<u>Lecture 1</u>

In science/engineering courses:

Students learn the state-of-the-art concepts, methods and tools

Why?

Learn the evolution and impact of tech over time

- Not just the latest and greatest

No focus on:

- Historical aspects of science/technology
- Evolution of science/technology
- Influence of science/technology on the society
- Understanding of science/technology as a process

Science/Engineering Case Histories:

- Emphasize the human aspects of science/technology
- Illustrate the role of human error/failure in scientific theories and engineering designs
- Demonstrate the practice of engineering as an art form
- Explain the difference between technological and scientific activities

3 Important aspects of history of science/technology studies:

- To understand the way in which scientific knowledge and Technological design progress
- To understand the notions of science and technology and their methodologies
- To understand the reciprocal influence of science, technology, and society

About the periodization of history

Examples: Cold War Era, Medieval Period, Modern Era

Periodization is the process or study of a period of history in a specific time frame containing common characteristics

Scientific Revolution

1500 - about 1700 (took 200 years to change way of thinking)

- New approach to understand nature
- Mathematization of nature (express everything in measurement and numbers)
- Natural laws (free fall of apple is the same law that causes jupiter to revolve) (no universal laws before this period, different laws for different places)
- Experimental philosophy (bring experimentation into science, no concept of lab)
- Instrumentation (Invented instrumentation for experimentation)
- New sciences

Industrial Revolution

Late 18th century to mid 19th century

- Introduction of **new sources of power**, and a major shift from **agriculture** and **trade** to the **mechanization of production**, the development of **global market system** to support industrial production
- **Iron, coal, and steam** became the emblematic resources of the society
- They discovered many things through trial and error
- Modern physics, chemistry, electricity and magnetism

What is Science? What is Applied Science? What is Technology? What is the relationship between pure science, applied science, and technology

First view of Science:
- Science is a pattern of behavior by which humans gain control over the environment
- In this view, science is associated with craft tradition and technology
- Wide definition of science

Prehistoric people can be regarded as the founders of science because they learned how to melt metals or develop agriculture

Second view of Science:
- Science is a body of theoretical knowledge, and a systematic way to discover natural laws
- This definition, distinguishes between science and technology

Technology of car making should be distinguished from the Internal Combustion Engine: Thermodynamics, aerodynamics, and mechanics

If we accept the second definition, then:
- We can define science based on the form of its statements: universal laws mostly expressed in the language of mathematics
- F = ma
- E = mc^2
- We can find ‘invisible’ planets based on universal gravitational laws based on other planets (force on other planets)

We can also define science by its methodology and epistemology:
- Science is associated with specific sets of procedures and approaches to explore and discover the secrets of nature
- These procedures are mostly **experimental**, starting from **collecting various data, categorizing them, find a relationship between them, making a hypothesis**(educated guess)**, performing experiments to validate the hypothesis, etc**
- Science doesn’t have ‘absolute truth’ unlike religion, only has probability and Science talks about how to increase this probability

In this definition, science is a body of knowledge, such as physics or biology, that we study in modern universities

But what about astrology, alchemy, and other “unscientific” approaches to discover nature?
- For our study of the history of science and technology we need to acknowledge a very broad definition of science and technology
- Science servers two human purposes: to know and to do
- Applied science: use of pure science for some practical human purpose

A time lag between the discovery of a theory and its application to practice is not uncommon
- Faraday’s discovery of the electromagnetic induction and its practical use in industry

<u>Lecture 2</u>

Discovery of conic sections by Apollonius of Perga in the 3rd Century BC, and their application in astronomy and engineering in the 17th century

Riemann's non-Euclidean geometry (early 19th century) and its application by Einstein in his theory of relativity in the 20th century (Gravity is curvature of space and time)

From Theory to Practice:
Three kinds of pursuits:
- Pure Science: Pure theoretical sciences are concerned with the discovery of natural laws and the description of nature (Spin of electrons)
- Applied science: application of existing scientific knowledge to practical applications; includes all applications of pure sciences (Spin of nucleons later used to create MRI imaging system)
- Intermediate or **modus operandi** level, which is represented by the scientist with an interest in the solution of the problems presented by the task of getting from theory to practice (From E = mc^2 and radioactivity to atomic bomb)

Technology
- Misunderstanding of the distinction between applied science and technology
- Applied science is guided by hypothesis deduced from theory, application of scientific knowledge into a physical environment
- Technology employs trial-and-error or skilled approaches derived from concrete experience (Improve old products, solve next stage of problems)

Historically, technology begins as an attempt to satisfy practical need without science, also aroused as an accident or trial and error (Answer for practical problem)
- Invention of telegraph (Inventor's wife passed away while he was away, practical problem is long distance communication)
- Wine discovery (Fermentation of grapes)
- Pacemaker, Vulcanized Rubber, Penicillin, Teflon, Safety Glass, Viagra (Was trying to make something for cardiovascular diseases), Ether Anesthesia, Stainless Steel, Microwave

Technology without Science (telegraph)
No applied science without pure science

Practice to Theory
- In the course of pursuing practical ends, abstract principles of science are often discovered
- Mathematical theory of probability was developed because some professional gamblers wished to know odds in games of chance
- Electromagnetics stimulated development of differential equations, and hydrodynamics function theory
- Carnot founded the pure science of thermodynamics as a result of the effort to improve the efficiency of steam and other heat engines
- War improved aerodynamics and atomic physics
- Hydrogen bomb made from interest from what happens in the sun

Crossfield Application - employment of practical effects of one science in those of another
Examples:
- Radio waves science/Technology + Astronomy: Radio Astronomy
- Use of electronics in determining electrical signals of nervous system
- Use of radioactive decay in medicine and medical imaging systems
- Bionics: Biological insight into mechanical design

Change in design of aircraft came from studying birds in flight (curl of wingtip)

Skolimowski's Article

1. Erroneous to consider technology as being applied science
2. Technology is not science
3. Difference between science and technology can be grasped by examining the idea of scientific progress and the idea of technological progress

Many believe technology is in principle a composition of variou crafts
Technology: Methodologically derivative from other sciences, has no independent methodological status

Decomposing technology to its underlying scientific components would not help us understand difference between science and technology, does not take into account the idea of technological progress

Basic methodological factors that account for growth of technology are different from the factors that account for growth of science

<u>Lecture 3</u>

Objective underlying science is the **increase of knowledge**

Technology

- Not an instrument to investigate reality
- Does not aim to enlarge knowledge and acquisition of truth

In science, we investigate the reality that is given. In technology, we create a reality according to our designs

Science concerts itself with what is, technology concerns itself with what is to be

Technological Process:

- New objects
- Better objects of the same kind

Praxeology (Praxiology) - analyzes action from point of view of efficiency

- Estables values, practical values, and accesses our action in terms of these values

"Betterness"

- More Durable
- More Reliable
- More Sensitivity
- Faster in performing
- Combination

- Shortening time required for production of object through reducing cost of production

Criteria cannot be applied to Science, to attempt to find a more better version of Newton's second law
Can be argued that in the pursuit of technological progress we often bring about scientific progress as well
Scientific progress may facilitate technological progress

In advancing technology, we advance science and vice versa
Ex: Atomic Bomb, Semiconductors, Aeronautics

Science

- Enlarges our knowledge through better theories

Technology

- Creating new artifacts through effectiveness

Mario Bunge

- Technology is applied science

Theories in technology come in 2 types

- Substantive theories - Provide knowledge about the object of action (Classical mechanics and statics)
- Operative theories - theories concerned with action itself (Machine design theory, focus on materials resistance under circumstances)

Substantive theories - largely applications of scientific theories
Operative theories - Not preceded by scientific theories but are born in applied research itself

Difference between Mario Bunge and Skolimowski

- Skolimowski: When grape turns into wine, it doesn't count as science because you don't know how it happened
- Bunge: Grape turning into wine counts as applied science because you knew about fermentation and you knew it would happen

Example Test Questions:

- According to Skolimowski, science and technology are different and the difference between them can be best grasped by examining the idea of scientific progress and the idea of technological progress
- A time lag between the discovery of a theory and its application to practice is not uncommon

Lecture 4

Only humans couldn't survive without tools, and only humans have been shaped by tools
Homo sapiens - wise man (think of ourselves as wise)

- 70k years ago, explosion of innovations (tools, art, religion, ocean navigation)
- 10k years ago, humans occupied almost every piece of loans on earth

Prehistoric life:

- Hunter gatherers had to keep moving following animals and going to plants
- Hunters clashed more often as hunting grounds crowded

Neolithic Revolution: End of the last Ice Age around 12k years ago

- Socio Economic and technological transformation
- Food gathering to food producing
- Domestication of wheat, rice, corn, potatoes, and animals

2 Alternative paths toward food production

- Gathering to Horticulture (Gardening) and then agriculture
- Hunting to herding and pastoral nomadism

- Through observations, found best areas to plant (early scientists) (observed sky, stars)

Technology
- Domestication of animals
- Food production

Geography
- Grasslands too arid for farming
- Atmospheric or surface water

Paths lead to
- Nomadic societies such as Mongols and Bedouins
- Other led to great agrarian civilizations and industrialization

Breeded submissive breeds to get more tame animals
- Sheep and goats were first animals to be domesticated, followed by pigs and donkeys and much later cattle

Domesticated animals:
- Dairy industry
- Meat
- Wool production / clothing (first looms around 6000 BCE)
- Animal droppings as fertilizer
- Animal power

Some areas had less success domesticating animals
- In New World, Andean communities domesticated llamas and guinea pig (protein deficiency)

Neolithic horticulture required large tools
Textile technologies:
- Shearing sheep
- Growing and harvesting flax or cotton
- Processing raw material
- Spinning thread
- Constructing looms
- Dyeing and weaving cloth

Pottery
- Production of metals occurred different times
- Originated independently in multiple centers around the world
- Key part of Neolithic revolution
- Arose in response for storage technology
- Pyrotechnology

Importance of Surplus
Rise of Astronomy, math, writing, taxation in this order from surplus

First civilizations
- Formed near water banks with agriculture using irrigation, plows, and draft animals
- Populations expanded and Neolithic economy spread rapidly
- Thousands of Agrarian villages established in Near East by 3000 BC
- Trading centers and real towns

- Example: Rich Neolithic town of Jericho, well watered brick walled city of at least 2k people
- Had systematic understanding of nature, knew about seasons
- The need to track seasons created astronomy, no accurate way to track seasons

Neolithic revolution was a techno-economic process, occurred without the aid of any independent science

Neolithic astronomy
- Neolithic peoples systematically observed heavens, patterns of motion of the sun and moon and creed monuments as seasonal calenders

Stonehenge - aligned with midsummer sunrise, midwinter sunrise, most southerly rising and northerly setting of the moon, estimated 30 million hours of labor

Lecture 5

Easter Island - carved and erected more than 250 monumental Moai statues with astronomical orientations

Key to transformation from Neolithic villages to civilizations was methods used to produce surplus of food to feed those who didn't farm

- As agriculture became more intensive, surplus increased

Early civilizations:
- More people in villages and cities
- Construction of big monuments
- Invention of writing, mathematics, and calenders
- Development of astronomy and medicine
- Development of religions, literatures, rts, philosophies, and other forms of culture
- Development of metal work

Mesopotamian Civilizations
- Based on irrigation agriculture
- Developed centralized political authority and complex bureaucracy to collect, store and redistribute agricultural surpluses
- Characterized by monumental buildings known as ziggurats
- Developed writing mathematics, and sophisticated astronomy

By 3500 BC
- Wheel was invented
- Connection between seasons and astronomical phenomena was discovered
- Therapeutic herbs was discovered
- Melting pottery, tool making, metal smelting, basic math, writing, simple machines

Definitions of science and technology
- Presentism - Employment of present day ideas and perspectives in interpretations of the pat (Whiggish history)
- One thing to know how to do things, another to know why they behave

Prehistoric culture was oral
Oralility - Verbal communication
- Archive is human memory
- Aggregative rather than analytic
- Thoughts are expressed with relatively close reference to human life world

Lack of any conception of Laws of Nature in Preliterate tradition
Lack of deterministic causal mechanisms to explain natural phenomena
Projection of human or biological traits onto natural phenomena
Personalization and individualization of causes

Egyptian:
In oral traditions, universe consists of sky, earth, underworld, deity, as well as invisible powers such as ghosts of the dead and spirits
Religion and magic
"Wise woman" or "Medicine man" was known as divine
Hieroglyphics

Invention of writing was prerequisite for philosophy and science
Development of philosophy and science was function of efficiency of system of writing
Sophisticated concepts and abstractions can develop within efficient language and writing system

Western science can be found in ancient Mesopotamia
- Astronomy
- Mathematics
- Geometry
- Number system
- Calendar

<u>Lecture 6</u>

Greeks believed mathematics originated in Egypt and Mesopotamia
- Pythagoras

Number system by Egyptians
- Addition and subtraction were easy but multiplication and division were difficult
- Geometrical knowledge
- Circumference, surface area, volume of shapes, pi

Lunar and Solar calendar
- 1 week was 10 days
- 3 weeks was one month
- Fourth months was one season
- 3 seasons and 5 holy days was one year

Babylonian Mathematics and Astronomy
- Superior to Egyptians
- Decimal number based on number 10
- Sexagesimal number system based on 60
- Used arithmetic instead of quadratic equations
- Observational and Mathematical Astronomy

- Lunar and Solar Calendars
- Development of Horoscp[ic Astrology

Chinese mathematics
- Decimal Place Value System
- Problem based, motivated by problems from calendar, trade, land measurement, architecture, government needs
- Chinese star clerks kept most consistent and continuous astronomical records

Indian mathematics
- Concept of 0
- Text called Surya Siddhanata contains modern trigonometry

Mayan Mathematics
- Vigesimal numbers system based on 20

Lecture 7

- Survey:
    - General social conditions of the period under discussion
    - Dominant materials and sources of power of the period
    - Application to food production
    - Manufacturing industry
    - Building construction
    - Transport and communications
    - Military technology
    - Medical technology
    - Social consequences of technological change

Requirements for special involvement in technological innovation:
1. Social need
2. Social resources
3. Sympathetic social ethos (characteristic spirit of a culture, era, or community s manifested in its beliefs and aspirations)

Development of Babylonian Mathematical and astronomical Science
Products of science and technology
- Improved abilities to measure land, weight, and time

Metal Age
- Discovery of alloying

Transportation
- Sailing ships in Egypt

Irrigation System
- Need for social control
- Justice in distribution of precious water
- Canal and aqueducts and water-raising devices suh as shadoof

Persia
- Constructed elaborate tunnel systems called qanats for extracting groundwater in dry mountain

Urban Revolution (3000-500BCE)
- Invention of City

- Better agricultural skill leads to growth in population
- Large populations leads to need for more products
- Need for more products leads to more specialized craftsmen
- Manufacturing industry concentrated on pottery, wines, oils, cosmetics
- Trade
- Different forms of press to produce wine and oil
- Metal plates for armor (military tech)
- Potter's Wheel: invented in Mesopotamia sometime between 6000 and 4000 BC and revolutionize pottery production
- In egyptian mythology, Khnum (deity) formed first humans on a potter's wheel
- Using wheel, pottery was more uniform and less prone to breakage

Machines, power and ancient economy
- Population growth -> need for more production -> natural restrictions/available resources -> problem of self sufficiency -> management

Population Growth
- Food/Shelter/Clothing/Job

Need for more Production
- Land/Irrigation/Transportation/Energy/Processing

Natural restrictions
- Land/Water/Fertile Soil/ Appropriate products/Energy/Natural resources/technologies

Problem of Self sufficiency
- Administration of agriculture/Irrigation/Transportation distribution/Processing/Marketing/Defense/Trade

Mechanical Power
- Sole power was muscles
- Man power was the main way of power
- Slaves (Rome 200k slaves)
- Prisoners of war (maintaining aqueducts, minig, agriculture, constructions)
- Lever - Archimedes laws of the lever

Devices related to Lever
- Wedge, Screw, Compound pulley, Wheel and axle, Inclined Plane

Combination of manpower and mechanical tools

Compound pulley
- Spring

Spring, Lever, Pulley ,Gears and Winch

Example: Bow is a combination of manpower and tools by introduction of lever or winch

Lecture 8

Watermills widely used in medieval times
- Horizontal windmill
- European Vertical windmill

Water powered mills were more important and numerous than windmills
- Some regions were too flat and rivers did not have enough flow
- Some regions rivers froze

Windmills had no efficient method to control strength of wind
- Not all regions were suited for watermills

Natural energies
- Free, more power than animals
- Transmission of energy

- Energy should be used very close to mills

Building
- Mesopotamia has sun-dried brick
- Building blocks remained same, scale of operations
- Ziggurats

Buildings in Egypt
- Clay was scarce but good building stone
- Stones were placed under supervision of priest-architects who were mathematicians and astronomers

Degree of development of any society is set by size of its surplus

Size of Surplus
- Amount of energy available to society
- Society's technology
- Mix of its economy
- Size of its population

Summary:
- Human/animal muscles, water, and wind power
- Wedge, screw, compound pulley, wheel and axle, inclined plane
- Clay/Mud/sun-dried bricks in Mesopotamia, Stone in Egypt
- Canals, Water raising devices (shadoof)
- Copper alloys

Ancient civilizations build huge monuments
- Demonstrate religious beliefs and rituals
- Assert power of the society and ruler
- Protect society and resources
- Collaboration of majority of people at the beginning of a society or an era
- Collaboration of the majority of people to glorify a deity or commemorate important person

Technical Issues
- Cutting harder than carrying
- Long lasting buildings

<u>Lecture 9</u>

Great Pyramid of Giza:
- About 2.3 million stones weighing from 2 to 30 tons watch, with some weighing 70 tons
- About 144k casing stones, all highly polished and flat to 1/100th of an inch, weight about 15 tons each nearly perfect right angles

On Pyramid Building
- Pyramid structures are not unique
- Ziggurats in Mesopotamia, Mexican Pyramids

Egyptian Pyramids are unique
- Orientation
- Precision

- Size of the building blocks
- Magnitude of the construction project
- Golden ratio: Ratio of length divided by width is equal to approximately 1.6

True pyramid- 4 smooth sides meet at a point in the sky

Main Questions:
- Methods of construction
- Methods of delivering stones to higher courses (ramp theories)
- Methods of orientation correction
- Methods of placing the casing stones
- Logistics
- Quarrying

2 Major Problems
- How to raise the stone to great heights
- Place the stone in position with accuracy

Theories:
1. Perpendicular Ramps

External Ramp and Crane Theories:
- Ramp was built on one side of the pyramid
- As pyramid grew, ramp was raised
- Blocks could be moved right up top

To build perpendicular ramps, huge volume of material is needed
Gradient can’t be very high, slope is 5 to 10 degrees
Every time ramp has reached a higher stone course it has to be made higher and lengthened
Must be ramps on each side to speed up construction process

Ramp Material:
- Wood? Made for small works, not big
- Burnt brick? Not employed by Roman
- Sand?
- Sun-dried mud brick? Think about the rain
- Stone masonry?

Building with stone is very time consuming
To have built a stone construction ramp to the top of the pyramid with gradient of 12 degrees, would have required a ramp over one mile long

Spiral/ZigZag Ramp
- Extremely difficult to maneuver large blocks of stone around corners

Second theory centrs on Herodotus machines (shaduf crane)
- Nowhere to place cranes, tremendous amount of timber

Primary difficulties in controlling construction were generated by enormous size of construction base, weight of building blocks, and magnitude of structure
1. Lay out the Base

2. Control of the Form of Pyramid
3. Movement of Stones

Pyramid of Meidum was built in 3 successive phases, each intended as finish product

Alternative theory:
- Presence of a central, stepped, core structure within later smooth pyramids suggests that the construction techniques used for the pyramid of Meidum may have established formula for all pyramids

Internal Ramp Theory
- Presented by Jean-Pierre Houdin
    1. Ramp was used to raise blocks to the top
    2. Ramp was internal and still exists inside the pyramid
    3. Bottom third of the pyramid was built using external ramp
    4. As the bottom of the pyramid was being built a second ramp was being built inside the pyramid, which blocks for the top 2/3rds of the pyramid would be hauled

Ancient Asian Architecture is rich and unique, unlike other parts of the world
- Unique building types
- Unique statues
- Unique garden and shrines
- Unique tower clocks

Four Great Inventions - compass, gunpowder, papermaking, printing

Chinese Astronomy:
- Lunar and Solar Calendars
- Astrology
- Chinese Constellations
- Prediction of Astronomical Phenomena
- Recording comets

Astronomical orientation of ancient Chinese buildings
- Structure uncovered in Taosi archeological site could be used as an astronomical observatory

Shang Dynasty
- Tools/weapons/religious objects: Mainly made of bronze
- Development of writing
- Construction of religious sites
- Kings were considered to have divine nature
- Decorated underground tombs
- Development of ceramic artifacts
- Structures had symmetry

Important feature in Chinese architecture:
- Emphasize on articulation and bilateral symmetry
- Enclosure
- Hierarchy
- Horizontal emphasis

- Cosmological concepts
- Gardens
- Screen walls - face the main entrance of the house
- Talismans - imagery of good fortune
- Door gods - displayed on doorways to ward off evil and encourage the flow of good fortune

Chinese garden contains
- Architecture, like a building or pavilion decorative rocks and a rock garden
- Plants
- Tree flowers and
- Water elements, like ponds
- Most Chinese gardens are enclosed by a wall and some have winding paths
- In Chinese gardens you cannot see the entire garden all at once, small scenes are set up so that as you walk through the garden, you see various elements

Rocks were believed to have concentrated amount of natural energy

Early Magnetism:
- Qin Dynasty (221 - 206 BCE)
- Discovery of magnetism in loadstoe
- Development of simple compasses
- Magnetic compass was used for a long time for geomancy and fortune telling by the Chinese
- Compass was later used for navigation by Song Dynasty
- Most probably, Chinese invention used in navigation predates the first European mention of a compass by 150 years

Great Wall of China
- 208 BC - 1640 AD
- Series of fortifications made of stone, brick, tamped earth, wood, and other materials, to protect the Chinese states against invasions of the nomadic groups of the Eurasian steppes
- Longest build structure in the world
- Stretches nearly 4k miles
- 5 separate walls were created in different phases of construction

Age of Asian Technology (AD 700 - 1100)
- Joseph Needham (History of science and technology in China)

Interaction between population and technology
- Increases in population have often been a spur to technological innovation, especially when more food and other necessities have to be produced from a fixed area or land

Great Silk Road - Trade and technological change
- Trade in luxury goods between China and West Asia was a stimulating factor in technological change both in the West and East
- Export of Chinese silk was a stimulus to textile industry in the West

Rapid Expansion of Iron Industry in China
- Hebei and Henana provinces

        - Iron ore + coal

- Wood or charcoal fuel for furnaces was becoming scarce because of deforestation and the expansion of the iron industry depended on an increased use of coal and coke

Chinese Hydraulic Engineering
- Spillways + Pound locks

Lecture

Liao threat:
- Song China built up an enormous army, exceeding 1 mil men by the 1040s
- Much of the iron went to manufacture military equipment
    - Suits of armor
    - Arrow-heads
    - Buddhist temples
    - Farmers for ploughs and farm tools

North of country in Yellow River asin has cool climate, and economy depended on wheat and millet crops rather than rice

Government Interference:
- Introduction of a new variety of rice from Champa (Vietnam) (Fast growing)

Chinese travels to Africa:
- First description of the African
- Flora and fauna

- Written history of Japan started approximately in the 6th century when Chinese writing, culture, and intuitions were brought in by Korean immigrants
- Traditional Japanese science, technology and medicine are highly influenced by Chinese paradigms
- Chinese world of learning was thoroughly structured with Confucian classics at the center of a structured bureaucracy
- Scientific subjects were of peripheral importance
    - Math and calligraphy were necessary for civil service

Japanese traditional architecture influenced by Chinese and Asian techniques
- Wood
- Screens and sliding doors
- Tatami - Floor material traditionally made using rice straw
- Verandas - Roped, open-air gallery or porch
- Genkan - traditional japanese entryway areas for a house
- Relationship with nature

Shinto - Japanese traditional religion
- Worship of ancestors and nature spirits and belief in sacred power (kami) in everything, influenced by Buddhism and Confucianism
- Kami - Sacred spirits or phenomena that live everywhere

Japanese swords - Symbol of samurai

No social role for scientists/researchers in Tokugawa period, also called Edo period
No institutional support for pursuit of knowledge for its own sake

Most careers were hereditary

Kingdom of Kush
- Ruled over vast territory along Nile River (Sudan)

Mali Empire
- Largest empire in West Africa and profoundly influence the culture of West Africa through spread of its language, laws, customs

Ruler of Mansa Musa - Passed out so much gold that created massive 10 year gold recession

Zimbabwe
- Medieval kingdom located in Zimbabwe
- Capital has largest stone structure in pre colonial Southern Africa
- Controlled ivory and gold trade from interior to southeastern coast of Africa
- Asian and Arabic goods can be found in abundance in kingdom

Writing Systems

Ancient Egyptian
- Hieroglyphs
- Hieratic - Cursive writing system developed in 3k BC
- Demotic

Ancient Meroitic
- Used in Kingdom of Kush from 300BC to 400AD
- Tifinagh or Lybico-Berber
- Ge’ez or Ethiopic
- Nsibidi
- Old Nubian
- West African Ajami script

Metallurgy
- Africans living on western showers of Lake Victoria in Tanzania had produced carbon steel
- Temp in blast furnace of African steel smelting furnace was higher than any achieved in an European machine until modern times
- Termite mound was excellent choice for furnace since it does not absorb water

Astronomy
- Megalithic site in NW Kenya
- 19 pillars non randomly orientated toward stars
- Could predict seasons from orientation of crescent moon

Mathematics
- Counting and numeration systems
- Games and puzzles
- Geometry
- Graphs
- Record-keeping of money, weights, measures
- Ishango bone
- Berber numerals

Colonialism distorted African pattern of economic development

- Brought about disarticulation of African economy, education, trade, market, transport and currency institution
- Colonialists distorted development of comprehensive transport system in Africa
- Aided a clear emergence and development of classes
- Did not allow for industrialization of Africa, assigned Africa role of production of primary goods or raw materials in international division labor
- Shaped both economic and political structure of colonies

Mayan, Aztec, Incas

Classic Period - Mayan civilization
- Accurate astronomy
- Writing System
- Number System
- Administration
- Monuments and temples
- Water management systems

Mayan Astronomy
- Syndromic month better than Ptolemy
- Accurate calendars
- Disaster - Arrival of Europeans on mainland of Central America

Ancient Greek civilization developed in phases
1. Hellenic - Independent city states in Ionia and on Greek peninsula, no king
2. Hellenistic - successively by confederation, imperialism, and conquest

Result was a vast expansion of Greek culture and learning

Philosopher

Aristotle
- Comprehensive system of philosophy
- Coherent theory of cosmos wherein categorized objects of the universe are arranged in a distinct configuration
- Medieval scholarship

Aristotle’s Cosmos - Based on our experience

Epistemology/Logic
Syllogism - Deductive scheme of a formal argument consisting of a major and a minor premise and a conclusion

Purpose of this philosophical scheme was to understand in the most fundamental way what things were and why they behaved as they did

Roots of the new scientific culture were planted in Egypt, governed by Greek ruling class = Ptolemaic Egypt

Four Element and Human Physiology
- Aristoelian elements
- Each of the four elements has associated humor, which connects Aristotle's view on matter with physiology and medical theory

Galenic physiology

Hellenistic Science
- Represents historical melding or hybridization of tradition of Hellenic natural philosophy with patterns of state supported science
- Kings and emperors had patronized a bureaucratic science that leaned toward useful applications
- Fusion of Ancient greek world with that of the Near East, Middle East, and Sothwest Asia

Romans were greatest technologists and engineers of ancient world
Contributed to art, architecture, urban development, warfare and medicine

Roman Navy - instrumental in Roman conquest of Mediterranean

Roman science is Greek science
Science is almost wholly adapted from previous intellectual work of the Greek natural philosophers

Decline and Fall
- Lack of clear social role
- No employment was available for individual as scientists or natural philosophers
- Seperation of science and technology in antiquity
- Role of religion
- Wars and decline of Roman Empire

<u>Lecture 10</u>

Ancient and Medieval War Tech

- Technological progress
- Needs/ resources
- Bottlenecks/End points
- Innovations
- Revolutions

Telescope

War Technology
- Personal level to state/national level
- Survival technology
- Directly connected to the state/government and uses state budget
- Directly connected to national (and international) interest
- Intense competition on effectiveness

Catapult
- Reliable information on the mechanical characteristics of catapults comes primarily from 3 sources
    1. Belopoiika of Philo of Byzantium
    2. Tenth book of Vitruvius De architecura
    3. Belopoiika of Heron of Alexandria

Marcus Vitruvius Pollio

- Roman writer, architect and engineer

Philo of Byzantium
Belopoiika is a section of this book on artillery

Mount of energy which can be stored in a bow is determined by stiffness of the bow, length of draw, subject to human physical limitations

Bottleneck/End point - Length of draw is limited by the length of the bowman's arm

Gastraphetes - Bow was mounted on a stock grooved on its upper surface

- Archer could use back muscles as well as hand muscles

Larger and more powerful bow-catapults were stand-mounted and spanned by winch but otherwise were similar in design to the gastraphetes

Dependence on the elasticity of the bow was a basic limitation of bow-catapults
Bow catapults were succeeded during the course of the fourth century by torsion catapults

Catapult Physics

- Basically use of stored energy to hurl a projectile without the use of an explosive
- Three primary energy storage mechanisms
    - Tension, torsion, and gravity

Small catapults/ missile engines

- Bottlenecks
    - Improvement in fortifications
    - New siege craft

Torsion catapults had important shortcomings, slow and cumbersome, disadvantages that increased as the catapult became more powerful

Problems inherent in the use of twisted skeins were more serious, tension of skeins varied with changes in atmospheric humidity

Counterweight Trebuchet

- Revolutionary intention
- Uses force of Gravity + angular momentum

Trebuchet was much more powerful machine than any earlier missile thrower, far simpler in design

Greek Fire - napalm like substance that burned in water and could be projected great distances from the bows of ships

Belgian historian: Henri Pirenne

Greek Fire Characteristics

1. Burned in Water
2. Greek fire always portrayed as a liquid
3. Shot from tubes or siphons located in bows
4. Appearance of smoke and a loud discharge or booming noise when the flaming liquid left the tube or siphon

- Most probably, real secret behind the weapon was preheating and pressurizing the liquid below decks before discharging it from the siphon on the main deck

- Greek fire was a weapon system, depended on array of knowledge associated with several components of the system

- Science is a papyrophilic enterprise, predicated on early and complete publication of knowledge
- Publication is the only mechanism of scientific advancement

Technology, in contrast, is papyrophobia
- Practitioners prosper by keeping heir secrets to themselves, passing on knowledge through apprenticeship, limiting spread of information through guild restrictions, and preventing at all costs the publication of their technique

Craft knowledge is a secret
- Industrial espionage, apprenticeship, migration of craftsmen
- Craft secrets came to be embedded in patents
- Secrecy is even more important in military technology
- Leonardo da Vinci protected all his inventions by his unique reverse writing
- Manhattan project were kept secret by compartmentalization

Coca Cola - Vault with recipe

Understanding ho secret might have been guarded requires some appreciation of components of technology

Technology may be defined as purposeful, human manipulation of the material world

4 components: Matter, power, tool or machine, technique

Formula provides only the matter for greek fire
Machine and technique was not obvious
Technique itself would have been a secret of almost as much sophistication as the formula
Even if the components of the weapon system came into enemy hands, no guarantee that it could be used successfully

Byzantines guarded secrets
1. Limited its use to the defense of the capital or to other fleet engagements, employing entrusted commanders
2. Compartmentalized knowledge of this technological system

What happened to the secret:
1. Kallinikos fire was immediately recognized as a weapon system of crucial importance
2. Secret of its preparation and use was compartmentalized and restricted
3. Chaos of succession to the golden throne disrupted the transmission of the complete secret

Internationalism in Science
- Theoretical studies/ laws of nature

    - Good cooperation, though discoveries assumed to be a national pride
- Technical/Industrial know-how
    - Good, as long as employed in scientific studies or by allies
- Military science
    - Always considered a secrete

Lost Technological Know-How
- Damascus Steel
- Stradivarius violins
- Chinese Tower Clocks

When Roman Empire fell, know how to make concrete was lost
- Rediscovered in 1710 by a French engineer

Lecture 11

Technology in Islamic Period

Translation Movement, from 8th to the 10th centuries at House of Wisdom in Baghdad

Almost all Greek and Hellenistic texts were translated to Arabic

Muslims scholars not only translated Greek and Hellenistic works, bugt also wrote numerous commentaries to explain or criticize them

Traditional scientific activities continued among Muslims, while new intellectual activities and the Scientific Revolution emerged in Europe

Patronage: Science and Technology
- Islamic fine technology
- Concept of prestige technology
- Technology connected with gardens
- Technology connected with astronomy
- Automata

Islamic civilization combined three advantages which are very important in the history of science and technology
1. Providing a direct contact with the far east
2. Preserving Greek intellectual materials
3. Perusing scientific inquiry

Muslim architecture is a combination of Hellenistic, Persian, and local traditions presented in

Islamic style

Impact of:
1. Religion
2. Local traditions
3. Geography

Impact of Religion:
- Orientation of mosques and shrines / prayer niche

- Aniconism (no statues, no paintings)
- Geometric Motifs/ Vegetal PAtterns
- Calligraphy
- Minarets (Towers)
- Fountains/Water
- Light

Materials:
- Stone
- Rubble
- Baked and Unbaked Bricks
- Clay
- Timber
- Mortar and Plaster
- Tile

Muhtasib - (Person appointed to police the enforcement of Islamic law in a particular area) exercised a close supervision over building construction
Muhtasib had template and codes to check the buildings

Road and Bridges:
- Trade
- Warfare
- Pilgrimage routes to Mecca
- Connection to the Silk Road
- The state postal service (barid)

Irrigation System:
- Water problem in dry lands
- Canals
- Dams
- Qanats
    - Irrigation/water consumption laws

Surveying
- Basic requirements for public works surveying as in the setting out of large buildings, the excavation of canals, are leveling and alignment

<u>Lecture 12</u>

Ptolemy postulates that
- Center of Epicycle moves on the Deferent
- Center of the deferent does not coincide with Earth
- Planet describes equal angles around another center called Equant

Equant - Transformers elliptical non uniform motion to a circular uniform motion
Ptolemy model was mathematically sound and accurate but had a fundamental physical problem
- Violated principle of concentric uniform circular motion
- Planetary motions must be uniform respect to eh center of the universe, not respect to equant

Tusi’s couple: 2 spheres internally tangent in 1 point, diameter of the small sphere is equal to half of the other, If small sphere uniformly moves twice as the big sphere in opposite direction, common point will move on linear path

Tusi’s couple: Uniform circular motions of 2 spheres create a linear motion

Copernicus:
- Tusi’s couple
- Urdi’s lemma
- Ibn al-Shatir Moon model
- Ibn al-Shatir Mercury model

Agricultural & Military Revolutions in Europe 800s - 1500s

Medieval Europe
Series of interlocked technical innovations shaped the history of medieval Europe
- Agricultural revolution
- New military technologies
- Dependence on wind and water for generation of power

After 9th century
- Europe transformed itself from an economy scarcely more advanced than that of traditional Neolithic societies to a vibrant and unique civilization that came to lead the world in the development of science and industry

Agricultural Revolution of Middle Ages was a response to
- Population increase
- Land shortage

In medieval Europe land was used for
- Agricultural and food production
- Pasture dairy animals for food, cattle and horses for traction ,sheep for wool

Expanding cities reduced the acreage available or agricultural production

Forest provided timber for construction, shipbuilding, and heating and industrial fuel

Wood was used as the fuel in making iron

800: Charlemagne is crowned emperor of Rome and established Carolingian Empire
European Agriculture:
- No water/irrigation problem

Problem: Plowing of heavy soils
- Unique ecological conditions of Northern Europe
    - Technological innovations
    - European Agricultural Revolution

First innovation:
- Introduction of Heavy plow

Heavy Plow- huge tool made up of wood and iron, mounted on wheels and armed with an iron cutter, tore up soil at the root line and turned it over, forming a groove and eliminating the need for cross plowing

Heavy plow
- More friction
- Needed more traction
- Sometimes pulled by as many as 8 oxen

Mediterranean scratch plow adapted to light soils
Heavy plow for heavy soils

Traditional neck harness: Oxen transfer their power to yoke beam by pushing with top of their neck
- Europeans most probably adapted the horse collar from Chinese who used several centuries before

Horse collar transferred pressure points from windpipe to shoulders and increased traction 4 or 5 fold

Third Innovation
Development of the three-field rotation system
- Two field farming system typically involved farming one field while leaving another fallow
- Thee field pattern: Arable land was divided into 3 fields with platings rotated over a 3 year cycle: 2 season plantings with third field left fallow

Social consequences:
Deep plow made it possible to farm new lands, particularly rich alluvial soils
Northward shift of European agriculture

Heavy plow and its team of oxen or horses were expensive
Development of collective ownership and patterns of communal agriculture and communal animal husbandry

Solidifying medieval village and manorial system as bedrock of European society

Three field rotation system:
- Spring crop of vegetables and oats
- Improved diets of common people
- Increased productive capabilities of European agriculture from 33 to 50 percent
- More food, more meat, more surplus
- Population increase

By 1300 the population of Europe trebled to 79 million from 26 million

Military Revolution
- Technological innovations in military affairs
- Role of military in European feudalism
- Military Revolution and Europe's eventual global dominance

In Europe prior to 8th century warriors mainly fought on foot

Without stirrups to provide stability only the most skilled horsemen could fight as true cavalier and could swing a sword or stretch a bow without losing his mount

One of definitive figures of European feudalism, armored knight mounted on armored charger, was created by a piece of technology called stirrup

- European knight evolved into medieval equivalent of tank

New European technology of mounted shock combat interlocked easily with manorial system brought about by Agricultural Revolution
Knight replaced peasant-soldier common in early Middle ages, knight became full time job

No strong central government was required to manage agricultural economy that needed no hydraulic infrastructure
Manorial System was well adapted to European ecology
Knight-village relation became characteristic of European feudalism

Europeans before 15th century were significantly behind Muslims, Chinese, and other major world civilizations in their ability to make war

Dramatic transformation of European warfare in the 15th and 16th centuries from Military Revolution

Military Revolution in Europe shifted power from local feudal authorities to centralized kingdoms and nation-states

3 elements of Military Revolution:

1. Replacing heavily armored cavalry by infantry
2. Introduction of gunpowder weapons, artillery
3. Rise in size of armies

Development of new machines and new sources of power (Watermill and windmill)

Lecture 13

Learning in cathedral schools and focused on 7 basic liberal arts
Trivium: Logic, Grammar, Rhetoric
Quadrivium: Arithmetic, Geometry, Astronomy, Music

Focus on Religious and theology
Some knowledge of astronomy

European University

- Weakly organized learning in early Middle Ages
- Eruption of European university
- By 1200, Europeans recovered much of ancient science along with several centuries of scientific and philosophical accomplishment produced within Islamic World

Agricultural Revolution:

- Foursihg cities
- Growing economy
- Increase in wealth
- Need for urban institutions to produced leaned people
- Unique institution, modeled after craft guilds of medieval Europe

- Independent feudal institutions

- Standardization of higher education, curriculum, and licensing
- European University and Natural Sciences
- Medieval university was not primarily a research institution nor was science pursuit primarily

Source of Knowledge
Toledo - Major center of Islamic culture
Became center of translation activity
Translation of classic scientific and philosophical texts from Arabic into Latin
Bilingual jewish scholars

Better translations made from original source

Problems:
- Eternity of universe
- Soul
- Cause and effect
- Unmoved mover

Scholastic Philosophy became backbone of education

Condemnation of 1277
- Bishop of Paris condemned 219 errors held by Aristotle

Medieval scholars interpreted world primarily from theological point of view
Overall, medieval worldview secular natural science took second place whenever Aristoleian natural philosophy clashed with traditional Christina theology

Lecture 14

General flow of techniques before 1500 was from east to west, from China and India to Europe

During 13th and 14th centuries
- Europe remained inferior to East in subtle handicrafts
- Europe begin to run ahead during early Renaissance in methods of basic production
- Overseas discoveries
    - Access to diverse material resources and ideas

Roman Numerals
- Addition and subtraction is relatively easy, but multiplication and division is very difficult

New Reckoning System in Europe
- Leonardo Fibonacci of Pisa produced first text to show Europeans how to calculate

Roman abacus

After Fiboniacc's work, Indian - Arabic numerals gradually replaced abacus in calculators made forommerce, government, and technology

Europeans turned to magnetism and gravity as forces more constant than wind and water

Mechanical designs through magnets and gravity

Long time for wide-spread acceptance of Hindu-Arabic numerals in Europe

Europe during 15th and 16th centuries, and after:
- Technological preparation
- Scientific progress
- Control of energy
- Increase in productivity
- Organizational skill
- Naval and military superiority
- Overseas expansion

New stimuli to technological advance in the 16th century

- Overseas discoveries
- Rise of national state
- OPatronage of technology and science by wealthy courts
- Publication of books on science and crafts
- Application of mathematics to traditional arts and crafts

The 16th century technological dialogue between Ruope and Asia
- Sailing chariot of Simon Stevin
- Chinese helicopter top
- Kite
- Paddle-wheel boats
- Wheel chair
- Caulking vessels in Chinese matter

Internal migration stimulated by
- Repressive state policies
- Disruptions of war
- Religious persecutions
- Desire for quick riches

Portuguese cartographers: Pilots, navigators carried what have been classified as state secrets to Spain, Italy, France and Holland

Clock - European advanced technology in scientific instruments at the beginning of 16yh century
Clockmakers were most innovative and ingenious of Europe's craftsmen

Clocks:
- Tool/Model/Symbol

Concept of Mechanical Order: Conceptualization of natural processes in terms of mathematical relationships known to be applicable to machines such as clocks

Technical advance and genuine designs slowed down in second half of the 16th century in all branches of mechanical endeavor

- Advances in communication
- Migration of artisans
- Multiplication of printed books dealing with mathematical methods and illustrated with numerous mechanical devices

Scientific progress
Mathematics and astronomy
- In europe trigonometry and Hindu-Arabic numerals were at first taken up by astronomers

Decimal system

Experts in practical astronomy, mathematics, and cartography were among the first to introduce this new system of reckoning to a larger public

Age of Voyages
- First stellar maps of southern hemisphere
- Magellanic Clouds

Aristotle believed there exists an uninhabitable torrid zone between Tropic of Cancer and Tropic of Capricorn

Discovery of New World

Lecture 15

New Cosmological ideas
- Copernicus
- Tycho Brahe

Calendar Reform - Gregorian calendar
Johannes Kepler

One of the most influential discoveries is that there are things worth discovering on the sea, distant lands, and at home

List of best dates for leaving main ports