Math/Science/Technology Projects

FOR THE TECHNOLOGY TEACHER

Edited by
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1984 Academy of Fellow Recipient

International Technology Education Association

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Preface

This monograph is the result of the efforts of many serious and dedicated professionals who were willing and able to take existing industrial arts/technology education activities and explore their possibilities for student enrichment in the areas of mathematics, science, social impact, and environmental impact.

The underlying development behind this monograph grew out of a series of 14 panels (20 in. × 28 in.) illustrating the basic linkages between existing industrial arts/technology education activities and mathematics or science principles or societal and environmental impacts. Specifically, each panel contained a full-color photograph of a student-made model of an important technological development. The remainder of each panel contained formulas or principles of mathematics and science or implications for societal and environmental impacts associated with the technological development pictured on the panel.

Each of the panels has been photographed and included in this publication along with a brief description of the particular technological development, a series of mathematics and science concepts, principles and formulas, or in some cases, a series of social and environmental impact statements relative to the project pictured on the panel. The person responsible for developing each of the panels (not the project) is listed at the beginning of each discussion of the panel and its contents.

It is important to note that the suggested mathematics or science principles/formulas/concepts or the listings of social or environmental impacts are purely examples of such items and do not represent all of the potential ideas. The creative and informed teacher could go well beyond the listings that have been limited in this case by the space allowed. The actual technological projects or models were made in industrial arts/technology education classes by students studying early technological developments that have contributed to the growth of civilization.

Table of Contents

Introduction

The concept behind this publication is linked to three important ideas that have a high degree of relevance to industrial arts/technology education teachers and professionals at all levels.

- First, if understanding is a goal to be achieved in the study of technology and technological innovation (past or present), there must be strong linkage with mathematics, science, society, and the environment.
- Second, industrial arts/technology education can, with an experiential activity-based study of technology, provide an excellent means whereby a "holistic" quality of education can be achieved and the elements of mathematics, science, social studies, and environmental concerns can be integrated into a relevant, meaningful, and functional learning experience.
- Third, the current emphasis on mathematics and science provides a rich opportunity for industrial arts/technology education to establish itself as an important partner in contemporary education.

The issue of understanding technology goes beyond the idea of making or constructing items, although this is a vital part of the industrial arts experience. The construction of a model of the Wright Brother's aircraft could be accomplished without any understanding of the principles of science, the mathematical concepts, or the societal or environmental impacts. It is through the process of a concerted effort on the part of teachers and students to reach beyond the constructed item into the relevant principles and concepts undergirding this important technological innovation that greater understanding is achieved. The constructed item becomes an instrument for interest development and a stimulator of curiosity that may be used to encourage a deeper penetration into the issue of "cause and effect," as well as the "how and why" behind such a technical item.

The issue of "holistic" learning is tied in with the first and third ideas presented above. Understanding is achieved to a greater degree when it is based on a total, organismic involvement, as opposed to a fractional, atomistic approach. Effective learning directed toward understanding requires a "holistic," integrated, multidisciplinary approach that finds its value and meaning in the relationships of subject matter from many disciplines. The value of "holistic" learning and its facilitation is greatly enhanced by the potential existing in an experientially based study of technology through industrial arts.

The third idea, dealing with an opportunity for establishing a closer partnership with the total school, is one that must be achieved. The impossibility for teaching any technological development to any extent within a single discipline makes a persuasive case for a partnership relationship as well as a requirement for integration of subject matter. Industrial arts/technology education has, within its content and methodology, a prime vehicle through which the subjects of the school are brought together for the purpose of meaning, understanding, and relevance on the part of the learner.

The following sections of this publication were designed to illustrate in concrete terms how the three preceding ideas could be accomplished in the industrial arts/technology education program. There are 14 such examples illustrating the relationships between construction and understanding, based on an extension of student involvement into the relevant scientific, mathematical, social, and environmental concerns or concepts. Each illustration centers around a technological development that has been chosen, investigated, and constructed by industrial arts/technology education students, most of whom were in the junior high school.

The actual way by which the principles and concepts are identified, developed, and discussed in a given class may vary from class to class as well as with the teacher involved. It is hoped that the teacher would be the stimulator and facilitator of the discussion, with a concerted effort made to draw on the background of the student to contribute to the presentation as well as arrive at the relationships to the several disciplines of the school. Learning requires involvement and the establishment of linkages, connections, and relationships with what is already known. The materials included in this publication are just one of many approaches through which this can be accomplished.

A special note of appreciation is due the authors of the various sections of this publication. Their construction and design of the original panels have won each the highest praise in a number of important exhibitions.

D. MALEY
Fall 1984

Mathematics & Science

The Waterwheel

Paul Richard Edmondson

A waterwheel is a vertical wheel mounted on a horizontal shaft and is made to rotate by direct action of water. This transformation of flowing linear motion into rotational motion opened the way for a revolution in grain production. Not only could the waterwheel lift the water into the fields for irrigation, but it could supply the energy to grind grain into flour. This small technological advancement was a driving force in the beginning of what some call the "agricultural revolution."

There are three major types of waterwheels, the first is the undershot waterwheel. The operation of this wheel was quite simple; the water flowed underneath the bottom edge of a large wheel onto which were attached paddles or buckets that impeded the flow of the water. This imposition of the water flow caused the wheel to rotate. The undershot waterwheel is believed to be the first type of waterwheel to be used. It can be traced back 2,000 years to Egypt, where it lifted water out of the Nile.

The second type of wheel developed was called the overshot wheel. This wheel not only used the flow of the water but also used the weight of the water to move the wheel. The overshot waterwheel had the water enter from the top of the wheel. This allowed the wheel to not only use the velocity of the water to produce rotation, but the weight of the water could now also be used as a source of power.

The third type of wheel is known as the breastshot waterwheel. This wheel had the water enter the wheel at a perpendicular to the center Y axis. Of major importance in this type of wheel was that the head of water above the wheel could be located below the apex of the wheel. This allowed the wheel to use both the flow and the weight of the water in applications where it was impossible to raise or lower the water supply or the wheel.

Science Principles and Concepts

- The transformation of kinetic energy (in this case the movement of the water as it flows past the buckets on the wheel) into that of mechanical energy, which then can be used to do work.
- The concept of gravitational force acting on the water and the resultant "weight" that the water takes on, thus supplying an additional power source for the wheel.

- Equilibrium and its consequent disruption, thus enabling the waterwheel to produce movement and the benefits arising from that movement.
- Levers and the relationship between the first, second, and third classes of levers, as well as the application of each in the wheel's operation.
- Potential energy and the concept of aquatic head.

Mathematical Principles and Concepts

The calculation of:

- **Work** If one has a 144-lb (65kg) weight and one moves it 39 ft (11m), one could express the amount of work that has been done as:

$$\text{Work (ft/lbs)} = \text{Force} \times \text{Distance}$$
$$\text{Work} = 144 \times 39$$
$$= 5616 \text{ ft/lbs of work}$$
$$\text{Joules (N/m)} = \text{Meters} \times \text{Newtons}$$
$$\text{Joules} = 65 \times 11$$
$$= 7000 \text{ N/m of work}$$

- **Efficiency** Given a gearing system that has an input of 100 ft/lbs of work and an output of 73 ft/lbs of work, one can calculate the efficiency of that gearing system.

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100\%$$
$$\text{Efficiency} = \frac{73}{100} \times 100$$
$$= 73\% \text{ efficient}$$

- **Power** If one were to now use the information from the work problem, with the additional knowledge that it was done in 50 seconds, one could calculate the amount of power needed to move that weight.

$$\text{Power (ft/lbs per second)} = \frac{\text{Work}}{\text{Time}}$$
$$\text{Power} = \frac{5616}{50}$$
$$= 112 \text{ ft/lbs per second}$$
$$\text{Watts} = \frac{\text{Joules}}{\text{Seconds}}$$
$$\text{Watts} = \frac{7000}{50}$$
$$= 140 \text{ watts}$$

- **Horsepower** Given the same weight, time, and distance as above, one can calculate horsepower.

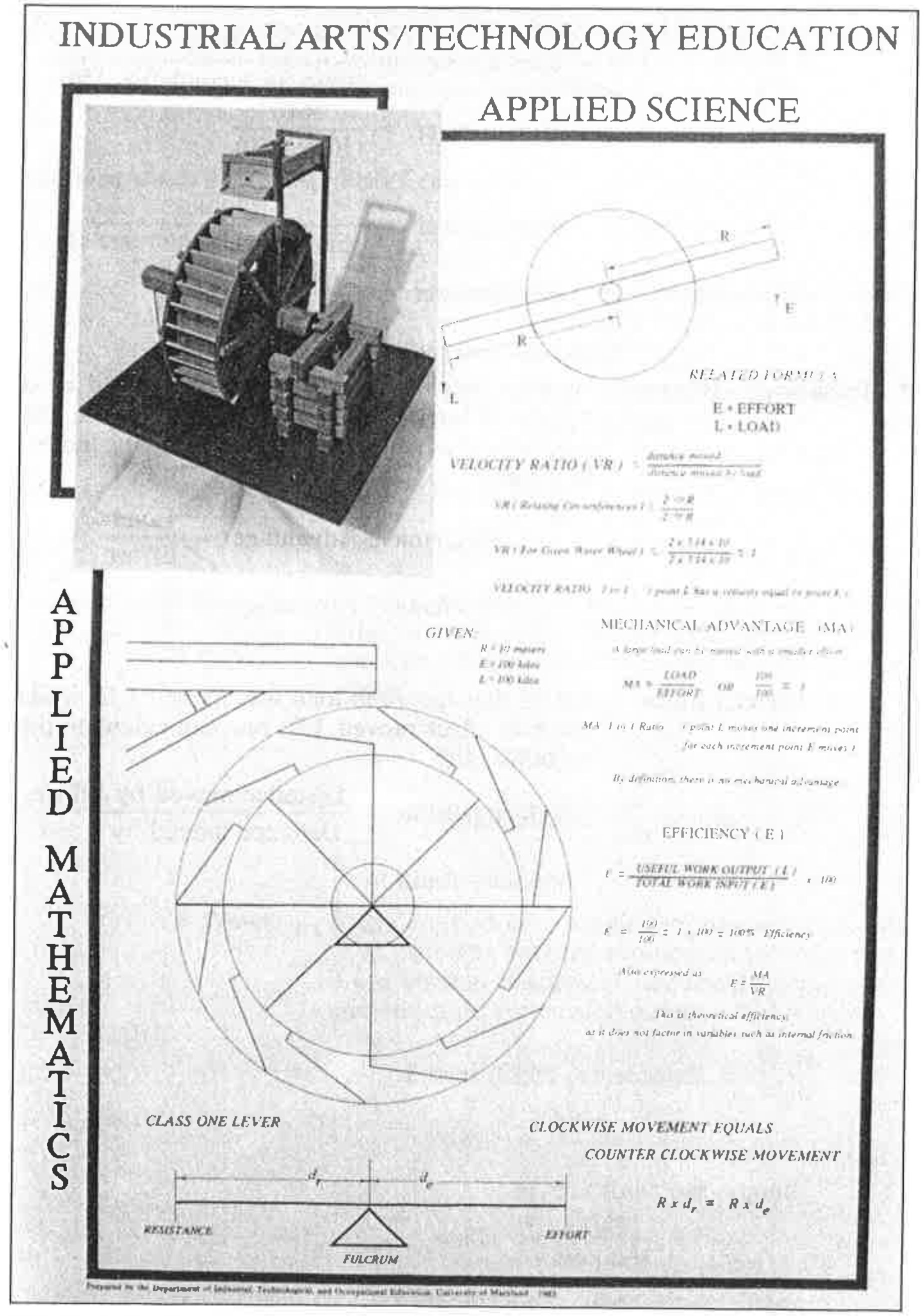
$$\text{Horsepower} = \frac{\text{Work}}{(\text{time [in seconds]} \times 550)}$$
$$\text{Horsepower} = \frac{5616}{(50 \times 550)}$$
$$= .2 \text{ hp}$$
$$\text{Horsepower} = \frac{\text{Joules}}{(\text{time [in seconds]} \times 543)}$$
$$\text{Horsepower} = \frac{7000}{(50 \times 543)}$$
$$= .257 \text{ hp}$$

- **Mechanical Advantage** Given a weight (load) of 10 lbs is moved by a weight (effort) of 6 lbs, one can calculate the mechanical advantage involved in moving the 10-lb weight.

$$\text{Mechanical Advantage} = \frac{\text{Load}}{\text{Effort}}$$
$$\text{Mechanical Advantage} = \frac{10}{6}$$
$$= 1.7$$

- **Velocity Ratio** Given that the 10-lb load was moved 1 ft, while the 6-lb effort moved 3 ft, one can calculate the velocity ratio.

$$\text{Velocity Ratio} = \frac{\text{Distance moved by Effort}}{\text{Distance moved by Load}}$$
$$\text{Velocity Ratio} = \frac{3}{1}$$
$$= 3 : 1$$



The Waterwheel

The Lateen Sail

Andy Batey

The lateen sail was developed by an unknown innovator or innovators in Mediterranean waters during the very early days of sailing. It was originally an auxiliary sail on vessels, such as galleys, that depended primarily on oars. From the Mediterranean, the lateen spread northward, becoming the sail used most of the time for the mizzen of three-masted ships of the 17th and 18th centuries. It was also a common rigging for smaller two-masted craft.

The lateen sail may have been adopted by the English and Dutch from the Spanish, who apparently used it as a naval rig on large boats that were both rowed and sailed. The lateen spread to American ports largely through the influence of the Dutch. It was a common rig around New York on small one- and two-masted boats during the second half of the 17th century. Very few lateen sails survived, except as mizzen riggings, after 1700. The lateen was replaced by the much improved square sail and the spiritsail–forestaysail combination. These two rigs were superior to the lateen and were preferred by the operators of the fishing boats and small merchant vessels of the day.

Science Principles and Concepts

- Newton's third law states: For every action there must be an equal and opposite reaction.
- Bernoulli's theorem states: A reduction of pressure must be accompanied by an increase in velocity and vice versa.
- In general, Bernoulli's theorem accounts for the greater percentage of the propulsive force when sailing close to the wind; while the importance of Newton's third law is greatest when sailing before the wind.
- Air striking the windward side of a sail rebounds in a backward direction. As it does an equal and opposite force acts in a forward direction propelling the boat.
- When sailing close to the wind, air deflected to the leeward side of the sail follows a longer path than that deflected to windward, and it attains a higher velocity. As a consequence, atmospheric pressure is lower on the leeward side. This, too, contributes to the forward propulsive force.
- Archimedes' principle states: Any body immersed in a liquid is buoyed up by a force equal to the weight of the liquid it displaces. This force acts vertically upward and is applied to the center of buoyancy of the displaced volume of liquid.
- A boat will sink to the point where it displaces a weight of water equal to its own weight. Thus the weight of a boat is also known as its displacement.
- A boat of a given displacement will sink to a specific depth in the water, which determines its submerged volume. The buoyant force that supports the boat acts on the center of buoyancy of this submerged volume.
- The center of buoyancy and the boat's center of gravity will work together to create a "righting couple," which gives the boat stability.

- When the boat is in a condition of trim, the center of buoyancy and the center of gravity are aligned vertically. Once this condition is disturbed, the force of the weight of the boat acting downward at the center of gravity and the buoyant force acting upward at the center of buoyancy are just equal and work together to return to boat to trim.

Mathematical Principles and Concepts

- As a boat moves through water, a resistance that results from friction is built up, which causes disturbances or waves on the surface. These waves take energy from the boat, which is no longer available for propulsion. The distance between these waves is a function of the boat's speed. A first crest is formed just behind the bow. The distance to the second crest is given by the following formula:

$$d = \left(\frac{V}{1.2}\right)^2$$

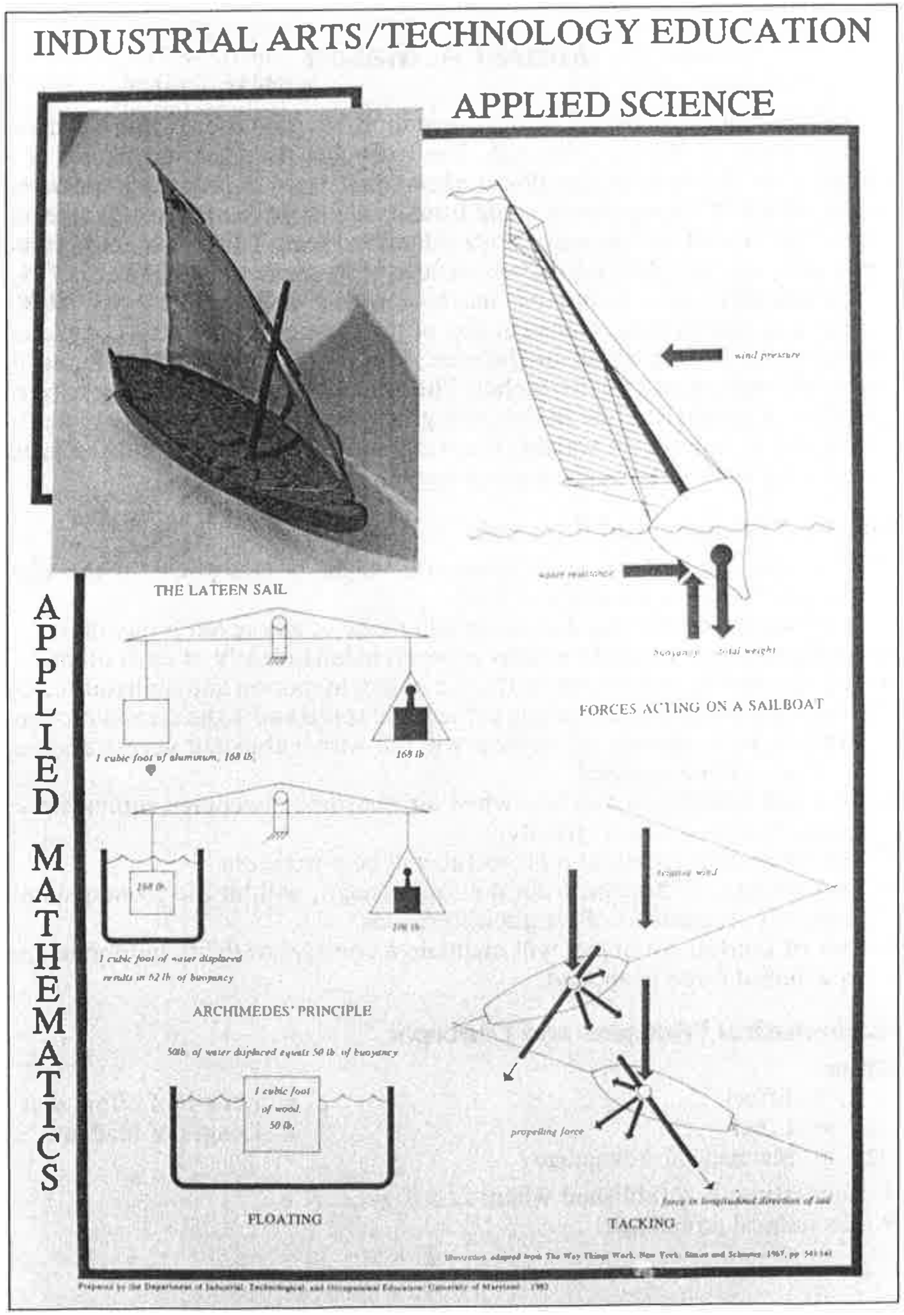
  Where d is distance in feet, and V is velocity in knots.

- As speed rises, the distance between waves increases. At a critical speed, the second crest will be at the end of the waterline near the stern. This critical speed can be calculated by the following formula:

$$V = 1.2\sqrt{L}$$

  Where V is velocity in knots, and L is the length of waterline in feet.

- If speed increases slightly beyond the critical value, the second crest will fall astern forming a deep trough. As this occurs, the stern of the boat will drop into the trough. Almost at once, resistance increases dramatically. Beyond the critical speed, a very large increase in power will produce only negligible gains in speed.



The Lateen Sail

The Trebuchet

Ronald A. Mason

The trebuchet, a medieval artillery invention, was first used by the Normans to siege Paris in the year 886 AD. The trebuchet used the mechanics of a simple lever to launch projectiles at enemy fortresses during many medieval sieges. Much of its popularity came from its ability to launch heavy objects, some in excess of 300 pounds, several hundred feet. The trebuchet became a popular, strong military weapon because of its tremendous power.

The trebuchet was a massive machine with weight in excess of 20,000 pounds and 50 feet long. Construction of the trebuchet had to be completed on the war site as a result of the size. Four to six men were required to construct and operate the trebuchet. The amount of time and energy used to reload were extensive; one person was given the sole responsibility of determining the counterpoise weight, the weight of the projectile, and the firing angle required to destroy the enemy target.

Science Principles and Concepts

- The time required to reach maximum height is equivalent to the time required to fall to the original level.
- A 45° angle will provide the maximum range of any given projectile.
- Horizontal and vertical motions proceed independently of each other.
- The first law of motion states that an object in motion and undisturbed by forces will continue indefinitely at the same speed and in the same direction.
- Gravity: In a vacuum, all objects will fall with a constant acceleration of 32 ft per second squared.
- Terminal velocity is reached when air resistance becomes equivalent to the acceleration due to gravity.
- The shape of the path of a projectile will be a parabola.
- Two objects, if dropped from the same height, will hit the ground simultaneously, regardless of weight differences.
- Law of Inertia: An object will maintain a constant-velocity motion unless an external force is applied.

Mathematical Principles and Concepts

Given:

E = Effort
L = Load
MA = Mechanical Advantage
e = Length of effort arm
l = Length of load arm

- Equilibrium is established when: $L \times l = E \times e$
- Mechanical advantage:

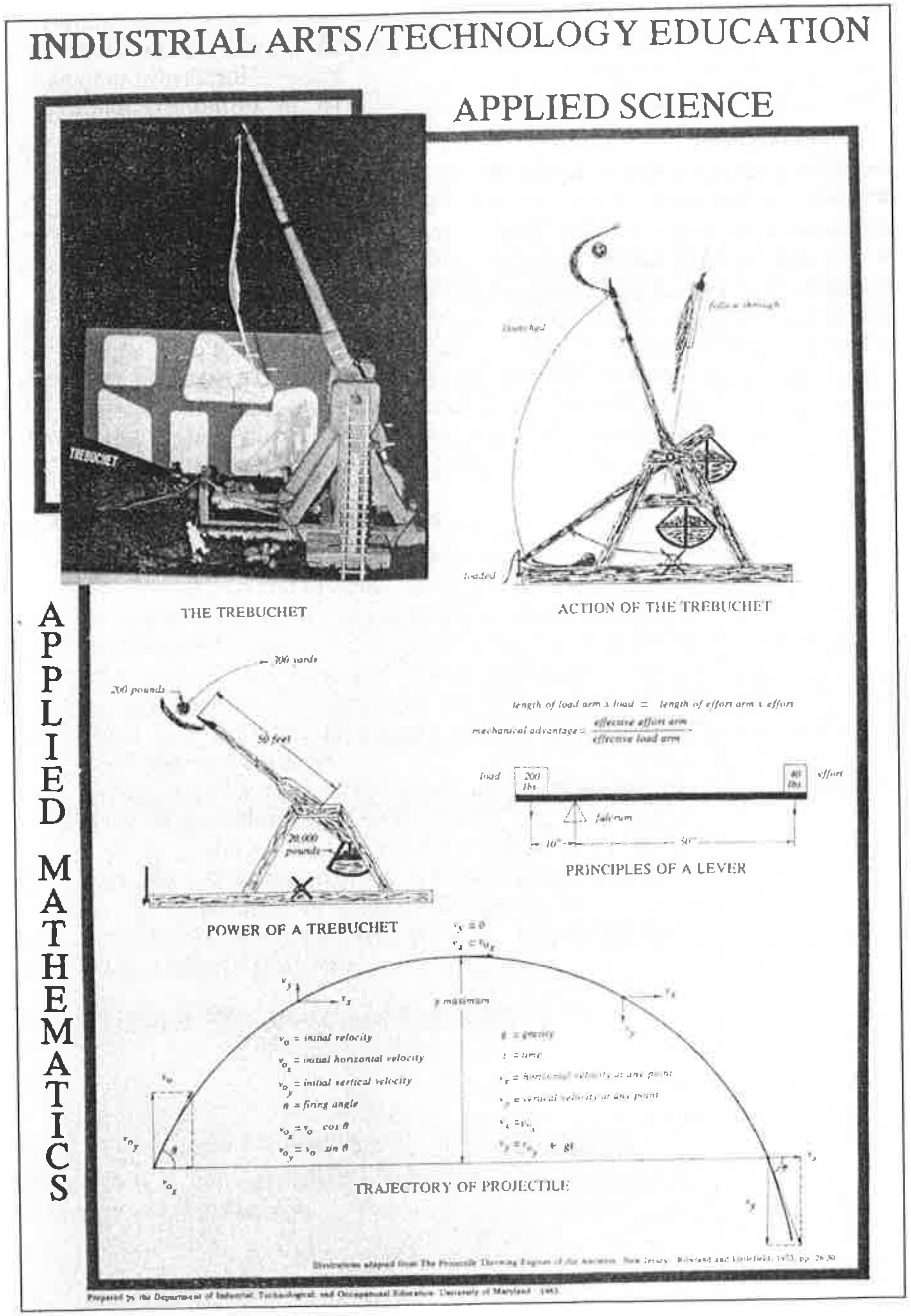
$$MA = \frac{E \times e}{L \times l}$$

- Effective effort arm $= E \times e$
- Effective load arm $= L \times l$

Given:

t = Time in seconds squared
y = Vertical height
Vy = Vertical velocity
Vox = Initial vertical velocity
$\propto$ = Angle of projection
x = Horizontal distance
Vx = Horizontal velocity
Vox = Initial horizontal velocity

- When y maximum is reached; $Vy = 0 \quad Vx = Vox$
- Initial vertical velocity; $Voy = Vo \text{ Sin } \propto$
- Initial horizontal velocity; $Vox = Vo \text{ Cos } \propto$
- Vertical velocity at any time; $Vy = Voy - 32t$
- Horizontal velocity at any time; $Vx = Vox$



The Trebuchet

The Block and Tackle

Ronald A. Mason

The date of the first known use of the pulley was about 427 B.C. The pulley was used in Greek plays; the gods were lowered onto the stage as though they were coming from heaven. This use, as well as the need for better shipbuilding techniques, led to the development of the pulley. The pulley provided the basis for the invention of the block and tackle. The block and tackle, a simple machine, has as a primary function a means of gaining mechanical advantage though the application and utilization of fixed pulleys, movable pulleys, and a rope to transfer the power. The fixed pulleys are used for the sole purpose of directional change, and the movable pulleys provide the mechanical advantage through the use of the principles of a simple lever.

The mechanical advantage to be gained by the block and tackle is phenomenal. Archimedes, the inventor of both the triple and compound pulley, demonstrated this mechanical advantage by pulling a fully loaded, three-mast ship onto dry land. Archimedes believed the power to be limitless. He claimed that if given a fixed point and a long enough rope, he could move the earth.

Science Principles and Concepts

- The mechanical principle of equilibrium is based on the equation: force × length of the arm of the force = load × length of the arm of the load.
- Mass is the property of resistance to change in speed or direction.
- Velocity resulting from gravity is 32 ft per second squared.
- Newton's first law is defined as follows: An object once placed in motion will not change speed or direction unless a force is applied.
- Newton's third law states that for every action, there is an equal and opposing action.
- Work is the product of force and distance.
- Ideal mechanical advantage is defined as $W = nP$, where n is the number of falls of rope and P is the force applied.
- Each moving pulley will double the mechanical advantage.
- The ideal mechanical advantage of a differential block is determined by the difference in the diameter of the pulleys.
- A fixed pulley provides only a directional change and no mechanical advantage.
- Work remains constant regardless of an increase in mechanical advantage.

Mathematical Principles and Concepts

Given:

L = Load distance	R = Large pulley radius
s = Force distance	r = Small pulley radius
W = Load	P = Force applied
n = Number of falls of rope	Mv = Momentum
F = Force	t = Time
D = Diameter of pulley	

- Load distance can be calculated with the formula

$$L = \frac{s}{n}$$

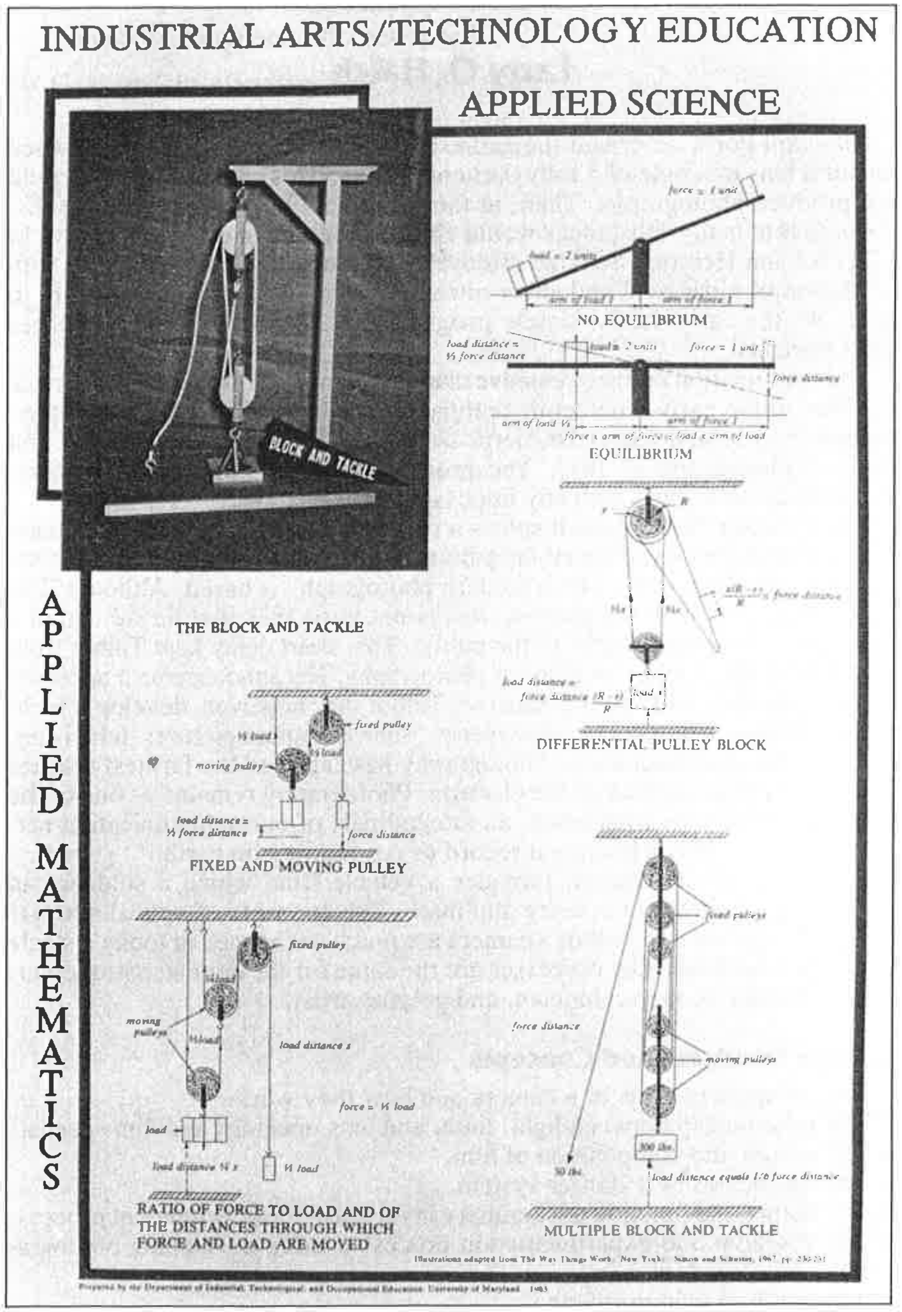
- The amount of force required to move a load is determined by the weight of the object divided by the number of falls of rope

$$P = \frac{W}{n}$$

- Mechanical advantage can be calculated using the following formula: $W = nP$.
- Mechanical advantage can be calculated when given a single mechanical advantage and various numbers of moving pulleys by applying the formula ($W = n^2P$).
- Circumference of the pulley can be found by using the equation of πD.
- Force will cause an object to gain or lose velocity and/or change direction. Force = Mass × Acceleration $F = MA$
- Mechanical advantage of differential blocks can be calculated by using the equation

$$\frac{P(R-r)}{R}$$

- Total momentum change can be calculated with the formula $Mv = F \times t$.



The Block and Tackle

The Camera

Larry O. Hatch

Giovanni Porta described the earliest camera concept in 1558 A.D. when he put a lens in a hole of a fully darkened room. This camera obscura could not produce photographs. Then, in the 16th and 17th centuries, it was discovered that many substances would change color when exposed to light. In 1727, Johann Heinrich Schulze discovered that chalk, when moistened with a solution of nitric acid and silver nitrate, became darker upon exposure to light. By the early 1800s, simple images could be printed, but the images soon vanished.

The combination of light-sensitive chemicals and the camera obscura came together in the early nineteenth century for the beginnings of photography. Joseph Niepce and Louis Daguerre developed what was perhaps the first positive photograph in 1837. The process used no negatives. Therefore, duplicating copies was virtually impossible.

The picture in this article displays a replica of the type of camera William Henry Fox Talbot used for taking pictures in 1835. Talbot used the negative/positive technique upon which modern photography is based. Although Talbot had success with his process, it was not until 1838 that he submitted a selection of his photographs to the public. This short delay kept Talbot from establishing his claim as inventor of photography. His announcement appeared at the same time as that of Daguerre. Talbot did, however, develop a technology that has led to further discoveries, such as motion pictures, television, and satellite communication. Photography has captured the farthest reaches of space and the essence of the electron. Photography remains as one of the most powerful tools of science, an integral part of our communication network, and provides a historical record of our journey on earth.

The study of the camera provides a vehicle from which a student can understand concepts of science and math. The concepts of optical systems and chemistry used in Talbot's camera are much unchanged in today's single lens reflex cameras. The processes are the same for the dentist, astronomer, microbiologist, X-ray technician, and graphic artist.

Science Principles and Concepts

- The component parts of a camera and how they work.
- The relationship between light, time, and lens openings and film speeds.
- The nature and composition of film.
- The mechanics of a shutter system.
- The nature and function of chemistry involved in the development process.
- The research and experimentation process used in developing photography.
- The depth of field principle.
- The reflected light principle.
- The importance of the camera to the field of science and industry.

Mathematical Principles and Concepts

- Balancing lens apertures with shutter speeds.

  light = f-number × shutter speed

- Compare the effects of film speeds (ASA).

  25 ASA = lower sensitivity to light
  400 ASA = higher sensitivity to light

- Measure focal lengths.

  Focal length = distance from optical center of lens to the focal point focused at infinity.

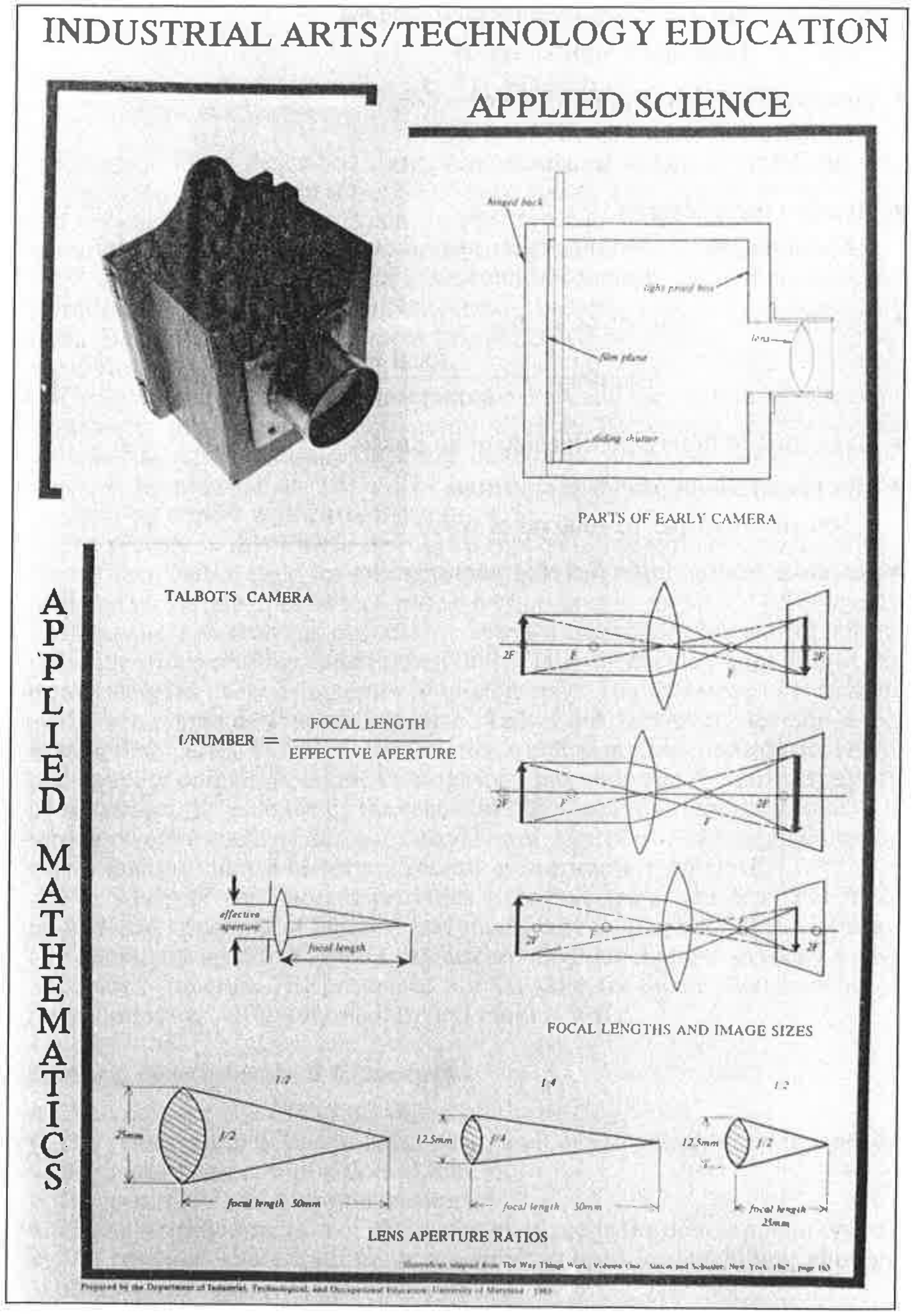
- Calculate the f-number of a lens.

$$\text{f-number} = \frac{\text{focal length}}{\text{diameter of aperture}}$$

- Use ratios to determine the size of an image.
- Mix chemicals in proper proportions.

  500 ml developer to 1000 ml of water

- Accurate timing in the development process.



The Camera

The Incandescent Lamp

Larry O. Hatch

The incandescent lamp represents a major technological breakthrough. Like most technological developments, the bulb developed out of the scientific principles previously discovered. The earliest predecessor to the bulb was an experiment conducted by Humphry Davy in 1802 A.D. In this early attempt at generating light, Davy passed electrical current through a platinum wire and brought it to incandescence. In 1845, J. W. Starr placed an electrically heated carbon rod in an evacuated tube. None of these experiments was successful or practical in providing light until Thomas Alva Edison tackled the problem.

Menlo Park, New Jersey, provided the setting for thousands of experiments to perfect the bulb. There, Edison applied electrical current to very thin filaments of carbonized thread sealed in an evacuated glass bulb. The voltage was increased until the incandescence provided a steady glow. By 1879, a carbon filament glowed for 40 hours before Edison deliberately increased the voltage, burning out the lamp.

Edison not only devised and manufactured the first lamp, but he envisioned an entire electrical distribution system. That vision became a reality by 1882, when Edison's Pearl Street station supplied power to 1,284 lamps in the Wall Street section of New York City. Edison opened the door to a new era. What is known today in electronics/electricity can gain meaning by experimentation with the lamp.

Science Principles and Concepts

- The component parts of an incandescent light bulb and how they work.
- Moving electrical charges constitutes an electric current.
- Resistance and its function in producing light.
- The concept of electron movement.
- Concepts of insulation and conductance.
- Energy can be neither created nor destroyed.
- Energy can be observed in at least five forms: heat, light, chemical, electrical, and mechanical.
- The bulb as an input/output energy model.
- The relationship between resistance, voltage, and amperage as expressed in Ohm's law.
- The relationship of Ohm's law to series circuits.
- The relationship of Ohm's law to parallel circuits.

Mathematical Principles and Concepts

- The light output of a bulb is measured in units called lumens.

$$1 \text{ Lumen} = \frac{1 \text{ footcandle}}{1 \text{ square foot}}$$

- The efficiency of a light bulb can be determined by measuring the light output of a bulb and wattage input.

$$\text{Efficiency} = \frac{\text{energy output}}{\text{energy input}}$$

- Current is the rate of flow of electrons.

$$\text{Amps} = \frac{\text{Volts}}{\text{Ohms}}$$

- The resistance of a conductor is measured in Ohms.

$$1 \text{ Ohm} = \frac{1 \text{ Volt}}{1 \text{ Amp}}$$

- The electrical pressure which causes the flow of current is measured in volts.

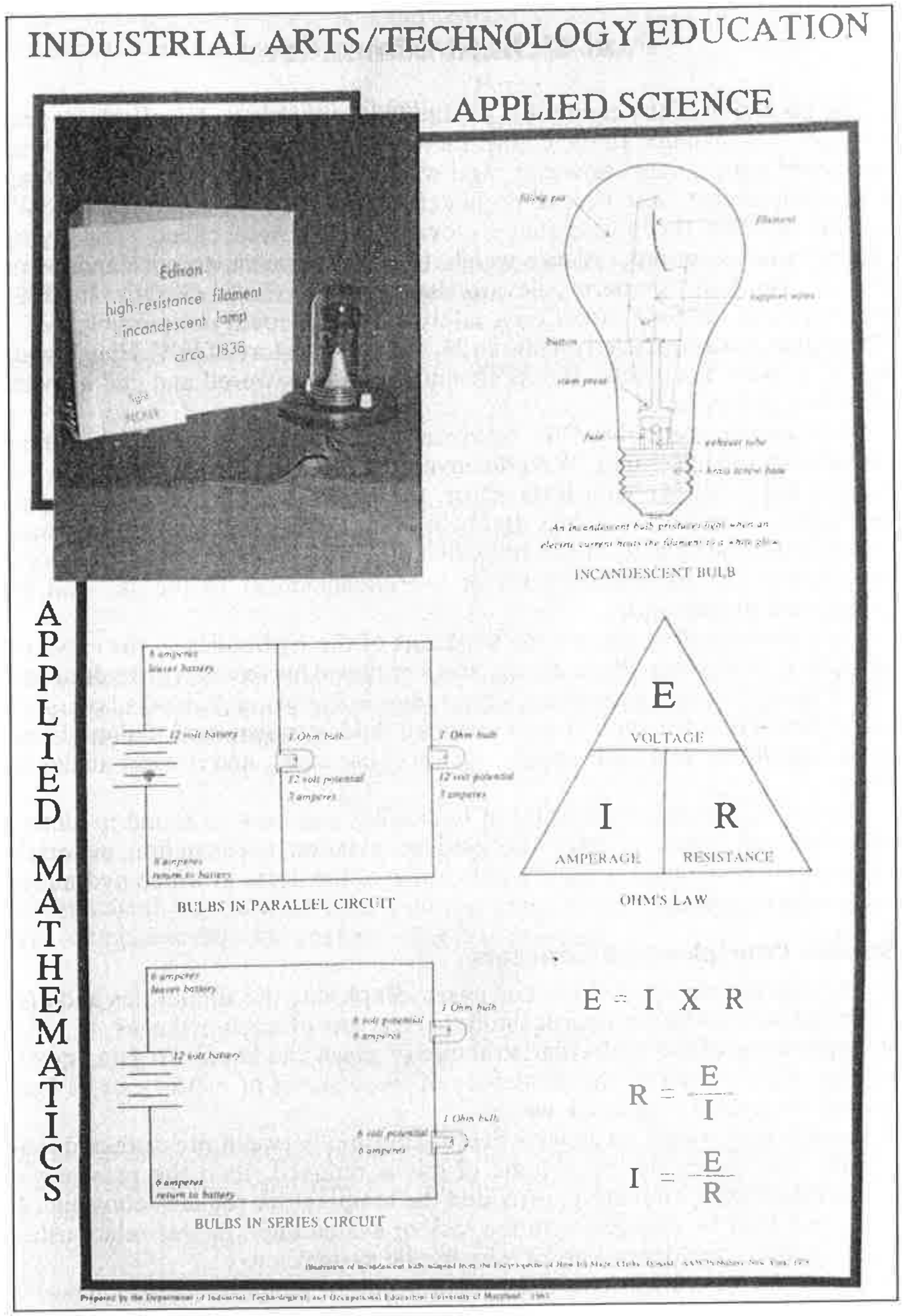
  $\text{Volts} = \text{Amps} \times \text{Ohms}$

- The unit of power is called the Watt.
  $\text{Wattage} = \text{Volts} \times \text{Amps}$

$$1 \text{ Watt} = \frac{1 \text{ Joule}}{1 \text{ Second}}$$

- Energy costs for lighting can be calculated.

$$\text{Cost} = \text{Kilowatts consumed} \times \frac{\text{Cost}}{\text{Kilowatt}}$$



The Incandescent Lamp

The Hydraulic Elevator

Paul Richard Edmondson

The invention of the elevator is credited to Leonardo da Vinci, whose first elevator was installed in the Cathedral in Milan, Italy. This "elevator" was only used once a year, however, and was more of a showpiece rather than a working device. The French architect, Velayer, in the early seventeenth century invented the first passenger elevator. This device, called "The Flying Chair," used a counter balance weight and human power to raise and lower the car. The first "modern" elevator is credited to Elisha G. Otis. In 1852, Otis took out the first patent on a safety car that "could not possibly fall." This elevator was installed on March 23, 1857, in the store of E.V. Haughwout & Co. in New York City. It was steam/hydraulic powered and had a speed of 40 feet per minute.

Some people argue that Otis, by virtue of his elevator, was also the father of the modern skyscraper. With the invention of a means to lift people to the tops of tall buildings with little effort, the expansion upward could begin. One other candidate is Henry Baldwin Hyde, who combined the elevator and an office building so successfully that others soon began raising the roofs. In either case, the prime mover of the advancement to the sky can be considered the elevator.

The principles that govern the workings of the hydraulics in the elevator go back to 1650, when Blaise Pascal first developed his theories on hydraulics. From those theories developed what today is known as Pascal's law. This law states: Pressure applied on a confined fluid is transmitted undiminished in all directions, acts with equal force on equal areas, and at right angles to them.

The evolution and application of hydraulics can now be found in almost every segment of our society. Automotives, aviation, construction, materials handling, and manufacturing are only a few of the areas in which hydraulics are used extensively.

Science Principles and Concepts

- The characteristics of fluids and gases. Exploring the similarities and dissimilarities of their properties under given sets of circumstances.
- Exploration of the molecular structure of gases and liquids to gain knowledge of how each of the properties of these states of matter can be best used for specific applications.
- Boyle's law, which deals with the relationship between pressure and volume, and states: If the volume of gas is reduced, then the pressure is increased proportionately, provided the temperature remains constant. A student may be charged with the task of evaluating how this relationship could affect the operations of a hydraulic system.
- Charles' law, which defines the relationship of temperature and pressure of a confined gas: If the temperature of a confined gas is increased, the pressure increases proportionately, provided the volume remains constant.

Mathematical Principles and Concepts

- **Pressure:** If a 300-lb force is being exerted by a cylinder having an area of 4 in.^{2} one can calculate the pressure in the system.

$$\text{Pressure (in psi)} = \frac{\text{Force}}{\text{Area}}$$
$$P = \frac{300}{4 \text{ in.}^2}$$
$$= 75 \text{ psi of system pressure}$$

- **Area:** Given a system with 450 psi of pressure exerting a force of 567 lbs one can calculate the area of the piston.

$$\text{Area} = \frac{\text{Force}}{\text{Pressure}}$$
$$A = \frac{567}{450}$$
$$= 1.26 \text{ in.}^2$$

- **Force:** Given a system with a pressure of 35 psi and a cylinder with an area of 25 in.^{2} what force can be exerted on an object?

$$\text{Force} = \text{Pressure} \times \text{Area}$$
$$F = 35 \times 25$$
$$= 875 \text{ pounds}$$

- **Potential Energy:** Given a tank 35 feet high filled with oil having a specific gravity of 0.89 what pressure would be measured at the bottom of the tank if it was one foot square?

$$\text{Potential Energy} = \text{Weight} \times \text{Height}$$
$$\text{Wt (oil)} = \text{Sp. Gr. (oil)} \times \text{Wt. (Water)}$$
$$= .89 \times 62.4 \text{ lb/ft}^3$$
$$= 55.5 \text{ lb/ft}^3$$

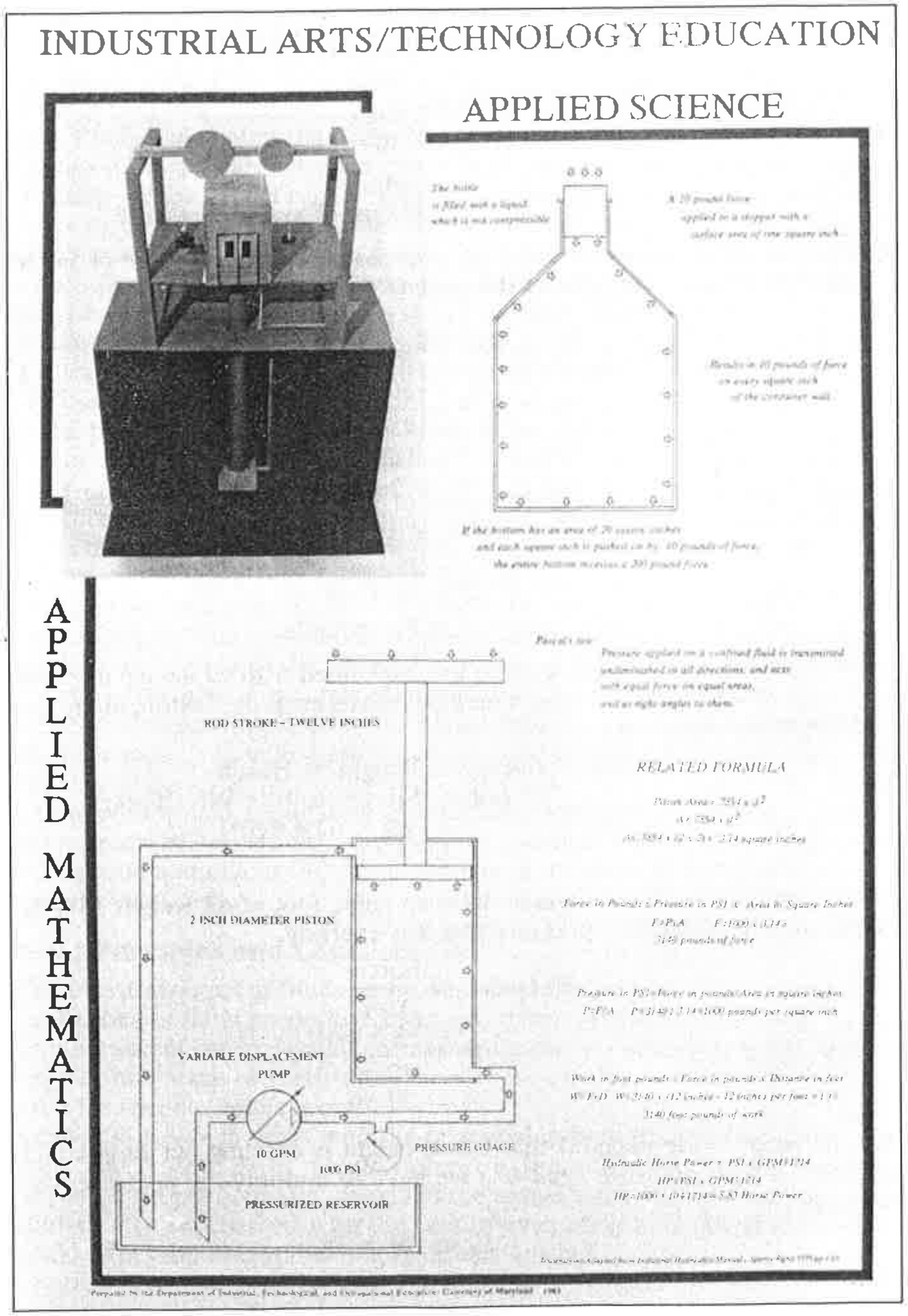
The statement can now be made that one cubic foot of oil weighs 55.5 lbs. Next, one has to find the pressure that it is exerting.

$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$
$$P = \frac{55.5 \text{ lb/ft}^3}{(12 \times 12)}$$
$$= .39 \text{ psi}$$

This is the pressure (weight) that 1 ft of height is exerting per square inch. To find the total pressure head (P_h) we have to multiply the pressure times the height.

$$P_h = .39 \times 35$$
$$= 13.7 \text{ psi}$$

This is the number of pounds per square inch than is being exerted on the bottom of the tank.



The Hydraulic Elevator

The Wright Brothers' Airplane

Andy Batey

In the autumn of 1903, the Wright brothers were embroiled in an unspoken competition with Professor Samuel P. Langley. Professor Langley, head of a federally funded project, was conducting experiments into powered flight near Washington D.C. His aircraft was an awkward, scaled-up version of successful smaller unmanned models. Two unsuccessful manned attempts, one on October 7, 1903, and a second on December 8, 1903, ended federal funding and Professor Langley's experiments.

Although the Wrights had received little formal education, the two bicycle makers from Dayton, Ohio, had prepared as scientifically for their work as had Professor Langley. They identified Kitty Hawk, North Carolina, as the location in the eastern states where winds were consistent enough to favor experimentation. Spending four consecutive summers at Kitty Hawk, the Wrights perfected such devices as manipulative control surfaces, a forward horizontal stabilizer, and a wing profile with less camber than gliders of the day. Their winters at Dayton were spent conducting lift experiments on a home-built wind tunnel and perfecting a lightweight, water-cooled, four-cylinder engine of their own design.

By December 17, 1903, just nine days after Professor Langley's second unsuccessful attempt, the Wright Brothers were ready for their historic break-through. Orville's first flight lasted only a few seconds and covered 120 feet. It was followed by three more flights that same day with Wilbur's final effort lasting 59 seconds and covering 852 feet. These were the first flights in human history in which a powered aircraft had lifted a man and carried him forward ultimately landing at a point as high as that from which it started.

Science Principles and Concepts

- Newton's third law states: For every action, there must be an equal and opposite reaction.
- Bernoulli's theorem states: A reduction of pressure must be accompanied by an increase in velocity and vice versa.
- Air deflected by the bottom surface of an airfoil, usually in a backward and downward direction, results in an equal and opposite lifting force, which acts in an upward and forward direction.
- Air deflected above the airfoil must travel a greater distance, in the same period of time, than that deflected below. Thus, air above the airfoil is moving at a higher velocity, which results in an accompanying lower pressure also contributing to lift.
- For normal angles of attack, the proportion of total lift accounted for by Newton's third law is about 30%, and by Bernoulli's theorem about 70%.
- Bernoulli's theorem contributes an increasing percentage of total lift with decreasing angle of attack. The lift derived from Newton's third law decreases correspondingly until the angle of attack is zero degrees when total lift is attributable to Bernoulli's theorem alone.

- Aerodynamic force is the total force resulting from the interaction of all forces acting on the airfoil.
- Drag is the direct result of friction and air resistance. Drag, combined with lift, results in the total aerodynamic force.
- Drag is minimal when the angle of attack is zero degrees and least resistance is offered to the airstream.
- Lift will increase with increasing angle of attack up to a limiting point known as the stalling point.

Mathematical Principles and Concepts

- The following mathematical models explain the many factors which interact to produce specific values of lift and drag:

$$L = C_L \frac{P}{2} S V^2$$

$$D = C_D \frac{P}{2} S V^2$$

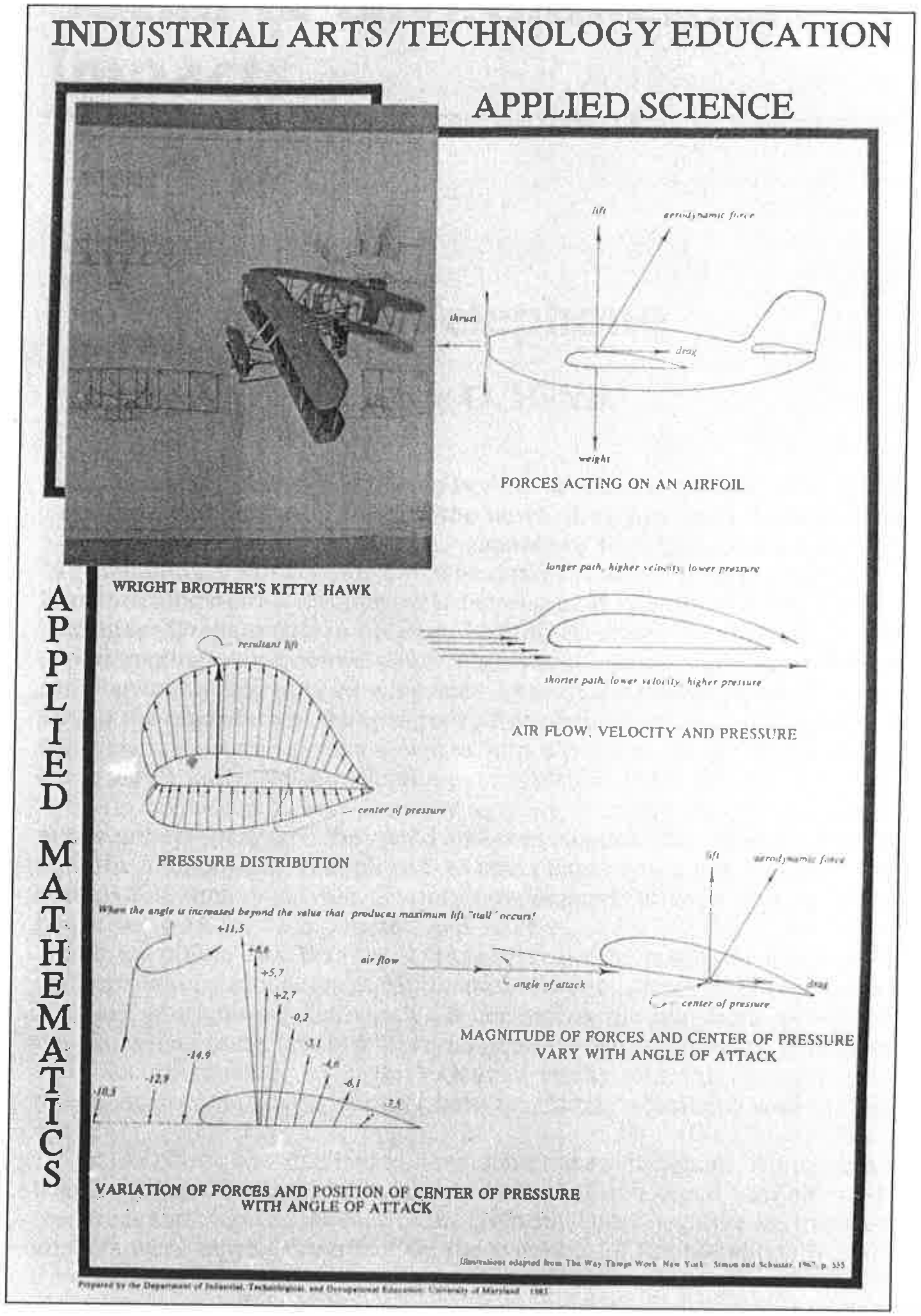
Where L and D are lift and drag in pounds, C_L and C_D are coefficients dependent upon airfoil contour and angle of attack, P is air density in slugs per cubic foot, S is the area of the wing in square feet, and V is velocity in feet per second.

- The drag coefficient increases as the square of the lift coefficient until the lift coefficient ceases to increase in direct proportion to the angle of attack. At that point, the drag coefficient increases much more rapidly.
- The effectiveness of an airfoil is expressed by the formula:

$$E = \frac{L}{D}$$

Where E is effectiveness, L is the lift coefficient, and D is the drag coefficient.

- For any airfoil design, there is one angle of attack at which the L/D ratio is greatest, or where lift is maximized and drag is minimized.
- The L/D ratio is zero at some negative angle of attack, which produces zero lift because the numerator is zero. As the angle of attack is increased beyond zero lift, the ratio increases rapidly, usually reaching its maximum value at an angle between 0° and 4°. As the angle of attack increases beyond the point of maximum effectiveness, the ratio gradually decreases.
- Finally, lift increases with angles of attack greater than 4°. Drag also increases with angle of attack, however, and the L/D ratio is smaller for angles over 4°.



The Wright Brothers' Airplane

Social & Environmental Impacts

The Telephone

Larry O. Hatch

Communication has long been a key element in the growth of civilization. The signal fire was used to send the news of victory back to Greece from Troy in 1084 B.C. By 1794 A.D., semaphore flags had demonstrated that large amounts of information could be rapidly relayed. In 1844, Samuel F. B. Morse demonstrated the magnetic telegraph. It was the telegraph that led Alexander Graham Bell to his discovery of the telephone. In 1875, Bell was experimenting with a device to carry several telegraph signals over one wire simultaneously. He noticed what seemed to be the transmission of sound by way of the reeds he was using to receive the individual electrical signals. The conversion of sound pressure waves into electrical energy and back again led to Bell's patent of the telephone on March 7, 1876.

Bell's device has affected society in many dramatic ways. First, the telephone greatly increased the speed and convenience of communication. Second, the telephone system placed, at one's fingertips, a link to almost every conceivable human service. Society now depends in large part on the telephone network for food, shelter, and safety.

The telephone has become a dominant tool in business, industry, and government on a global scale. Multinational corporations, international banking, and international diplomacy all depend on the telephone system. The telephone has more recently been adapted for teleadvertising, telebanking, and teleconferencing. Even the extended family structure depends on the telephone to keep close contact between family members who are miles apart.

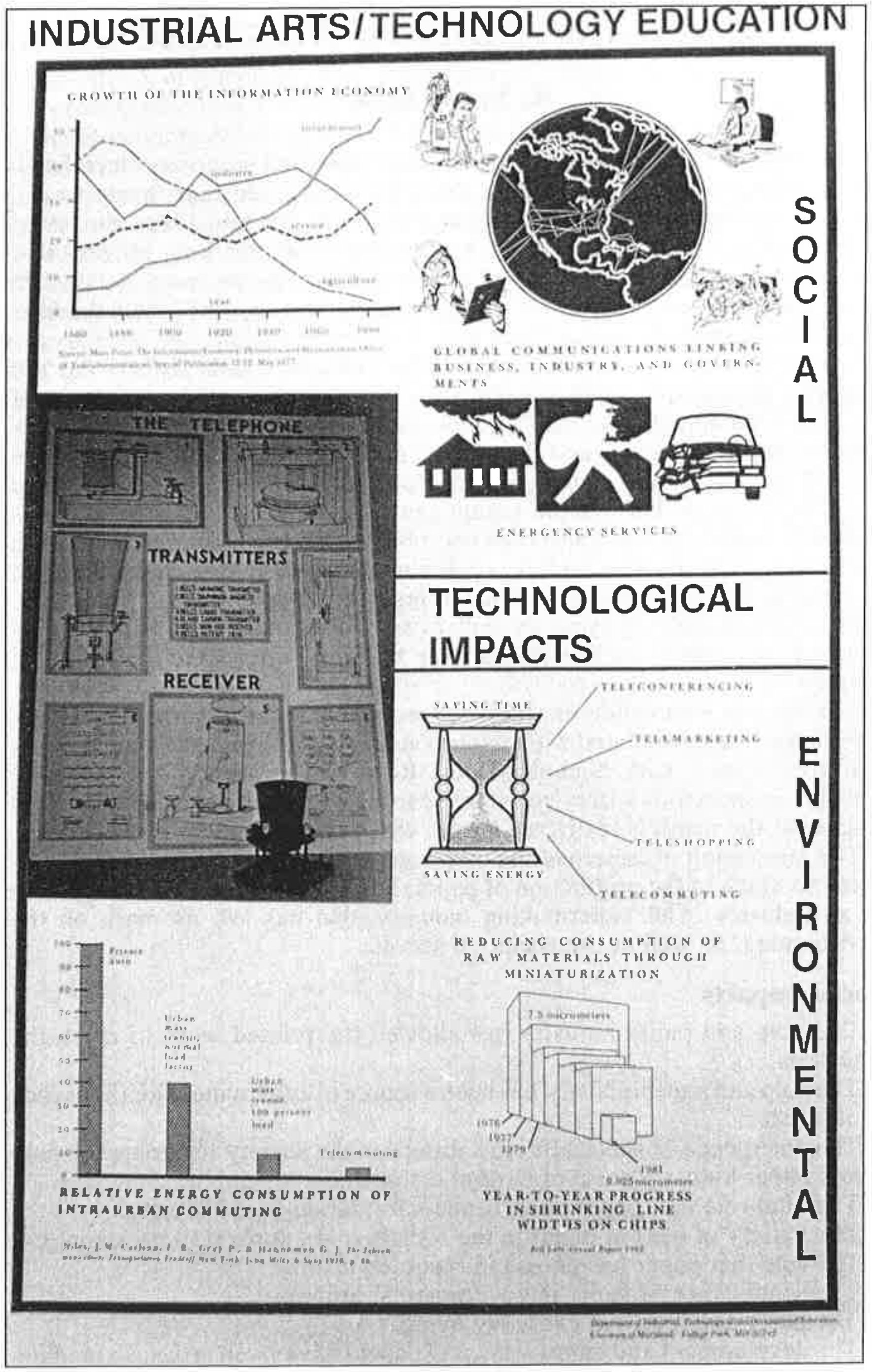
The telephone has also had an impact on the environment. Along with the telephone came millions of poles and lines that consumed vast amounts of resources and changed the face of the country. These negative environmental impacts were more than offset by the potential of the telephone to reduce transportation costs, thereby reducing dependence on finite natural resources. The telephone industry has also been a technological leader in reducing consumption of raw materials through satellite technology, fiber optics, and the miniaturization of electronic components.

Social Impacts

- Linked governments around the globe.
- Provided immediate access to fire departments.
- Provided immediate access to medical services.
- Provided immediate access to police protection.
- Transformed business and industry by changing the way people work.
- Linked the extended family in an age of great mobility.
- Connected banks and financial institutions.

Environmental Impacts

- The aesthetics of our landscape have been altered with the introduction of telephone poles.
- Time and resources spent traveling have been reduced (through teleconferencing, telebuying, telemarketing).
- The consumption of precious materials (e.g., copper) has been reduced through the miniaturization of electronic components.
- The location of work is affected by the telephone. Home-based microcomputers, when combined with the telephone network, allow office work to be accomplished at home.
- The profusion of communication satellites in orbit may create space clutter.
- Finite fuel reserves can be extended through telecommunication technology.



The Telephone

The Papermaking Machine

R. Scott Gray

The art of papermaking has taken on many forms and processes since Ts'ai-Lun developed the idea of making paper from bark, old rags, hemp waste, and fish nets in about 105 A.D. It was not until in the late 1700s, however, that Nicholas-Louis Robert began to develop a papermaking process that would revolutionize the making of paper. Robert was awarded a patent in 1799 for this new process, which used an endless screen, onto which the fiber solution was poured.

The papermaking machine invented by Nicholas-Louis Robert did not resemble the modern machines of today, nor did it have the appearance of the earlier equipment used to produce paper. There were two major components to this machine, and these were mounted on a heavy frame to give the unit stability. One component was a large wooden vat or tub, which held the fiber solution. The second component was an endless screen that was turned on rollers so that the screen was able to move in a continuous motion over the vat or tub. The endless screen made it possible to make paper of any length. The width was controlled or restricted by the width of the screen. This same principle of using an endless screen was used in a papermaking machine developed for the Fourdrinier brothers, who were stationers in London.

The name of Fourdrinier has become prominent in the papermaking industry and has been associated with modern versions of the papermaking process that got its start with Nicholas-Louis Robert. The modern papermaking machine is enormous with a very large capacity to produce paper of endless length but the width is restricted by the width of the machine.

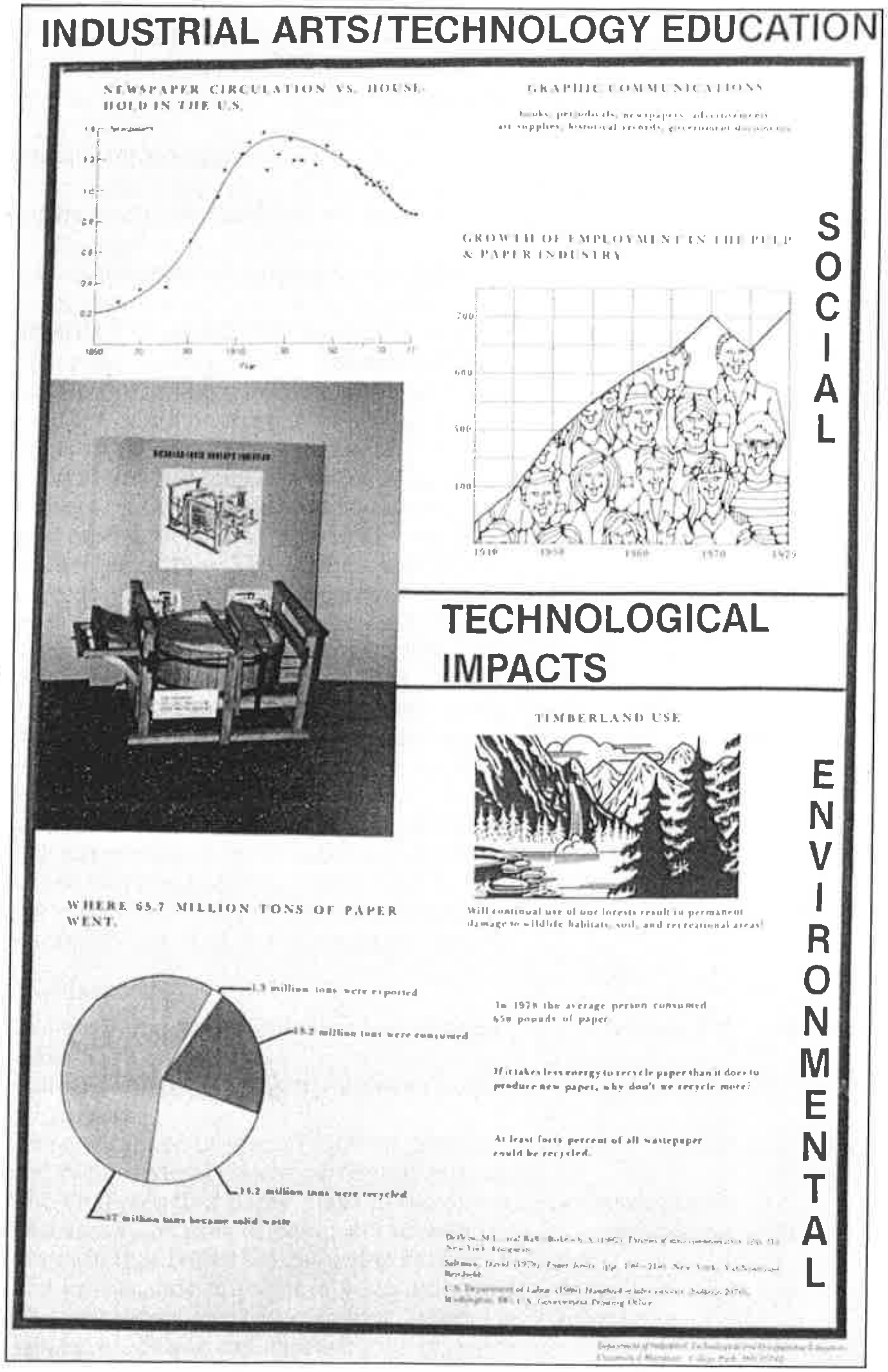
The innovation of papermaking on a continuous screen, which has contributed so much to the production of paper, has also contributed to the growth of an industry. The papermaking industry also has left its mark on the environment, as well as the society it serves.

Social Impacts

- The pulp and paper industry has allowed the printed word to reach the masses.
- The pulp and paper industry has been a source of employment for thousands of workers.
- The emergence of special interest groups in the society regarding the pulp and paper industry's use of natural resources.
- The vital role that paper plays in the information-based society.
- The variety of uses of paper in the society (e.g., apparel to packaging).
- The role that paper has played in recorded history.
- The significance of paper in governmental processes.
- The part paper plays in everyday living.
- The development and improvement of papers have given artisans a medium with which to work.

Environmental Impacts

- The effects of the clearing of timberland on the ecosystem.
- Problems associated with paper litter.
- The growing problem of solid waste disposal.
- The problems of air and water pollution associated with paper production.
- The lack of paper recycling in the society.
- The pulp and paper industry's involvement in the reforestation of cleared timberland.
- Effect on the ecosystem during the period of pulpwood transportation on rivers.
- Possible effects on the ecosystem as scientists alter the genetic structure of trees to improve the timber yield per acre.



The Papermaking Machine

The Automobile

James M. Smith

The automobile, as we know it today, is powered by the internal combustion engine. The earliest attempts at a self-propelled vehicle used steam power. As early as 1769, the Frenchman Nicholas Joseph Cugnot developed the first transportation vehicle using steam for military purposes. Because of the very large size of the steam engine, the vehicle was not accepted overall.

In 1805, Oliver Evans propelled a steam-powered dredge through the streets of Philadelphia. These first horseless carriages met strong opposition. The Commonwealth of Pennsylvania refused Evans the right to operate his vehicle on its streets. Another example of resistance was the English Red Flag Law of 1865, which required operators of motor vehicles to limit their speed to 4 miles per hour and to be preceded by a man on foot waving a red flag.

The development of the internal combustion engine was an answer to the need for a smaller, lighter power plant. Although others claim to have developed the first automobile incorporating the internal combustion engine, credit is given to Karl Benz and Gottlieb Daimler in 1885. The first American gasoline vehicle was made by Charles and Frank Duryea in 1893. Following the Duryeas' vehicle came those of Haynes (1894); Maxim (1895); King, Ford, and Winton (1896); and Olds (1897).

It was not until 1908 that Henry Ford popularized the auto with the production of the Model T. By 1928, 15 million Model T's had been sold. Ford, using what is now considered to be the first modern assembly line, made it possible for most people to own an automobile. It was this manufacturing technique that has had one of the largest impacts on the quality of life in the United States this century. From these humble beginnings, the automobile has imposed great changes on our society, both good and bad.

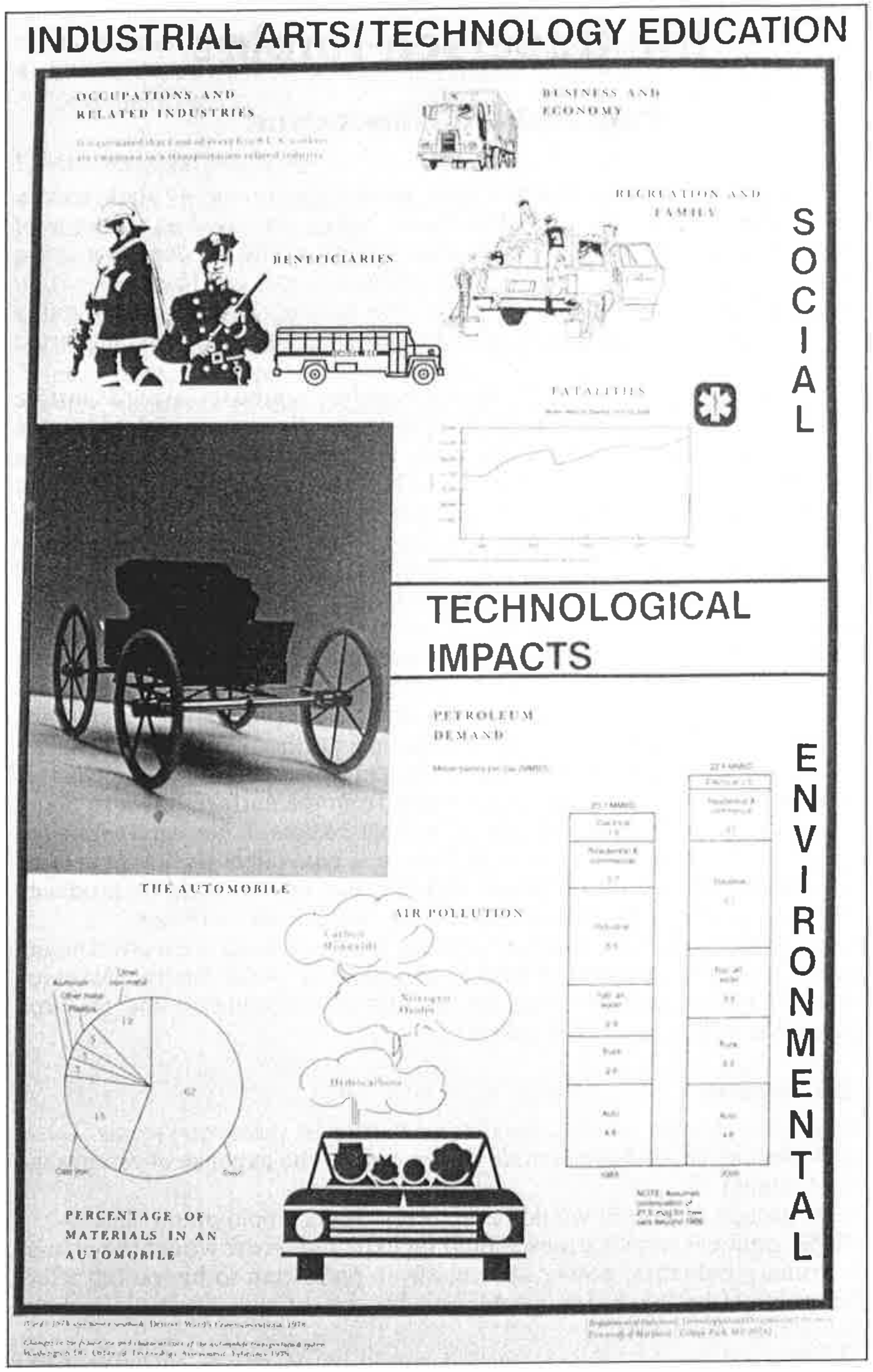
Social Impacts

- Changed the life-style of people in the United States.
- Decentralization of the extended family structure.
- Increased the mobility of people.
- Provided greater entertainment and recreational opportunities.
- Allowed for technological developments in other occupational areas requiring powered vehicles.
- Made possible mass transit by bus.
- Allowed for greater agricultural productivity.
- Provided transportation for public education.
- Centralized the schools into stronger, larger units.
- The automobile transportation system accounts for approximately 10% of the gross national product.
- Extensive federal and state costs to maintain road systems.
- Created higher productivity of all products through innovative mass production methods in the auto industry.

- Employed directly 1 out of every 18 American workers in the transportation system.
- Increased labor forces to meet the needs of the automobile's supporting industries.
- Employed an estimated 1 out of every 6 to 8 U.S. workers in a transportation-related industry.
- Increased employment in highway construction.
- Increased commerce through the trucking industry.
- Allowed one to live and work in two different communities.
- Improved services in the area of fire and police protection.
- Created extensive loss of life and high rate of injury in highway accidents.
- Created problems caused by people operating vehicles while under the influence of alcohol.
- Improved emergency lifesaving facilities.

Environmental Impacts

- Consumed large quantities of natural resources.
- More than 13 million tons of solid waste must be disposed of annually.
- Approximately 80% of automotive waste is recycled.
- Consumed large quantities of petroleum in the U.S. and worldwide.
- Decreased petroleum reserves drastically.
- Synthetic fuels a potential major environmental hazard.
- Changed the form of the land through urban development.
- Consumed extensive land for roads.
- Disrupted community life with the expansion of highways.
- Created traffic congestion in urban areas.
- Polluted the air from automobile emissions.
- The major source of carbon monoxide, hydrocarbons, and nitrogen oxides in the atmosphere.
- Contaminated the waterways with fuels and road salts.
- Subjected people to traffic noise.



The Automobile

The Undersea Turbine

Paul Richard Edmondson

For hundreds of years, humans have used water to supply their energy needs. As far back as the early Egyptians, water was used as a source of low-cost, "clean" energy to improve the quality of life. Today, that quest for larger and lower cost "clean" sources of energy goes on. The introduction of the undersea turbine is an example of a technology being explored today that will continue the momentum of hydrological energy development started by the Egyptians long ago.

The Coriolis project (named for the 19th century scientist Gaspard Gustive de Coriolis, who published a paper in 1835 on the distortions of fluid motion due to the Earth's rotation) is one such attempt aimed at harnessing the energy found in the ocean's currents. The project was the brainchild of William J. Mouton, a registered civil engineer and professor of architecture at Tulane University in Louisiana. He and his group of researchers propose to develop and deploy huge ducted turbines, each larger than a football stadium, to be submerged in the North Atlantic.

Each unit is to be about 240 feet (75m) in diameter and rated at about 5 megawatts. This unit would have a plant/construction cost of approximately $1,500 per kw and would be capable of delivering energy at a cost of about 4.5 cents per kwh. At present they are looking at the possibility of deploying them in the Gulf Stream. This current runs in a northerly direction along the Florida coast 20 miles off shore. The current has a central core, which is estimated to be 16 miles wide and extends from the surface down to about 750 ft. Here, the annual average speed is about 3 knots. It has been estimated that the energy available in the Gulf Stream is equivalent to that generated by 25 1,000-megawatt power plants and that this power could be produced at competitive prices during the 1980s using the Coriolis turbines.

The Coriolis group has received positive feedback from such government agencies as the Department of Energy and the U.S. Solar Energy Research Institute. This support has been in the form of information and research assistance as well as research grants.

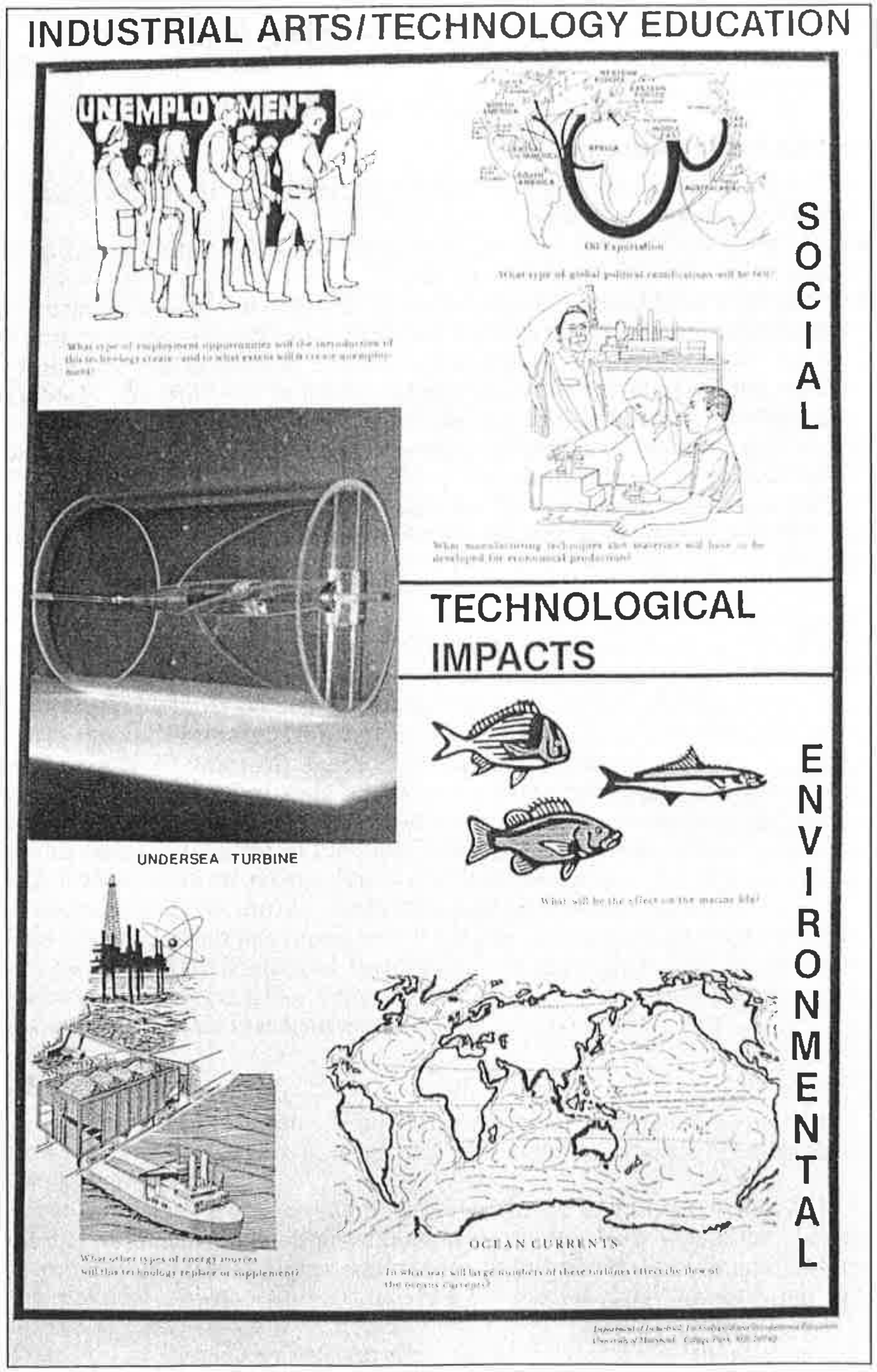
Social Impacts

- Employment opportunities would arise to support the new systems. These new jobs can be, and are in many cases, won at the expense of established employment.
- What groups of people would be involved in the employment shift?
- Global political ramifications should be explored. How would the change in primary industrial power sources (from petroleum to hydraulic) affect the political power bases established by the oil rich "haves" and the importing "have nots"?
- The type of regulatory system that would be necessary to prevent the congesting of shipping and recreational waterways.

- The availability of the technology, and the criteria for its dispersal.
- As with the environmental considerations, what would be the second-order consequences?

Environmental Impacts

- The effect these turbines have on the marine life living in the area surrounding such installations.
- The extent to which the feeding, reproduction, and migratory habits of the aquatic life in the area are disrupted.
- It has been established that one or two of the turbines placed in the major currents of the ocean will not have a significant effect on the direction or speed of the current. To make full use of the benefits of the technology, many hundreds of the turbines will be placed in the currents. How will this inflated number of turbines affect the currents?
- A concern for the second-order consequences resulting from a slowdown or rerouting of the currents.
- The impact on currently employed energy sources by the introduction of this technology and how it would affect the micro- and macrocosms involved.



The Undersea Turbine

The Space Shuttle

Anthony F. Gilberti

The National Aeronautics and Space Administration (NASA) began operation of the space shuttle program in January of 1972, when then President Richard M. Nixon gave final approval to necessary funds for research and development for a space shuttle. With these funds in hand, NASA laid the foundation to a unique type of space travel. The initial plans were to develop a reusable earth-to-orbit vehicle with ready access to space at lower costs and greater flexibility. As a cargo and personnel carrier, the shuttle is designed to deliver payloads into orbit, eliminating the need for costly launch vehicles. The savings, an estimated billion dollars per year, can then be translated into additional payloads to meet predicted needs for more earth-oriented applications.

Developed under the direction of NASA's Johnson Space Center in Houston, the space shuttle allows whole teams of experimenters to go into space in the Spacelab. The Spacelab, a pressurized module which fits into the orbiter's cargo bay, enables scientists to work in a shirtsleeve environment for up to 30 days. Spacelab thus offers a platform from which the earth can be examined as a whole. It provides astronomical observation unobscured by the earth's atmosphere and renders a new range of human-directed experiments under long-term, gravity-free conditions.

The space shuttle offers scientists two other important contributions. First, the space shuttle has the ability to retrieve satellites for repair or refurbishment, thus greatly extending a satellite's working lifetime and savings in replacement costs. Second, when equipped with an upper stage, the orbiter can become a launch facility for sending interplanetary spacecraft into deep space trajectories or serve as a base for deploying large-scale space structures.

NASA has acquired a vast fund of scientific knowledge from the space shuttle program. Although this knowledge has found many applications within the space program, it has more importantly become valuable to society. The knowledge generated by the space program eventually finds practical application in society. Although some of the technological applications bring relatively low economic or life-style gain, others amount to considerable public gain, with economic values running into millions of dollars.

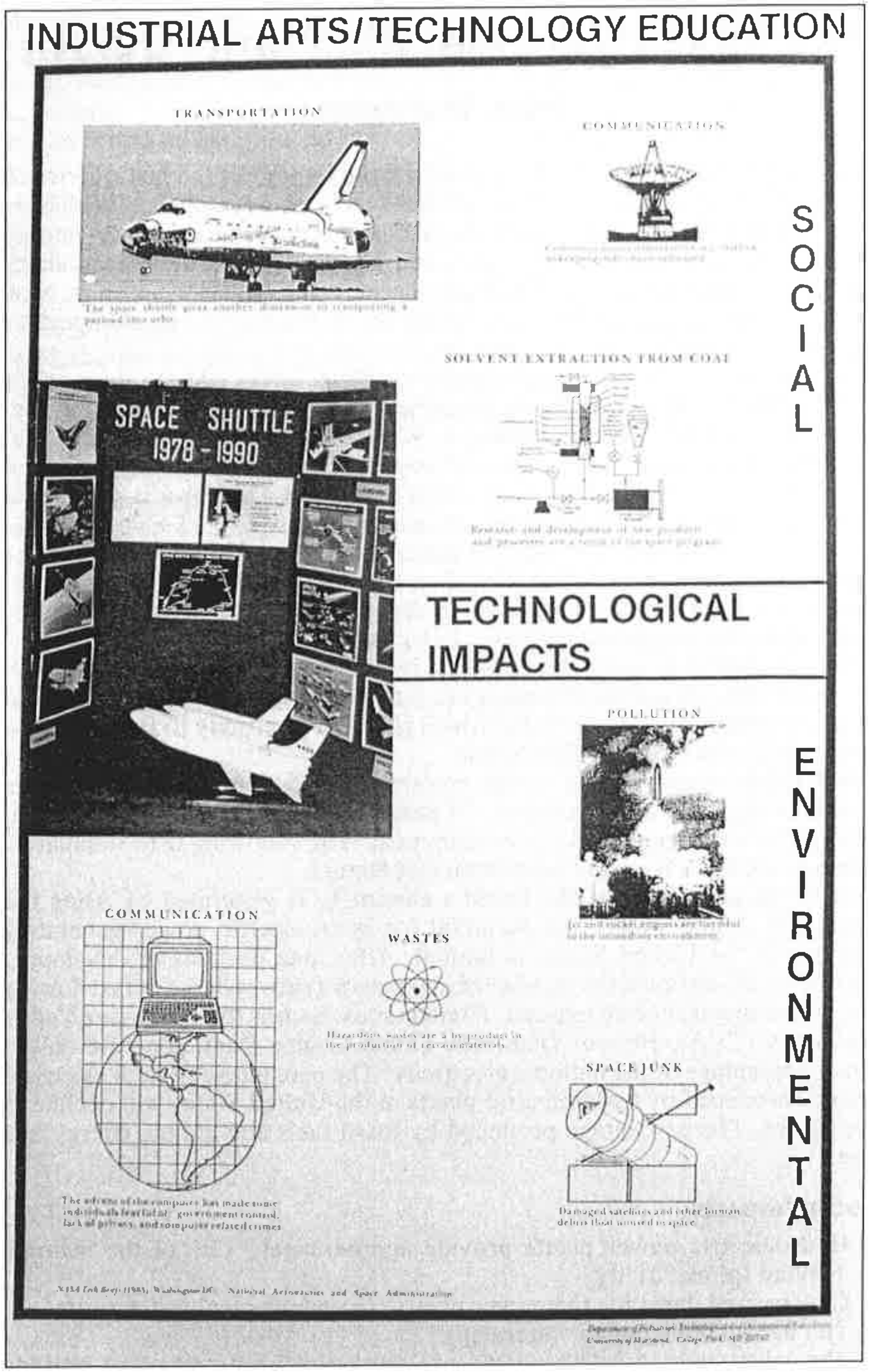
Social Impacts

- Development of advanced communication satellites.
- Promotion in the use and research of X-ray technology.
- Promotion of laser technology.
- Development of unique measuring devices.
- Enlargement in the development of composite materials.
- Development of advanced data processing systems.
- Development of medical equipment and "clean rooms."

- Research and development of robotics for industry.
- Wind analyses studies for safer building design.
- Research projects concerning the nation's defense.
- Disaster assessment via satellite use.
- Improvement of teaching aids for technicians and engineers.
- Research on improving the performance, efficiency, and environmental acceptability of general aviation.

Environmental Impacts

- Research and development of solar power.
- Research in new life-support systems.
- Promotion of external noise-reduction devices on planes.
- Nuclear energy research.
- Heat transfer research to improve efficiency in industry.
- Development of advanced oil-recovery systems.
- Development of noise-abatement equipment.
- Development of energy efficient protective coatings.
- Energy conservation devices for industrial motors.
- Development of unique firefighting equipment.
- Research on alternative fuels.
- Research on the use of aquatic plants for treatment and recycling of waste-water.
- Forest and rangeland management, crop forecasting, mineral exploration, and water evaluation via satellite.



The Space Shuttle

The First Hydroelectric Plant (U.S.A.)

John Walstrum

Hydroelectric power generation has a rich history. In the last quarter of the 19th century, there were many innovations in the development of electric power. The technology of converting mechanical energy to electrical energy reached an important starting point when Thomas Edison developed direct current generators in 1882. The Pearl Street steam electric station in New York City was an important beginning for one of the nation's most important industries—electric power production.

Twenty-six days after the opening of the Pearl Street station, the world's first hydroelectric power plant generated electricity for commercial use. Located on the Fox River in Appleton, Wisconsin, the station's first customers were two nearby paper mills and one residence. Within a few months, the station's two generators were supplying about 25 kilowatts of electric power to other small mills and residences.

Located on the river, the station had a waterwheel 42 inches in diameter operated under a head of 10 feet. The two Edison-type K direct current generators at the Appleton station initially provided electricity for incandescent lamps, the primary use of electricity in the late 19th century.

Direct current systems were limited by the fact that greater efficiency is obtained with alternating current over long distances. One such AC system began operating at Niagara Falls, which supplied electricity to Buffalo, New York, approximately 20 miles away.

Not unlike other forms of energy production, hydroelectric production has its advantages and disadvantages. Of particular note is the impact this technology has on society and the environment. The following lists summarize some of these societal and environmental factors.

Even though much of the world's electricity is generated by using the energy of falling water, the potential for hydroelectric power generating stations in the United States is limited. After nine decades of developing hydroelectric stations, the number of inexpensive sites on large or fast flowing rivers has already been exploited. Famous sites, such as the Tennessee Valley Authority (TVA), Hoover Dam, and Grand Coulee Dam, generate only a small percentage of the nation's electricity. The percentage of total electrical energy produced by hydroelectric plants in the United States will decline in the future. The percentage produced by fossil fuels and atomic energy will rise.

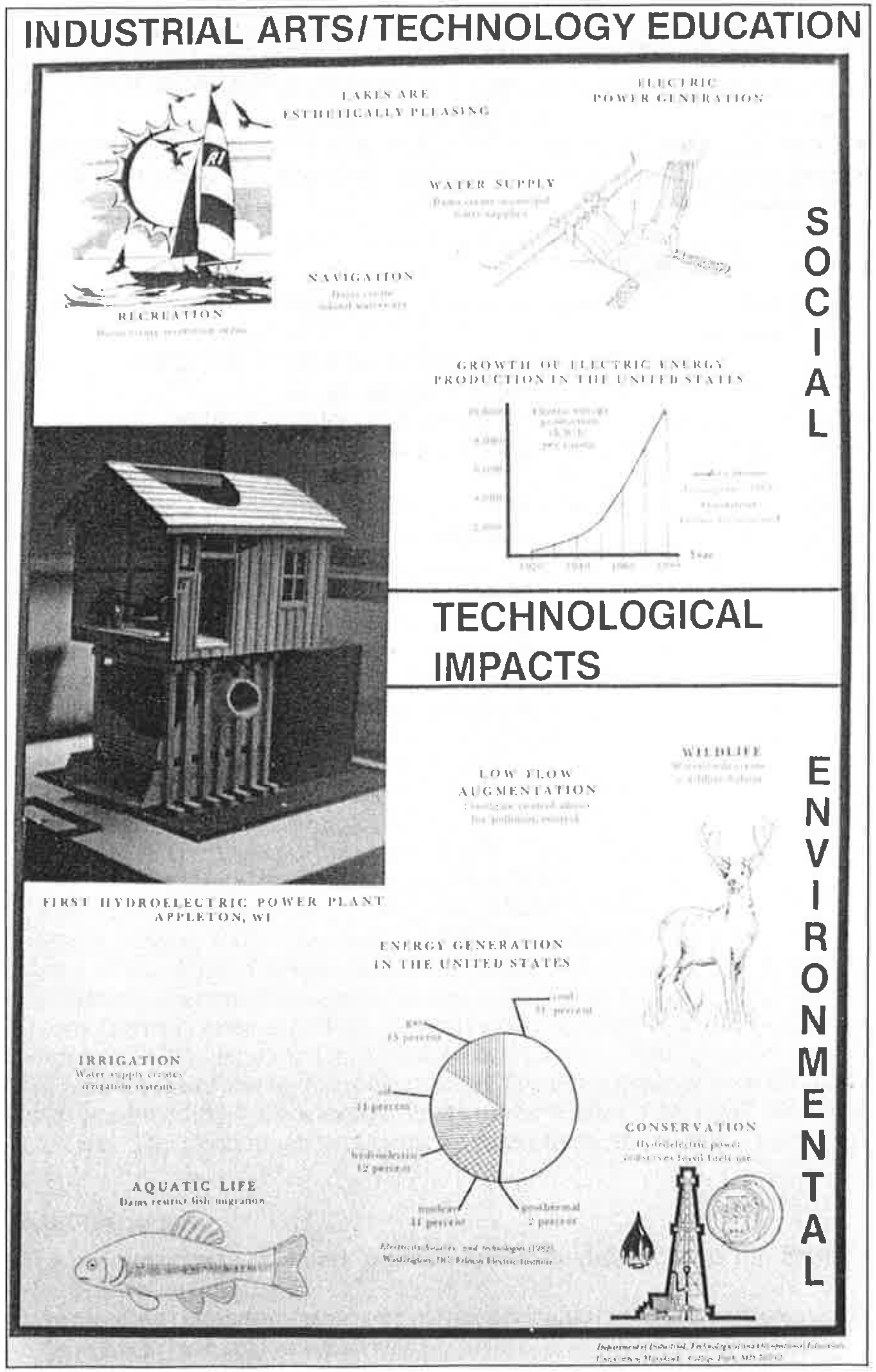
Social Impacts

- Hydroelectric power plants provide approximately 12% of the nation's demand for electricity.
- Constructed dams for the power plants create municipal water sources.
- The dams create inland waterways.
- The lakes created by the dams are aesthetically pleasing and provide recreation areas.

- Recreation resorts are frequently located along the lakes caused by damming for hydroelectric plants.
- An inexpensive form of electricity is developed through the hydroelectric process.
- Cities and towns grow up in close proximity to the hydroelectric plants.
- Hydroelectric power plants stimulate the growth of industries requiring extensive electricity in their operation.

Environmental Impacts

- Hydroelectric power generation conserves fossil fuel use and thus reduces air pollution.
- Hydroelectric generating plants do not require the disruption of the environment that is characteristic of coal mining.
- Watersheds created by the dams provide wildlife habitats.
- The dam floodgate control allows for improved water flood control for areas downstream.
- The dams create an obstacle to fish migration.
- The stored water of the hydroelectric plant provides for the irrigation of many acres of land in the dry areas.
- The potential for flooding downstream of the dam, in case of a major leak or break in the retaining unit, is a concern.
- The dangers and hazards of water sports, boating, and swimming are everpresent.
- The pollution of water sources by campers, boaters, and fishermen is a concern.



The First Hydroelectric Plant (USA)

POSTLUDE

The intent of this monograph was to provide examples by which the manipulative activity related to technological developments may be extended into the realm of mathematical, scientific, and social or environmental understanding.

What happens next? Perhaps, from the examples presented, the reader may want to pursue the underlying concept behind the examples illustrated and demonstrate, through actual practice, the direct connection and linkage between industrial arts/technology education activities and mathematics, science, society, and environment.

Additional materials from ITEA are available to help in the areas of:

- Project areas and development
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