of placing an astronaut in orbit around the Earth. Alan Shepard became the first American in space in 1961, and John Glenn became the first American to orbit the Earth in 1962.
- **Project Gemini (1961-1966):** Project Gemini was the United States' second human spaceflight program, aimed at developing the technologies and techniques required for lunar missions. Gemini spacecraft featured rendezvous and docking capabilities, and astronauts conducted the first American spacewalks during these missions.

- Apollo Program (1961-1972): The Apollo Program was the United States' third human spaceflight program, which aimed to land humans on the Moon and bring them safely back to Earth. The program achieved this goal on July 20, 1969, when Apollo 11 astronauts Neil Armstrong and Buzz Aldrin walked on the Moon's surface. Apollo 17, the final mission of the program, took place in 1972.
- Venera Program (1961-1984): The Soviet Union's Venera Program was a series of robotic missions aimed at exploring Venus. Venera 7 became the first spacecraft to land on another planet in 1970, and Venera 9 returned the first images from the surface of Venus in 1975.
- Mars exploration (1971-1976): Both the United States and the Soviet Union launched missions to explore Mars during this period. The Soviet Mars 3 mission achieved the first soft landing on Mars in 1971, while the United States' Viking 1 and Viking 2 missions successfully landed on Mars in 1976, returning detailed images and scientific data about the Martian surface.
- Skylab (1973-1974): Skylab was the United States' first space station, which was occupied by three different astronaut crews between 1973 and 1974. The station's primary objectives were to study the effects of long-duration spaceflight on the human body and to conduct scientific experiments in microgravity.

From 1980 to 2022, space exploration continued to advance and expand, with numerous countries and private companies contributing to the development of new technologies, scientific discoveries, and human exploration of space. Some notable achievements and events during this period include:

- Space Shuttle Program (1981-2011): NASA's Space Shuttle program consisted of reusable spacecraft designed for human spaceflight missions, satellite deployment, and construction and maintenance of the International Space Station (ISS). The program began with the launch of Space Shuttle Columbia in 1981 and concluded with the final flight of Space Shuttle Atlantis in 2011.

- **Mir Space Station (1986-2001):** The Soviet Union, and later Russia, operated the Mir Space Station as a platform for long-duration human spaceflight and scientific research. Mir was continuously inhabited for a record 9 years and 357 days and was visited by astronauts from various countries, including the United States.
- **Hubble Space Telescope (1990-present):** Launched in 1990, the Hubble Space Telescope has provided stunning images and vital scientific data about the universe. Its observations have led to numerous discoveries, including the existence of dark energy and the expansion rate of the universe.
- **Mars Pathfinder (1997):** NASA's Mars Pathfinder mission successfully landed the Sojourner rover on Mars, marking the first successful rover mission to the Red Planet and paving the way for future Mars rovers.
- **International Space Station (1998-present):** The ISS is a collaborative project involving multiple countries, including the United States, Russia, Canada, Japan, and members of the European Space Agency. Construction began in 1998, and the ISS has been continuously inhabited since 2000. It serves as a laboratory for scientific research, a platform for technology development, and a training ground for future human spaceflight missions.
- **Cassini-Huygens Mission (1997-2017):** The joint NASA-ESA mission to explore Saturn and its moons provided detailed data and stunning images of the planet, its rings, and its diverse moons. The Huygens probe landed on Saturn's moon Titan in 2005, revealing a complex world with a thick atmosphere and liquid hydrocarbon lakes.
- **Mars Exploration Rovers (2004-present):** NASA's Spirit and Opportunity rovers landed on Mars in 2004 and far exceeded their expected lifetimes. They made groundbreaking discoveries, including evidence of past water activity on Mars. NASA's subsequent Mars rovers, Curiosity and Perseverance, continue to explore the Red Planet.

- New Horizons (2006-present): Launched in 2006, NASA's New Horizons mission conducted a flyby of Pluto in 2015, providing the first detailed images and data about the dwarf planet and its moons. The spacecraft later performed a flyby of the Kuiper Belt object Arrokoth in 2019.
- Private spaceflight and commercialization (2000s-present): Companies such as SpaceX, Blue Origin, and Virgin Galactic have emerged as significant players in space exploration, developing reusable rockets, satellite launch systems, and spacecraft for human spaceflight. SpaceX's Falcon Heavy rocket and Crew Dragon spacecraft have been particularly notable, with Crew Dragon enabling crewed missions to the ISS.
- China's space program (1990s-present): China has made significant progress in space exploration, becoming the third country to independently launch humans into space in 2003. China has also launched lunar missions, including the Chang'e 4 rover that landed on the far side of the Moon in 2019, and the Mars mission Tianwen-1, which successfully deployed the Zhurong rover on Mars in 2021.

The James Webb Space Telescope (JWST), named after NASA's second administrator, is a joint project between NASA, the European Space Agency (ESA), and the Canadian Space Agency (CSA). The JWST is the largest, most powerful, and complex space telescope ever built. It is designed to observe the universe in the infrared spectrum, which will allow it to study the early universe, the formation of galaxies, and the birth of stars and planets. The telescope is equipped with a 6.5-meter primary mirror, which is made up of 18 hexagonal segments. The mirror is coated with a thin layer of gold, which will allow it to reflect infrared light more efficiently. The JWST is also equipped with a range of advanced instruments, including a Near Infrared Camera, a Near Infrared Spectrograph, and a Mid-Infrared Instrument. The telescope is set to be launched in 2021, and it will be positioned in space, about 1.5 million km from Earth.

The JWST will be able to detect and observe some of the earliest and most distant galaxies in the universe, which will provide insight into the evolution of the universe. The JWST is expected to be a game-changer in the field of astronomy, and it is set to make significant contributions to our understanding of the universe.

8.4. Electronics, communication and computer systems

Between 1945 and 1960, the field of electronics and computer systems experienced significant advancements. This period saw the emergence of early computers and innovations in electronics, driven by the needs of World War II and the subsequent Cold War.

ENIAC (1946): The Electronic Numerical Integrator and Computer (ENIAC) was one of the first electronic general-purpose computers. Developed at the University of Pennsylvania, it was initially designed to calculate artillery firing tables for the United States Army but was later used for various calculations, including nuclear weapon simulations.

Transistor (1947): Invented by John Bardeen, Walter Brattain, and William Shockley at Bell Laboratories, the transistor revolutionized electronics by replacing bulky vacuum tubes. Transistors were smaller, more energy-efficient, and more reliable, paving the way for miniaturization and the development of modern electronics.

Manchester Mark 1 (1949): Developed at the University of Manchester in the United Kingdom, the Manchester Mark 1 was one of the earliest stored-program computers. It was the first machine to use the Williams-Kilburn Tube, a cathode ray tube used for random-access memory (RAM).

EDVAC (1951): The Electronic Discrete Variable Automatic Computer (EDVAC) was an early stored-program computer designed by John von Neumann and built at the University of Pennsylvania. EDVAC introduced the concept of the von Neumann architecture, which became the basis for most modern computers.

UNIVAC I (1951): The UNIVAC I (UNIVersal Automatic Computer I) was the first commercially produced electronic computer. Built by Remington Rand, it was used for a variety of applications, including the United States Census Bureau and the United States Air Force.

Integrated circuit (1958): Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor independently invented the integrated circuit (IC) in 1958. The IC combined multiple electronic components, such as transistors and resistors, on a single semiconductor chip, further enabling the miniaturization and increased functionality of electronic devices.

FORTRAN (1957): FORTRAN (FORmula TRANslation) was the first high-level programming language, developed by IBM for scientific and engineering calculations. It enabled programmers to write code in a more human-readable format, greatly simplifying the process of creating software for early computers.

LEO (1951): The Lyons Electronic Office (LEO) was the first business computer, developed by British catering company J. Lyons & Co. to handle its payroll, inventory, and other data processing tasks. LEO marked the beginning of computers being used for commercial purposes beyond scientific and military applications.

SAGE (Semi-Automatic Ground Environment) (1950s-1983): SAGE was a large-scale computer system developed by IBM for the United States Air Force. It was designed to process radar data and help coordinate the defense against potential Soviet bomber attacks during the Cold War.

These developments in electronics and computer systems between 1945 and 1960 laid the groundwork for the modern digital age, enabling the creation of increasingly powerful and sophisticated computers and electronic devices in the following decades.

Between 1960 and 1990, the field of electronics and computer systems experienced rapid advancements, driven by the semiconductor revolution, increasing miniaturization, and the growth of the software industry. Here are some key developments during this period:

Integrated Circuits (ICs) and Microprocessors: IC technology continued to evolve, enabling more transistors to be placed on a single chip. The first microprocessor, Intel's 4004, was introduced in 1971. Microprocessors became the heart of computers and various electronic devices, making them more powerful, versatile, and affordable.

In the 1960s and 1970s, minicomputers emerged as smaller, less expensive alternatives to mainframe computers. Notable minicomputers include the DEC PDP-8 and PDP-11, which were widely used in laboratories, universities, and businesses.

The 1970s and 1980s witnessed the birth of the personal computer industry, with early models like the Altair 8800, Apple I and II, and the IBM PC. PCs brought computing power to homes and offices, revolutionizing how people worked, communicated, and entertained themselves.

The ARPANET, a precursor to the modern Internet, was developed in the late 1960s and early 1970s by the U.S. Department of Defense. It enabled the sharing of data and resources between computers, laying the groundwork for the World Wide Web in the 1990s.

Graphical User Interfaces (GUIs): Early computers used text-based interfaces, which were not very user-friendly. The introduction of GUIs, like Xerox PARC's Alto and later Apple's Macintosh, allowed users to interact with computers more intuitively using windows, icons, and menus.

In 1965, Gordon Moore, co-founder of Intel, observed that the number of transistors on a microchip doubles approximately every two years, resulting in exponential growth in computing power. Moore's Law has largely held true and has been a driving force in the development of electronics and computer systems.

Computer-Aided Design (CAD): The development of CAD software in the 1960s and 1970s allowed engineers and designers to create digital models of their designs, streamlining the design process and enabling greater precision and complexity.

The first video games emerged in the 1970s and quickly became a popular form of entertainment. Early consoles like the Atari 2600 and arcade games like Pong and Space Invaders laid the foundation for a multibillion-dollar industry.

The emergence of portable electronic devices, such as the Sony Walkman (1979), revolutionized how people consumed media. Portable computing devices, like the Osborne 1 (1981) and the early laptops, allowed users to work on the go.

With the rise of personal computers, the software industry boomed. Companies like Microsoft, Apple, and IBM developed operating systems, productivity software, and programming languages that enabled the creation of diverse applications for home and business users.

These advancements in electronics and computer systems between 1960 and 1990 formed the basis for the digital world we live in today. The continued evolution of computing technology has led to powerful smartphones, tablets, and other devices that have profoundly impacted how we live, work, and communicate.

The 1990s saw the introduction of the first Pentium microprocessors, which were the first processors to use the x86 architecture. In the 2000s, Intel introduced the Pentium 4 processor, which was the first processor to feature Hyper-Threading Technology. This technology allowed a single processor to act as two virtual processors, increasing processing power and efficiency. In 2006, Intel introduced the Core 2 Duo processor, which was the first dual-core processor for desktop computers. The Core 2 Duo processor offered better performance and efficiency than its predecessors, making it a popular choice for consumers. In 2011, Intel introduced the Sandy Bridge architecture, which was the first processor to include an integrated graphics processing unit (GPU). The Sandy Bridge architecture also introduced the Turbo Boost feature, which allowed the processor to dynamically adjust its clock

speed to improve performance. In recent years, Intel has continued to develop its processors, introducing the Core i series in 2008 and the 10th generation Intel Core processors in 2020. These processors feature advanced technologies such as Hyper-Threading, Turbo Boost, and Intel Optane memory, which is a non-volatile memory technology that can significantly improve computer performance. Intel has also been working on developing processors for artificial intelligence (AI) and deep learning applications. In 2021, Intel announced the Alder Lake processors, which feature a hybrid architecture that combines high-performance cores with energy-efficient cores to provide better performance and efficiency. Intel's processors have been at the forefront of the computer industry for decades, and they are set to continue to be a key component in the development of new technologies in the future.

In the 1990s, AMD introduced the K5 microprocessor, which was the first processor to use the Super Socket 7 interface. In the 2000s, AMD introduced the Athlon processor, which was the first processor to reach 1 GHz clock speed. The Athlon processor was a popular choice among computer enthusiasts and gamers, offering excellent performance at a competitive price. In 2003, AMD introduced the Opteron processor, which was the first processor to use a 64-bit architecture. The Opteron processor was designed for server and workstation applications and offered improved performance and efficiency compared to its predecessors. In the late 2000s, AMD introduced the Phenom processor, which was the first processor to use a quad-core design. The Phenom processor also introduced the HyperTransport technology, which improved communication between the processor and other system components. In 2011, AMD introduced the Bulldozer architecture, which was the first processor to use the modular design. The Bulldozer architecture offered improved efficiency and performance, particularly in multi-threaded applications. In recent years, AMD has continued to develop its processors, introducing the Ryzen series in 2017 and the EPYC processors for server and data center applications in 2019. These processors feature advanced technologies such as Precision Boost,

which dynamically adjusts the processor's clock speed to optimize performance, and Simultaneous Multithreading, which allows a single processor to act as two virtual processors. AMD's processors have been a popular choice for computer enthusiasts and gamers, offering excellent performance and value. AMD has been competing with Intel in the processor market, and their processors have been instrumental in driving innovation and development in the computer industry.

ARM is a company that specializes in the development of microprocessor architecture, which is used in a wide range of devices, including smartphones, tablets, and other embedded systems. In the 1990s, ARM introduced the ARM7 architecture, which was the first processor to use the Thumb instruction set. The Thumb instruction set allowed for smaller and more efficient code, making it ideal for embedded systems with limited memory and processing power. In the 2000s, ARM introduced the ARM9 architecture, which offered improved performance and efficiency compared to its predecessors. The ARM9 architecture was used in a wide range of devices, including smartphones, digital cameras, and MP3 players. In 2011, ARM introduced the Cortex-A7 architecture, which was the first processor to use the big.LITTLE design. The big.LITTLE design combines high-performance cores with low-power cores to provide better performance and efficiency, particularly in multi-tasking applications. In recent years, ARM has continued to develop its architecture, introducing the Cortex-A53 and Cortex-A57 processors in 2013, which were designed for use in smartphones and other mobile devices. ARM's architecture has also been used in the development of supercomputers, with the ARM-based Fugaku supercomputer being ranked as the world's fastest in 2020. In 2020, NVIDIA announced its acquisition of ARM, which is expected to bring significant changes and new developments to the microprocessor industry. ARM's architecture has been instrumental in the development of mobile and embedded systems, and it is set to continue to be a key component in the development of new technologies in the future.

During the period between 1945 and 1960, communication technologies underwent significant advancements, setting the stage for the later development of the Internet. Some key developments in this era include:

In the late 1940s and early 1950s, microwave transmission systems were developed to carry long-distance telephone and television signals. These systems used microwave radio frequencies to transmit information between relay towers, providing a faster and more efficient alternative to coaxial cables and long-distance telephone lines.

In 1956, the first transatlantic telephone cable, TAT-1, was laid between the United States and the United Kingdom. This cable allowed for more reliable and higher-capacity telephone communication between North America and Europe.

The first modems, or modulator-demodulators, were developed in the 1950s to allow digital data to be transmitted over analog telephone lines. These early modems facilitated the communication between computers, laying the groundwork for future computer networks.

In 1957, the Soviet Union launched Sputnik, the world's first artificial satellite. This event triggered the space race and led to significant advancements in satellite communications. By the early 1960s, satellites were being used to relay telephone and television signals, enabling global communication.

In the late 1950s and early 1960s, researchers began exploring the idea of connecting computers in a network to share data and resources. One example of such an early network is the SAGE (Semi-Automatic Ground Environment) system, developed by the United States Air Force for air defense in the 1950s. This system connected multiple computers across the U.S. and Canada to share radar data and coordinate responses to potential threats.

In the late 1950s and early 1960s, computer scientists like Paul Baran and Donald Davies independently developed the concept of packet switching. This method of data transmission breaks data into small packets that can be sent independently and reassembled at the destination. Packet switching would later become a core technology for the development of the ARPANET and the Internet.

In 1948, Claude Shannon published "A Mathematical Theory of Communication," which laid the foundation for modern digital communication and information theory. Shannon's work provided the theoretical basis for data compression, error correction, and other techniques essential to digital communication.

Between 1960 and 1990, the advancements in communication technologies and the development of the Internet progressed rapidly. Many key milestones were achieved during this period, which paved the way for the modern digital age:

In 1969, the Advanced Research Projects Agency Network (ARPANET) was launched by the US Department of Defense. It was the first operational packet-switching network and the precursor to the Internet. Initially connecting four major US universities, ARPANET aimed to facilitate communication and collaboration among researchers.

In the early 1970s, Vint Cerf and Bob Kahn developed the Transmission Control Protocol (TCP) and the Internet Protocol (IP), which laid the groundwork for the modern Internet. TCP/IP was first implemented on ARPANET in 1983, replacing the original Network Control Program (NCP) protocol.

In 1973, Bob Metcalfe and his team at Xerox PARC invented Ethernet, a technology that enabled computers to be networked together within a local area. Ethernet soon became the most widely used LAN (local area network) technology worldwide.

The emergence of personal computers in the late 1970s and early 1980s, such as the Apple II, IBM PC, and Commodore 64, facilitated the widespread adoption of computing and communication technologies by businesses and consumers.

In 1979, Usenet, a global distributed discussion system, was created by Tom Truscott and Jim Ellis. It allowed users to post and read messages in newsgroups, enabling communication and collaboration among researchers and early Internet users.

Email was developed in the early 1970s as a way for users on ARPANET to send messages to one another. Ray Tomlinson is credited with inventing the first email system and establishing the use of the "@" symbol for addressing messages. By the 1980s, email had become an essential communication tool for businesses and individuals.

In 1983, Paul Mockapetris invented the Domain Name System (DNS) to simplify the process of locating and connecting to computers on the Internet. DNS translated human-readable domain names (e.g., www.example.com) into IP addresses, making it easier for users to navigate the growing network.

In 1989, Tim Berners-Lee proposed the concept of the World Wide Web while working at CERN. He later developed the first web browser, web server, and HTML (Hypertext Markup Language) in 1990. The World Wide Web revolutionized the way people accessed and shared information on the Internet, making it more accessible and user-friendly.

These milestones in communication technologies and the Internet from 1960 to 1990 laid the foundation for the interconnected digital world we live in today. The period saw significant progress in networking, computing, and communication technologies, which enabled the rapid growth and adoption of the Internet worldwide.

The mid-1990s marked a significant period for the development of the internet. In 1995, the first popular web browser, Netscape Navigator, was released, which made browsing the internet more user-friendly and accessible to the general public. The emergence of search engines, such as Google, in the late 1990s made it easier to find information on the internet. The early 2000s saw the rise of social media platforms, with sites such as MySpace and Facebook becoming popular among

internet users. In 2007, the launch of the iPhone marked a significant turning point in the development of the internet, as it made accessing the internet on mobile devices more convenient and practical. In the late 2000s and early 2010s, the development of cloud computing and online storage made it easier to store and access data over the internet. The rise of streaming services, such as Netflix and YouTube, in the 2010s, has also had a significant impact on the internet, as more people are using the internet for entertainment purposes. In recent years, the development of 5G technology has significantly improved internet speeds and connectivity, making it possible for new technologies such as the Internet of Things (IoT) and autonomous vehicles to become a reality. The internet has also become a critical component of remote work and education, particularly in the wake of the COVID-19 pandemic.

The development of the internet has had a significant impact on society and has fundamentally changed the way people communicate, access information, and consume entertainment. As technology continues to evolve, the internet is expected to continue to play a critical role in the development of new technologies and the advancement of society.

The Internet of Things (IoT) is a concept that refers to the interconnectivity of everyday objects through the internet. In the mid-1990s, the development of Radio Frequency Identification (RFID) technology paved the way for the development of the IoT. RFID technology allowed objects to be identified and tracked wirelessly, which made it possible to collect data on objects in real-time. In the early 2000s, the development of wireless sensor networks made it possible to connect sensors to the internet, which allowed for the collection and analysis of data in real-time. The emergence of smartphones and other mobile devices in the late 2000s and early 2010s made it possible to connect a wide range of devices to the internet. In recent years, the development of 5G technology has significantly improved internet speeds and connectivity, which has further facilitated the development of the IoT. The IoT has numerous applications, including smart homes, smart cities, and the industrial internet. Smart homes allow for the control and

automation of home appliances and systems, while smart cities use the IoT to improve energy efficiency and manage resources more effectively. The industrial internet, also known as Industry 4.0, uses the IoT to improve efficiency and productivity in manufacturing and other industrial processes. The development of the IoT has the potential to significantly improve efficiency, reduce waste, and improve the quality of life for people around the world. However, the development of the IoT also poses significant challenges, including privacy concerns, security issues, and the potential for increased dependence on technology. The IoT is set to continue to be a key component in the development of new technologies and the advancement of society, and as technology continues to evolve, it is expected to play an increasingly significant role in our daily lives.

Quantum computers are a new class of computers that operate on the principles of quantum mechanics, which is the study of subatomic particles. In the mid-1990s, researchers developed the first quantum computers capable of performing basic operations. In the early 2000s, the development of quantum error correction algorithms improved the reliability and stability of quantum computers, paving the way for the development of more advanced quantum computing systems. In 2011, D-Wave Systems released the first commercially available quantum computer, which was designed for use in optimization and machine learning applications. In recent years, the development of quantum computers has significantly accelerated, with companies such as IBM, Google, and Microsoft investing heavily in quantum computing research and development. In 2016, IBM launched the IBM Quantum Experience, a cloud-based platform that allows users to access and experiment with quantum computers. In 2019, Google announced that it had achieved quantum supremacy, which is the ability of a quantum computer to solve a problem that would take a classical computer an impractical amount of time. The development of quantum computers has significant implications for a wide range of applications, including cryptography, machine learning, and drug discovery. Quantum computers are capable of solving complex problems much faster than classical computers,

making it possible to solve problems that are currently unsolvable with classical computers. However, the development of quantum computers also poses significant challenges, including the development of new algorithms and software that can take advantage of the unique capabilities of quantum computers. The development of quantum computers is expected to significantly impact the fields of computing and technology in the coming years, and it has the potential to fundamentally change the way we think about computing and problem-solving.

Blockchain is a digital ledger technology that was first introduced in 2008 by an unknown person or group using the pseudonym Satoshi Nakamoto. The technology was originally developed for use in the cryptocurrency Bitcoin, but it has since been used in a wide range of applications. Blockchain is a decentralized system that records transactions on a public ledger in a secure and immutable way. This means that once a transaction is recorded on the blockchain, it cannot be altered or deleted. In the early years of the technology, blockchain was primarily used for financial transactions, but in recent years, it has been used in a wide range of applications, including supply chain management, voting systems, and even in the art world for the verification of authenticity. One of the most significant benefits of blockchain technology is its security, as it is nearly impossible to hack or alter the data on the blockchain due to its decentralized nature. Blockchain also offers transparency and accountability, as all transactions are recorded on a public ledger. In recent years, blockchain has also been used for non-fungible tokens (NFTs), which are digital assets that are unique and cannot be replicated. This technology is becoming increasingly popular in the art world, as it allows for the verification of authenticity and ownership of digital art. The development of blockchain technology has significant implications for a wide range of industries, and it has the potential to transform the way we think about security and accountability in the digital age. As technology continues to evolve, blockchain is expected to play an increasingly significant role in the development of new technologies and the advancement of society.

Big Data is a term used to describe the large and complex data sets that are generated in the digital age. In the mid-1990s, the development of the World Wide Web and other digital technologies led to a significant increase in the amount of data generated and stored digitally. The term "Big Data" was first coined in the early 2000s, and since then, the amount of data generated has increased exponentially, with an estimated 2.5 quintillion bytes of data generated every day.

The rise of social media, the Internet of Things (IoT), and other technologies has significantly contributed to the growth of Big Data. Big Data offers significant opportunities for businesses and organizations to analyze and utilize the data to gain insights and make better decisions. The development of data analytics and machine learning algorithms has made it possible to extract valuable information from Big Data, which can be used for a wide range of applications, including marketing, healthcare, and scientific research. However, the analysis of Big Data also poses significant challenges, including data privacy, data security, and data quality. The development of Big Data has significant implications for society and the economy, and it is expected to continue to be a key component in the development of new technologies and the advancement of society. As technology continues to evolve, the role of Big Data is set to become increasingly significant, and it is likely to become a fundamental part of how we understand and interact with the world around us.

Augmented Reality (AR) is a technology that overlays digital information onto the real world. In the mid-1990s, AR technology was primarily used in military and industrial applications, but in recent years, it has become more accessible and is now used in a wide range of applications. AR is commonly used in mobile applications, such as Pokemon Go and Snapchat, which allow users to interact with digital objects in the real world. AR is also used in retail and marketing, allowing consumers to try on clothes or see how furniture would look in their homes before making a purchase. In education, AR is used to create interactive learning experiences that allow students to engage with educational content in a more immersive way. AR is also used in healthcare, allowing medical professionals to visualize and interact with patient data

in real-time. In recent years, the development of AR glasses, such as Microsoft HoloLens, has made it possible to use AR in a hands-free way, which has significant implications for a wide range of applications, including manufacturing and logistics. AR has the potential to significantly improve efficiency, productivity, and creativity in a wide range of industries.

However, the development of AR also poses significant challenges, including the development of new software and hardware, and the potential for increased dependence on technology. The development of AR technology is expected to continue to have a significant impact on the fields of computing and technology, and it has the potential to fundamentally change the way we interact with the world around us. As technology continues to evolve, AR is expected to play an increasingly significant role in our daily lives.

3D printing is a technology that enables the creation of three-dimensional objects from digital designs. The technology was first developed in the mid-1990s, but it was not until the early 2000s that it became more widely used. The first 3D printers were primarily used in industrial applications, such as prototyping and design. In recent years, the development of consumer-level 3D printers has made the technology more accessible and has led to a wider range of applications. 3D printing is now used in a wide range of industries, including healthcare, aerospace, and automotive. In healthcare, 3D printing is used to create customized medical implants and prosthetics. In aerospace and automotive, 3D printing is used to create lighter and more efficient parts. In the arts, 3D printing has been used to create sculptures and other works of art. 3D printing is also being used in the construction industry, with the development of large-scale 3D printers that can create buildings and other structures. The development of 3D printing has significant implications for the manufacturing industry, as it has the potential to significantly reduce costs and increase efficiency. 3D printing also offers the ability to create complex and customized objects that would be difficult or impossible to produce using traditional manufacturing methods.

However, the development of 3D printing also poses significant challenges, including the potential for intellectual property theft and the environmental impact of 3D printing materials. The development of 3D printing is expected to continue to have a significant impact on the fields of manufacturing and technology, and it has the potential to fundamentally change the way we think about the design and production of physical objects. As technology continues to evolve, 3D printing is expected to become increasingly sophisticated and accessible, opening up new possibilities for innovation and creativity

Control Questions:

1. Discuss the key advancements in electric power engineering and electrical systems during the second half of the 20th century and the beginning of the 21st century. How did these developments contribute to the modernization of various industries?
2. Describe the major innovations and trends in metallurgy and chemical technologies during this period. What were some of the most significant breakthroughs in these fields?
3. How did mechanical engineering evolve from the mid-20th century to the early 21st century? What were some of the most notable inventions and advancements in this field?
4. Outline the major developments in transport during this period, including innovations in automobile, rail, and maritime transportation. How have these advancements changed the way people and goods move around the world?
5. Explain the growth and progress of aviation during the second half of the 20th century and the beginning of the 21st century, including key milestones and technological advancements.

6. Describe the history of space exploration and the development of cosmonautics during this period, including significant missions, discoveries, and milestones.
7. Discuss the emergence and growth of electronics during the second half of the 20th century and the beginning of the 21st century. What were some of the most important inventions and discoveries in this field?
8. Explain the evolution of communication and computer systems during this period, including the development of the internet, mobile devices, and other digital technologies.
9. Reflect on the ways in which advancements in science and technology during this period have impacted society, culture, and the global economy.
10. Considering the rapid pace of technological change in the second half of the 20th century and the beginning of the 21st century, what do you think the future holds for science and technology in the coming decades?

Basic literature: [2]; [5]; [9]; [16].

Additional literature: [8]; [12]; [13]; [14]; [15]; [17]; [22]; [38]; [45]; [52].

CHAPTER 9. HISTORY OF THE EMERGENCE AND DEVELOPMENT OF ENGINEERING EDUCATION AND TECHNICAL SCIENCES

- Origin and development of education and scientific research.
- Creation of technical sciences.
- Establishment of technical educational institutions.
- Development of technical educational institutions in 20th century

9.1. Origin and development of education and scientific research

The origin and development of education and scientific research in the ancient world can be traced back to various civilizations, including Mesopotamia, Egypt, Greece, China, and India. Each of these civilizations made significant contributions to the growth of education and scientific research.

The Sumerians, who inhabited Mesopotamia around 3500 BCE, developed the first known form of writing called cuneiform. This allowed them to record information and pass on knowledge to future generations. Schools were established to teach reading, writing, and arithmetic, and the first libraries were built. Babylonian and Assyrian scholars also made advancements in mathematics and astronomy.

In Egypt, education was closely linked to religious institutions, and priests were responsible for teaching various subjects, including reading, writing, mathematics, and medicine. The ancient Egyptians made significant contributions to geometry, astronomy, and medicine. The famous Library of Alexandria, founded in the 3rd century BCE, became the center of learning and scholarly pursuits.

Greek civilization was renowned for its emphasis on education and intellectual pursuits. The Greeks developed the first known form of higher education, with institutions like the Academy (founded by Plato) and the Lyceum (founded by Aristotle). Greek scholars made significant advancements in mathematics, astronomy, physics, biology, and medicine. The works of great thinkers like Socrates, Plato, and Aristotle laid the foundation for Western philosophy and science.

Chinese civilization placed great importance on education and intellectual development. Confucianism, which emerged around the 5th century BCE, emphasized moral and ethical education. The Chinese imperial examination system, established during the Han Dynasty (206 BCE – 220 CE), promoted meritocracy and facilitated the spread of education across social classes. Chinese scholars made significant contributions to mathematics, astronomy, medicine, and technology, including the invention of paper, the compass, and gunpowder.

Education in ancient India was primarily based on the Vedic system, which emphasized the study of sacred texts, philosophy, and religious rituals. The ancient Indian universities of Takshashila (Taxila) and Nalanda, established around the 5th century BCE and 5th century CE respectively, attracted scholars from around the world and became centers of learning in various fields, including astronomy, mathematics, medicine, and philosophy. Indian scholars made significant advancements in mathematics (including the invention of the concept of zero), astronomy, and medicine (Ayurveda).

The ancient world laid the foundation for education and scientific research that would continue to evolve over time. The contributions of these civilizations have had a lasting impact on human knowledge and intellectual development.

During the Middle Ages, education and scientific research evolved further in various parts of the world, shaped by religious, cultural, and political factors. Some of the key developments during this period include:

- Islamic Golden Age (8th-13th centuries): The Islamic Golden Age witnessed a flourishing of science, technology, and intellectual pursuits. The Abbasid Caliphate established the House of Wisdom in Baghdad, where scholars from various backgrounds translated Greek, Persian, and Indian texts into Arabic, preserving and expanding upon the knowledge from the ancient world. Islamic scholars made significant contributions to mathematics (including the development of algebra), astronomy, medicine, chemistry, and philosophy.
- Byzantine Empire (4th-15th centuries): The Byzantine Empire, which preserved much of the Greek and Roman intellectual heritage, continued to foster education and scientific research. The University of Constantinople, founded in the 5th century, became a center of learning, teaching subjects such as rhetoric, philosophy, and medicine. Byzantine scholars made significant contributions in preserving and transmitting classical knowledge to the Islamic world and later to Western Europe.
- Western Europe (5th-15th centuries): In the early Middle Ages, the fall of the Western Roman Empire led to a decline in education and scientific research. However, monasteries and cathedral schools emerged as important centers of learning, preserving and transmitting classical knowledge. In the High Middle Ages, the rise of universities, such as the University of Bologna, the University of Paris, and the University of Oxford, transformed education and fostered intellectual pursuits. Scholasticism, a method of learning that combined logic, dialectics, and theology, became the dominant approach to education. European scholars made advancements in fields such as astronomy, medicine, and natural philosophy.

- China (6th-16th centuries): During the Middle Ages, China continued to be a center of education, scientific research, and technological innovation. The Tang (618-907) and Song (960-1279) Dynasties saw the development of the civil service examination system, promoting meritocracy and facilitating the spread of education. Chinese scholars made significant contributions to fields such as astronomy, mathematics, medicine, and engineering, including inventions like the mechanical clock, movable type printing, and gunpowder weapons.
- India (5th-15th centuries): In medieval India, education continued to be centered around religious institutions and the royal court. The Hindu and Buddhist traditions fostered the growth of intellectual pursuits, with scholars making advancements in astronomy, mathematics, and medicine. The Indian mathematician and astronomer Aryabhata made significant contributions to trigonometry and the understanding of planetary motion. Medicine, especially Ayurveda, continued to develop, incorporating new insights and practices.

The Middle Ages was a period of both continuity and change in education and scientific research. The preservation and transmission of knowledge from the ancient world, combined with new innovations and discoveries, laid the groundwork for the intellectual developments of the Renaissance and the Scientific Revolution that would follow.

9.2. Formation of technical sciences and engineering

The origin and development of education and scientific research institutions in the 14th to 18th centuries marked a crucial period for the advancement of knowledge and the establishment of organized centers for intellectual pursuits.

During the 14th to 18th centuries, universities across Europe experienced significant growth and transformation. These institutions became increasingly important as centers for the development of education and scientific research. Key features of this period include the establishment of new universities, the diversification of the curriculum, and the rise of the scientific method.

During this period, many new universities were founded across Europe. These institutions were often sponsored by religious or political authorities and aimed to provide education and training to the growing urban population. Some notable examples include the University of Vienna (1365), the University of Heidelberg (1386), the University of St. Andrews (1413), and the University of Leuven (1425).

The curriculum in these universities expanded beyond the traditional trivium (grammar, rhetoric, and logic) and quadrivium (arithmetic, geometry, music, and astronomy) to include a broader range of subjects. Humanist ideals influenced the inclusion of subjects such as history, philosophy, and literature, while the practical needs of society led to the development of faculties dedicated to law, medicine, and theology.

Alongside universities, new scientific societies and academies emerged during this period, promoting the development of scientific research and the dissemination of knowledge. These institutions, such as the Royal Society of London (1660) and the French Academy of Sciences (1666), facilitated collaboration among scholars and provided a platform for the presentation and discussion of scientific findings.

The emergence of the scientific method, which emphasized empirical observation, experimentation, and the use of reason, transformed the approach to education and research in universities. Scholars such as Francis Bacon, René Descartes, and Isaac Newton were influential in promoting the importance of the scientific method, which became increasingly integrated into university curricula.

During this period, the role of the professor became more formalized, with an increasing emphasis on research and the production of scholarly work. Professors were expected to contribute to the advancement of knowledge in their respective fields, and their findings were often published in the form of books, treatises, or articles in scholarly journals.

The invention of the printing press in the 15th century played a critical role in the dissemination of knowledge and the development of education and scientific research institutions. The availability of printed books made it easier for scholars to access and share information, which in turn facilitated the growth of libraries and other research facilities within universities.

These developments during the 14th to 18th centuries contributed to the establishment of universities as central institutions for the advancement of knowledge and the promotion of scientific research. The legacy of this period continues to shape modern education and research institutions today.

During the Renaissance, a period of renewed interest in learning and the arts from the 14th to the 17th century, the origin and development of education and scientific research institutions flourished. The Renaissance was marked by a shift from religious and theological studies to secular subjects, such as the natural sciences, mathematics, literature, and the arts.

Sponsored by the influential Medici family, the Platonic Academy was a center for intellectual discussion and the dissemination of humanist ideas. Under the leadership of Marsilio Ficino, the academy focused on the study of Platonic philosophy, Greek literature, and the arts. It attracted renowned thinkers, such as Pico della Mirandola and Angelo Poliziano, who were instrumental in the development of humanist thought during the Renaissance.

A *studium generale* was a university-level institution that provided education in the liberal arts and higher learning. These institutions, which could be found throughout Europe, were characterized by their focus on secular subjects and their openness to scholars from different regions. Notable examples include the University of Padua, the University of Pisa, and the University of Ferrara.

Founded in 1303 by Pope Boniface VIII, the Sapienza University of Rome became a prominent center for learning during the Renaissance. It provided education in a range of subjects, including medicine, law, philosophy, and the arts, and attracted some of the most renowned scholars and artists of the time, such as Galileo Galilei, Michelangelo, and Raphael.

Established in 1475 by Pope Sixtus IV, the Vatican Library played a crucial role in the dissemination of knowledge during the Renaissance. Housing a vast collection of manuscripts, books, and maps, the library served as a vital resource for scholars and artists seeking access to classical texts and other works that had been lost or forgotten during the Middle Ages.

The Casa di San Giorgio, founded in 1407 in Genoa, was a financial institution that supported education and the arts. It funded the construction of various buildings, such as the University of Genoa and the Church of San Giorgio, which became centers of learning and artistic expression during the Renaissance.

Many artists during the Renaissance ran workshops and ateliers, which functioned as informal centers for education and the exchange of ideas. These spaces provided apprentices and students with the opportunity to learn from masters, collaborate on projects, and develop their artistic skills.

These institutions and centers for learning played a significant role in shaping the intellectual and artistic landscape of the Renaissance, providing scholars and artists with the resources and opportunities necessary to advance their knowledge and skills. The Renaissance laid the foundation for the further development of education and scientific research institutions in the centuries that followed.

During the 14th to 18th centuries, scientific societies emerged as important institutions for the advancement of education and scientific research, complementing the role of universities. These societies provided a platform for scholars to exchange ideas, collaborate on research projects, and disseminate their findings. Some notable scientific societies established during this period include:

- **Accademia dei Lincei (1603):** Founded in Rome by Federico Cesi, the Accademia dei Lincei (Academy of the Lynxes) was one of the earliest scientific societies. The society aimed to promote the study of natural sciences, mathematics, and philosophy. Its members included prominent scientists such as Galileo Galilei, who published some of his works under the academy's auspices.
- **Royal Society of London (1660):** The Royal Society was established in England as a means to promote the natural sciences, following the ideas of Francis Bacon. It became a leading scientific institution, with a mission to improve understanding of the natural world through experimentation and observation. Members of the Royal Society, known as Fellows, included some of the most prominent scientists of the era, such as Isaac Newton, Robert Boyle, and Christopher Wren. The society's journal, *Philosophical Transactions*, was the first scientific journal of its kind and remains in publication today.
- **French Academy of Sciences (1666):** The French Academy of Sciences was founded by Louis XIV to promote scientific research and education in France. It brought together leading French scientists, mathematicians, and engineers to work on collaborative research projects and share their findings. The Academy was instrumental in the development of many scientific fields, including physics, chemistry, and astronomy, and its members included luminaries such as Blaise Pascal, Antoine Lavoisier, and Pierre-Simon Laplace.
- **Berlin Academy of Sciences (1700):** The Berlin Academy of Sciences, founded by Elector Frederick III of Brandenburg, was an important center for scientific research in Germany. Its members were involved in various scientific disciplines, including mathematics, astronomy, and physics. The Academy's journal, *Miscellanea Berolinensia*, published the works of its members and other European scholars.
- **Russian Academy of Sciences (1724):** Established by Peter the Great, the Russian Academy of Sciences aimed to promote scientific research and education in Russia. The Academy facilitated collaboration among Russian and

European scholars, with members including both local scientists and foreign experts. It played a crucial role in the development of Russian science, fostering research in fields such as mathematics, physics, and chemistry.

These scientific societies in the 14th to 18th centuries helped to foster a scientific culture, encouraging collaboration and the sharing of knowledge among researchers. They played a significant role in the development of modern scientific disciplines and contributed to the advancement of education and scientific research throughout Europe.

During the 14th to 18th centuries, observatories emerged as important scientific research institutions, particularly for the study of astronomy. These observatories played a crucial role in advancing human understanding of the universe, providing astronomers with the means to observe celestial bodies and make accurate measurements. Some notable observatories from this period include:

- **Ulugh Beg Observatory (1420):** Built by the Timurid ruler and astronomer Ulugh Beg in Samarkand (now in Uzbekistan), this observatory was a leading center for astronomical research during the 15th century. The observatory housed a giant sextant, which was the largest astronomical instrument of its time, allowing astronomers to make precise measurements of celestial bodies.
- **Tycho Brahe's Uraniborg Observatory (1576):** Located on the island of Hven (now part of Sweden), this observatory was built by the Danish astronomer Tycho Brahe. It was equipped with state-of-the-art instruments for its time, enabling Brahe to make some of the most accurate astronomical observations of the pre-telescopic era. His detailed records of planetary positions laid the groundwork for Johannes Kepler's laws of planetary motion.
- **Paris Observatory (1667):** Established by Louis XIV and designed by architect Claude Perrault, the Paris Observatory was an important center for astronomical research in France. Astronomers at the observatory, such as Jean-Dominique Cassini, made numerous discoveries, including the observation of Jupiter's Great Red Spot and the determination of the oblateness of Earth.

- Royal Greenwich Observatory (1675): Founded by King Charles II of England, the Royal Greenwich Observatory played a pivotal role in the history of astronomy and navigation. The observatory was the site of several important discoveries and innovations, including the development of the marine chronometer by John Harrison and the establishment of the prime meridian, which is still used as the basis for global timekeeping.
- Royal Observatory, Edinburgh (1674): Founded in Scotland by James Gregory, the Royal Observatory, Edinburgh, aimed to advance astronomical knowledge and improve navigation. It was the first purpose-built observatory in Scotland and played a significant role in the development of astronomy during the 17th and 18th centuries.

These observatories from the 14th to 18th centuries were instrumental in the advancement of astronomy, as they provided scientists with the tools and facilities to observe and study celestial bodies. They contributed significantly to the development of modern astronomy and the understanding of our place in the universe.

The origin and development of technical schools in the 14th to 18th centuries occurred alongside the emergence of universities, scientific societies, and observatories, playing a crucial role in the growth of practical knowledge and skills. Technical schools focused on the teaching and application of crafts, trades, and engineering principles, as opposed to the more theoretical and philosophical education provided in universities.

One of the earliest forms of technical education during the Middle Ages was through the system of guilds and apprenticeships. Guilds were organizations of skilled craftsmen who protected and promoted their respective trades. They established a system of apprenticeships, where young individuals would learn a specific trade under the tutelage of a master craftsman. This hands-on training provided practical knowledge and skills necessary for a variety of trades, including blacksmithing, carpentry, masonry, and textiles.

The emergence of technical schools specializing in mining and metallurgy began in the 16th century in response to the growing demand for skilled workers in these industries. One of the earliest examples is the Freiberg Mining Academy in Germany, founded in 1765 by Prince Franz Xaver. The academy taught mining, metallurgy, and related subjects, preparing students for careers in the mining industry.

Engineering and military schools: In the 17th and 18th centuries, engineering and military schools were established to meet the increasing demand for skilled engineers and military officers. Examples include the Royal Military Academy at Woolwich in England, founded in 1741, and the École Royale des Ponts et Chaussées in France, founded in 1747. These schools offered education in civil and military engineering, fortifications, and other practical skills essential for military and infrastructure projects.

As maritime trade and exploration expanded during the Age of Exploration, navigation schools were established to train sailors and navigators in the art of navigation, cartography, and shipbuilding. For example, the Casa de Contratación in Seville, Spain, founded in 1503, trained pilots and navigators for the Spanish fleets exploring and trading with the New World.

The Renaissance period saw the emergence of art and architecture schools, which taught students the principles of design, drawing, painting, sculpture, and architecture. Examples include the Accademia di Belle Arti in Florence, Italy, founded in 1563, and the Royal Academy of Arts in London, established in 1768.

These technical schools in the 14th to 18th centuries played a vital role in the advancement of practical knowledge and skills across various industries. They laid the foundation for modern technical and vocational education, contributing significantly to the progress of science, engineering, and technology over time.

Overall, the 14th to 18th centuries marked a period of significant growth and development in education and scientific research institutions, which laid the groundwork for the modern academic and research landscape.

9.3. Establishment of the first technical educational institutions

The 18th and 19th centuries saw significant advancements in science, technology, and industry, leading to the establishment of various technical educational institutions. These institutions aimed to provide practical education and training in various fields, such as engineering, manufacturing, and applied sciences, to meet the growing demand for skilled professionals during the Industrial Revolution. Some of the prominent technical educational institutions established in the 18th and 19th centuries include:

- **École Polytechnique, France (1794):** Founded during the French Revolution, the École Polytechnique aimed to provide scientific and engineering education to the nation's brightest students. It quickly became one of the most prestigious institutions in France and Europe, producing many prominent engineers, scientists, and mathematicians.
- **Royal Institution, United Kingdom (1799):** Established by Count Rumford, the Royal Institution was dedicated to promoting scientific research and education. It became renowned for its public lectures and demonstrations, which were instrumental in popularizing science and technology in the 19th century.
- **Rensselaer Polytechnic Institute, United States (1824):** Founded by Stephen Van Rensselaer and Amos Eaton, RPI was the first engineering school in the United States. Its curriculum focused on the practical application of science and engineering principles, helping to drive the rapid industrialization of the U.S. in the 19th century.
- **Massachusetts Institute of Technology, United States (1861):** MIT was founded in response to the industrialization of the U.S. with the goal of providing advanced technical education in science, engineering, and other fields. Its emphasis on hands-on learning and research has made it one of the world's leading technical institutions.

- Technische Universität Berlin, Germany (1879): Founded as the Royal Technical Higher School of Charlottenburg, TU Berlin aimed to provide education and training in engineering, architecture, and other applied sciences. It became a model for other technical universities in Germany and across Europe.
- Tokyo Institute of Technology, Japan (1881): Established during the Meiji Restoration, Tokyo Tech was created to provide technical education in engineering and applied sciences to support Japan's rapid industrialization and modernization. It has since become one of the leading technical institutions in Asia.
- Imperial College London, United Kingdom (1907): Formed through the merger of the Royal College of Science, the Royal School of Mines, and the City and Guilds College, Imperial College London focused on education and research in science, engineering, medicine, and business. It has since grown into one of the world's top universities in these fields.

These technical educational institutions played a pivotal role in the development and dissemination of scientific and technical knowledge during the 18th and 19th centuries. They not only contributed to the growth and advancement of various industries but also helped shape the modern world by producing skilled professionals and leaders in science, technology, and engineering.

During the 18th and 19th centuries, Ukraine was a part of the Russian and Austro-Hungarian empires, and the establishment of technical educational institutions in the region was influenced by the empire's educational policies and advancements.

Institute of Practical Technology, Kharkiv (1812): The Institute of Practical Technology in Kharkiv (now known as Kharkiv Polytechnic Institute) was one of the first technical institutions in Ukraine. Founded by Vasily Karazin, it was initially established as the Department of Physics and Mathematics at Kharkiv University. The institution later evolved into a separate polytechnic school, offering education and training in engineering and applied sciences.

Lviv Polytechnic National University (1844): Originally founded as the Technical Academy in Lviv (then part of the Austrian Empire), Lviv Polytechnic National University has a long history of providing technical education in engineering, architecture, and applied sciences. After World War I and the formation of the Second Polish Republic, the institution became the Lviv Polytechnic Institute. Following World War II and the incorporation of Lviv into the Soviet Union, it was renamed Lviv Polytechnic Institute and eventually became the Lviv Polytechnic National University after Ukraine gained independence.

Odessa Polytechnic University (1918): Established as the Odessa Technological Institute, Odessa Polytechnic University aimed to provide education and training in engineering and technology. The institution has since evolved into a comprehensive technical university, offering a wide range of programs in engineering, computer science, and other applied sciences.

Kyiv Polytechnic Institute (KPI), now known as Igor Sikorsky Kyiv Polytechnic Institute, was founded in 1898 in Kyiv, which at the time was part of the Russian Empire. The establishment of KPI was part of an effort to advance technical education in the region and to support the growing industrial sector. The decision to create the institute was influenced by the rapid industrialization taking place in Europe and the successful experiences of other countries in creating polytechnic schools.

Viktor Kyrpychov, a prominent engineer, scientist, and educator, played a significant role in the establishment of KPI. He was appointed the first rector of the institute and was responsible for the development of its structure, educational programs, and scientific activities. Kyrpychov's vision for KPI was to create a modern technical institution that would combine theoretical knowledge with practical skills, emphasizing applied research and innovation.

The initial construction of the KPI campus began in 1898 on a plot of land donated by Kyiv's city council. The architectural design of the main building was developed by the architect Vladimir Nikolaev, and the construction was completed in 1902. The campus was designed with ample green spaces and modern facilities to create a conducive environment for learning and research.

KPI initially offered four major fields of study: mechanical engineering, civil engineering, chemical engineering, and agricultural engineering. The curriculum was designed to provide a comprehensive education, combining lectures and practical training. Over the years, the range of programs expanded to include electrical engineering, metallurgy, and other applied sciences.

From its early years, KPI attracted talented students and faculty from across the Russian Empire and later, the Soviet Union. The institution played a vital role in the development of Ukraine's scientific and technical expertise, contributing to the country's industrialization and technological advancements.

These technical educational institutions played a crucial role in the development of Ukraine's industrial and technological sectors during the 18th and 19th centuries. They provided a foundation for the growth of Ukraine's technical expertise and workforce, contributing to the country's economic development and technological advancements over time.

The process of education in technical educational institutions was focused on equipping students with practical knowledge and skills to contribute to the growing industrial sector. The curriculum and educational methods employed during this time were primarily designed to bridge the gap between theoretical knowledge and practical application.

Technical educational institutions in the 18th and 19th centuries offered programs in various fields, such as mechanical engineering, civil engineering, chemical engineering, and electrical engineering. The curriculum was designed to cover both fundamental scientific concepts and specialized knowledge required for the chosen field. Subjects like mathematics, physics, and chemistry formed the core of the curriculum, while specialized courses were tailored to specific industries and technologies.

A key feature of technical education during this period was the emphasis on hands-on experience and practical training. Students were often required to engage in workshops, laboratory work, and field trips to gain a deeper understanding of the practical aspects of their field. This approach was aimed at ensuring that graduates were well-equipped to contribute to the industries they would eventually work in.

Technical educational institutions often had close ties with local industries, allowing students to gain practical experience through apprenticeships or internships. These opportunities provided valuable exposure to real-world challenges and helped students develop the skills required for their future careers.

Lectures were a common method of instruction in technical educational institutions during the 18th and 19th centuries. However, there was also a strong emphasis on collaborative learning, with students working together on projects, experiments, and problem-solving tasks. This approach encouraged students to learn from one another and develop their problem-solving skills.

Technical educational institutions in the 18th and 19th centuries often played a crucial role in driving research and innovation in various fields. Faculty members and students were encouraged to engage in research activities, develop new technologies, and contribute to the advancement of their respective fields.

During this period, access to technical education was limited, with many institutions only admitting male students. Moreover, education was often reserved for the upper and middle classes, as tuition fees and other expenses made it difficult for lower-income families to afford such opportunities. Over time, however, efforts

were made to expand access to technical education, and by the late 19th century, more women and individuals from various social backgrounds were able to pursue technical education.

In summary, the process of education in technical educational institutions in the 18th and 19th centuries was characterized by a strong emphasis on practical training, hands-on experience, and the integration of theoretical knowledge and applied skills. These institutions played a vital role in shaping the industrial and technological landscape of their time, producing skilled professionals capable of contributing to the rapidly evolving industrial sector.

9.4. Development of technical educational institutions in 20th century

The 20th century saw significant advancements in science and technology, with new industries and technologies emerging at an unprecedented pace. To support these advancements, a number of technical educational institutions were established around the world, with the goal of training the next generation of scientists, engineers, and technicians.

One of the earliest technical educational institutions was the Massachusetts Institute of Technology (MIT), which was founded in 1861. MIT quickly became one of the leading technical institutions in the world, with a focus on engineering, science, and technology. The school was instrumental in developing new technologies, including radar and the digital computer, and it played a major role in shaping the future of science and technology.

In the years following World War II, a number of new technical institutions were established, with a focus on training engineers and technicians for the growing aerospace and defense industries. These institutions included the California Institute of Technology (Caltech), which was founded in 1891 and became a leading institution in the field of aerospace engineering.

The 1950s and 1960s saw the establishment of a number of technical institutions around the world, with a focus on training engineers and technicians for the growing industries of the time. These institutions included the Indian Institute of Technology (IIT), which was founded in 1951, and the Korea Advanced Institute of Science and Technology (KAIST), which was founded in 1971.

The 1970s and 1980s saw the emergence of new technologies, including the personal computer and the internet. This led to the establishment of new technical institutions, with a focus on training the next generation of computer scientists and software engineers. These institutions included the Massachusetts Institute of Technology's Media Lab, which was established in 1985 and focused on the development of new technologies and applications for the internet.

The 1990s saw the establishment of a number of technical institutions in developing countries, with a focus on providing education and training in science and technology. These institutions included the African Institute of Science and Technology (AIST), which was established in 1996, and the Indian Institutes of Technology (IITs), which saw significant expansion during the decade.

The 21st century has seen a further expansion of technical educational institutions, with a focus on training the next generation of scientists and engineers for new and emerging technologies. These institutions include the National University of Singapore (NUS), which has established itself as one of the leading institutions in the world for research in science and technology, and the Indian Institutes of Technology (IITs), which continue to expand and provide education and training for the growing technology industry in India.

The 20th century saw the establishment and development of technical educational institutions in Ukraine, which played a significant role in shaping the country's scientific and technological progress. These institutions provided education and training to the next generation of scientists, engineers, and technicians, and were instrumental in the development of new technologies and industries.

One of the earliest technical educational institutions in Ukraine was the Kyiv Polytechnic Institute, which was founded in 1898. The institute quickly became one of the leading technical institutions in the country, with a focus on engineering, science, and technology. In the years following the Bolshevik Revolution, the institute underwent significant changes and became the National Technical University of Ukraine "Kyiv Polytechnic Institute," which continues to operate to this day.

The 1930s saw significant changes in the structure and focus of technical educational institutions in Ukraine, as the Soviet government sought to expand the country's industrial and technological capabilities. This led to the establishment of a number of new technical institutions, including the Kharkiv Aviation Institute, which was founded in 1930 and became a leading institution in the field of aerospace engineering.

The 1950s and 1960s saw the establishment of a number of technical institutions around the country, with a focus on training engineers and technicians for the growing industries of the time. These institutions included the Lviv Polytechnic National University, which was founded in 1844 and remains a leading technical institution in the country to this day.

The 1970s and 1980s saw the emergence of new technologies, including the personal computer and the internet. This led to the establishment of new technical institutions, with a focus on training the next generation of computer scientists and software engineers. These institutions included the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", which established its first computer science department in 1971.

The 1990s saw significant changes in the structure and focus of technical educational institutions in Ukraine, as the country transitioned to a market economy. This led to the establishment of a number of new technical institutions, including the Kyiv International University, which was founded in 1994 and focused on providing education and training in business and technology.

The 21st century has seen a further expansion of technical educational institutions in Ukraine, with a focus on training the next generation of scientists and engineers for new and emerging technologies. These institutions include the Lviv Polytechnic National University, which established a department for renewable energy in 2009, and the National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", which continues to expand and provide education and training for the growing technology industry in the country.

The educational process in technical educational institutions varied depending on the institution and the field of study, but generally included a combination of classroom instruction, laboratory work, and practical training. Students typically began their studies with a general education program, which included courses in mathematics, physics, and chemistry, as well as general education courses in areas such as humanities and social sciences.

Once students completed their general education program, they typically began more specialized courses in their field of study. These courses included a combination of classroom instruction and laboratory work, with a focus on the practical application of theoretical concepts. Students were also typically required to complete a capstone project, which allowed them to apply the knowledge and skills they had learned to a real-world problem or project.

In addition to classroom instruction and laboratory work, technical educational institutions also placed a strong emphasis on practical training. This often included internships and apprenticeships, which allowed students to gain hands-on experience in their field of study. These practical training programs were often conducted in collaboration with industry partners, providing students with valuable exposure to real-world applications of the knowledge and skills they were learning.

The 20th century saw significant changes in the educational process in technical educational institutions, particularly with the development of new technologies and industries. The emergence of new technologies such as the personal computer and the internet led to the development of new fields of study, such as

computer science and information technology, which required new educational models and approaches.

The educational process in technical educational institutions also became more global in the 20th century, with the establishment of international collaborations and partnerships. These collaborations allowed students and faculty to gain exposure to new ideas and approaches, and helped to foster innovation and creativity in technical education.

In the 21st century, the educational process in technical educational institutions has continued to evolve, with a growing focus on interdisciplinary approaches and the integration of emerging technologies into the curriculum. Technical educational institutions are increasingly focused on developing the skills and knowledge that are required for success in the 21st century workforce, with a particular emphasis on areas such as innovation, entrepreneurship, and sustainability

Control Questions:

1. Describe the origin and early development of education and scientific research, with a focus on the ancient world and the Middle Ages. How did these early efforts contribute to the foundation of modern engineering education and technical sciences?
2. Explain the creation of technical sciences during the Renaissance and the subsequent centuries. How did the development of technical sciences differ from the development of other branches of science during this period?
3. Discuss the establishment of technical educational institutions in the 18th and 19th centuries. What were the key factors that led to their formation, and what roles did these institutions play in the advancement of engineering education and technical sciences?

4. Analyze the development of technical educational institutions in the 20th century. How did the rise of new technologies and industries during this period impact the growth and focus of these institutions?
5. Identify and discuss the major milestones in the history of engineering education and technical sciences. How have these milestones shaped the current state of these fields?
6. Explain the relationship between engineering education and technical sciences, and how this relationship has evolved over time.
7. Discuss the influence of global events, such as wars and economic crises, on the development of engineering education and technical sciences.
8. Compare and contrast the development of engineering education and technical sciences in different regions of the world. How have regional differences impacted the evolution of these fields?
9. Reflect on the role of engineering education and technical sciences in promoting innovation and technological advancement. How has this relationship changed over time?
10. Considering the importance of engineering education and technical sciences in the modern world, what do you think the future holds for these fields? What challenges and opportunities do you anticipate for engineering education and technical sciences in the coming decades?

Basic literature: [2]; [5]; [7]; [11]; [15]; [16].

Additional literature: [5]; [9]; [31]; [45]; [56].

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Навчальне видання

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Перга Юрій

ІСТОРІЯ НАУКИ І ТЕХНІКИ

**Підручник для студентів
факультету прикладної математики**

(англійською мовою)

Викладено історію розвитку світової наукової думки, розглянуто історію розвитку техніки, подано основні етапи розвитку інженерної освіти. Особливу увагу надано питанню розвитку науки і техніки в сучасний період та переходу до нових тенденцій у XXI столітті.

Лекційний курс «Історія науки і техніки» спрямовано на допомогу студентам під час підготовки до семінарських занять, виконання самостійної роботи, підготовки до семестрового контролю.

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