From Sundials To Digital Clocks

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I. History

A. History of Major Events

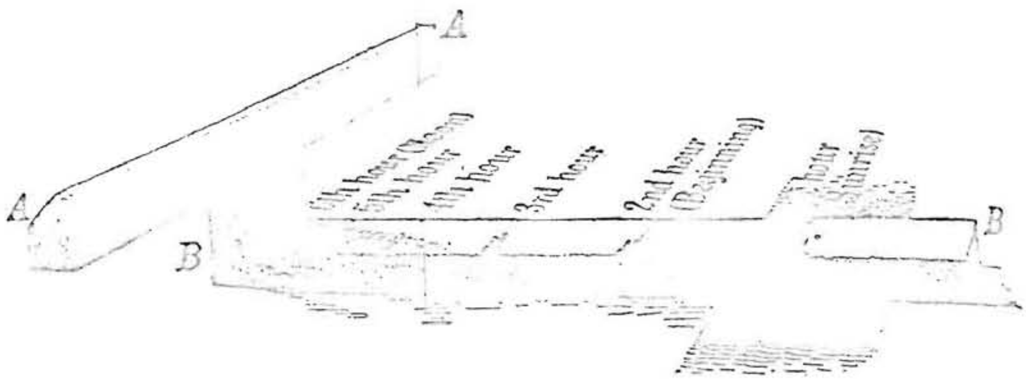
1. Incisions in Time

In man's earliest days, he decided that he needed something to distinguish parts of time. He knew of night and day, but he needed a greater amount of cuts in time for keeping track of things, such as when the best hunting could be done, etc.

During the night, man could not go into the terrible unknown, so he waited until the sun shone again. Then, during his daily hunt, he wanted to know ahead of time when he should find new shelter for the following night.

Very early, primitive man must have observed the shadows of the sun and the angle at which they slant. To a man of the north, shadows were longest and pointed westward in the morning. They were short and stubby at noon. Towards night the shadows became long again and swung around towards the east. Out of these observations, man evolved the idea of measuring time, and developed the sundial.

The sundial is based on the angles of the sun. We do not know what the first sundial looked like, but it probably was a stick in the ground with stones around it referring to the different major time periods of the day. But sundials



AN ANCIENT EGYPTIAN SUN CLOCK. *The shadow-casting cross-piece* (AA) *was turned toward the east in the morning and toward the west in the afternoon. The hour was indicated by the edge of the shadow on the arm* (BB). (*Drawing courtesy of the Oriental Institute, the University of Chicago*)

AN EIGHTEENTH-CENTURY BRASS SUNDIAL. (*The Metropolitan Museum of Art, gift of Mrs. Stephen D. Tucker, 1903*) only worked when the sun shone. How could man distinguish lengths of time during the night?

Priests in Babylonia and Egypt were active star and moon watchers. They believed that the sun, stars, planets and moon moved above the flat earth. The priests watched the heavens every evening and found patterns in their movement. They gave the stars and planets names. They could see these stars at a given time each night. They realized that as the seasons changed, the patterns of the sky changed also. They had no calendar yet, but could see differences in the heavens at different times. They also realized that the patterns went in a cycle.

One star, Sirius, or, the Dog Star, appeared in the western sky, but then vanished for many days at a time. Then, it reappeared in the eastern sky! But even stranger, the priests noticed that Sirius rose simultaneously with the sun! And immediately following this, the Nile River flooded! This boggled the priests.

They counted 365 sunrises until the next occurence of this miracle. They discovered that the patterns in the sky repeated after the flooding of the Nile.

365 is a very odd number. They decided to call their year 360 days like the moon year. They called the leftover five days "feast days." The year was invented over six thousand years ago.

Now they needed meetings to discuss and assemble this calendar. They also needed designated times to eat, sleep, work, and pray. So far they had had years, months, weeks, and days, and now, hours!

Until this point, all divisions in time were natural. But now, they ran out of natural time periods. They now had to make up their own incision.

Even before the sundial was invented, man knew a circle had 360 degrees. Days were divided into two parts, day and night. Each represented a half of a day. Half of 360 is 180. They asked themselves,"what goes into 180?" They concluded with 10, 9, or six. So a full day would have 20, 18, or 12 hours. Instead of the 24 hours we use today, they decided to use 12.

A year has 12 full moons. 12 goes into 360 and 180 evenly. All of these figures, you will notice, are intertwined with each other.

interesting but not directly needed for this report

But the priests gaced a problem: the only time days were divided perfectly into two symmetrical parts were the equinoxes; March 21, and September 21. Only on these two days would time be accurately correct. The priests knew this but they did not mend very much. Their discoveries and inventions were close enough for their needs.

2. Earliest Time-tellers

Some people though, were upset with the inaccuracies of sundials. In some places, the sun moved across faster or slower than in other places. Other types of sundials were tried. The Babylonian method kept better time. Sundials became more and more scientific.

People decided that the differences in the sun and the length of days had to do with the geography and the location of the sundial. Therefore, a different sundial was used for different locations. Lines of latitude helped in making sundials more accurate.

What about cloudy regions? What could they use when the sun was behind the methods for telling time without relying on natural phenomona.

The first mechanical clock was the clepsydra or water clock, first used about 1400 B.C.E. Water flowed slowly from one vessel to another. There were two types of water clocks: inflow and outflow. On the outflow method, water leaves the vessel and shows the increase of hours by moving down the vessel. On the inflow method, the water increases in the vessel and moves up the vessel showing the hours.

Sometimes, a notched rod was attached to a float on the water. The rod was engaged with gears attached to a dial which turned every hour shown by little hands.

Another clock was the fire clock--a candle that burned while the wax melted from one marking to another.

Finally, the hourglass was used. Sand from one vessel flowed slowly to another vessel in a certain length of time.

The clepsydra eventually reached Greece and Rome. The Romans started to use it about 150 B.C.E. They placed clepsydras in public places where everyone could see them, unlike Egypt, where only the high priests used them in temples. They were also used by the Roman court to see if a lawyers speech was too long.

Eventually, people found that they could not live with the inaccuracies of the clepsydra. Evaporation and rain made the clepsydra innaccurate.

The clepsydra was the direct ancestor of the later mechanical clocks. The water, falling in drops, could be the ticks of the later clocks. Weights were substituted for the water--they are both based on gravity.

In later mechanical clocks, cords that held the weights were wrapped around a drum which turned, so the weights descended.

In the first experiments with these newer clocks, the drum turned much too fast. They tried different methods for slowing it down, but all their ideas failed. The clocks lost up to two hours daily and would have to be reset every day, by a clepsydra.

Mechanical clocks were very rare and only the rich could afford them before the 1300's. They were only built for powerful churches and royalty.

The mechanical clock soon became fully automatic. People were amazed at things that moved without any manual assistence. But these weight clocks simply did not keep good time. At first, the clock is slow. But as the weights get closer to the ground, the speed starts to increase due to inertia and acceleration. The only way to stop inertia is to constantly interrupt the movement of the object, and then let it start again. This is so it does not get a chance to accelerate.

Clockmakers had to add something to the clock that would do this process of interrupting constantly. It was

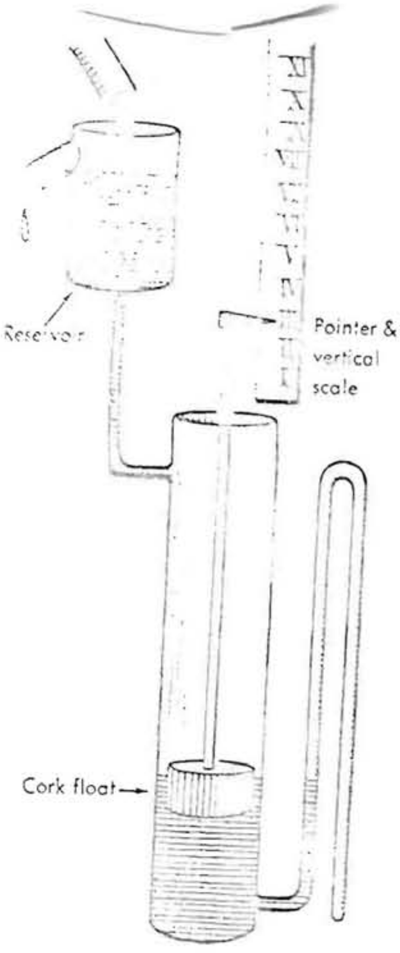
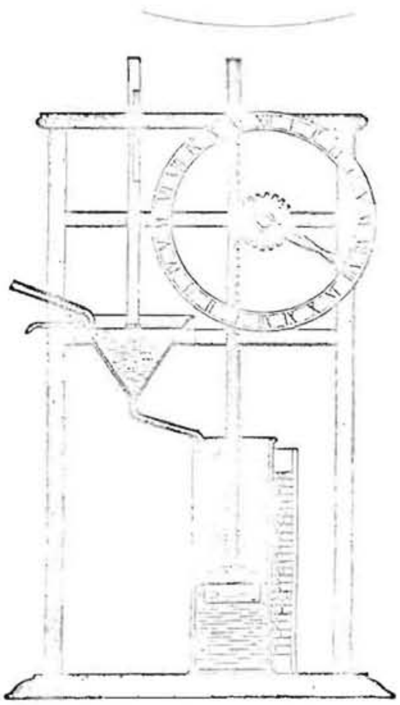
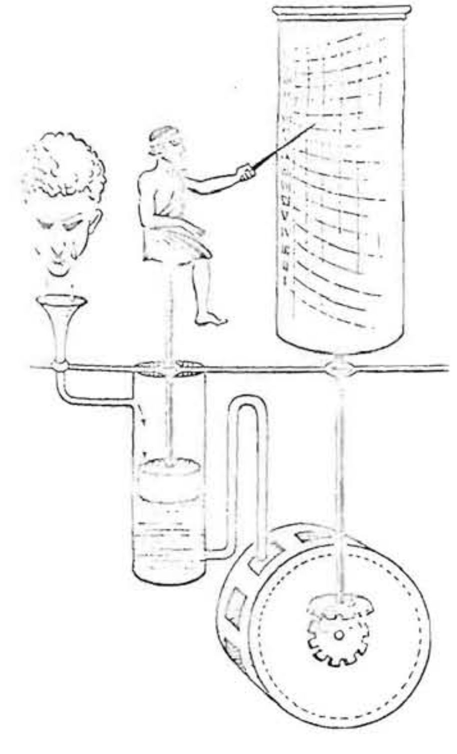


DIAGRAM OF A CLEPSYDRA. *In this device, water flowed from the reservoir, equipped with an overflow spout to maintain constant pressure, into the vessel below. The cork-float base of the pointer rose as the vessel filled and indicated the passing of hours on the vertical scale. The bent tube on the right acted as a siphon which emptied the vessel, making it possible for the water clock to begin another time-telling cycle automatically.*



A COMMON VARIETY OF CLEPSYDRA USED IN GREEK AND ROMAN TIMES. *The float stick in this water clock was equipped with teeth which meshed with a cog-wheel attached to a rotating pointer on the circular dial.*



THE WATER CLOCK OF CTESIBIUS, *invented about 250* B.C., *had water dropping like tears into a funnel from the eyes of a statue. A float mechanism raised another human figure with a pointer which indicated the hours on a vertical cylinder. The figure descended to the bottom of the column once every twenty-four hours by means of a siphon device at the base of the water vessel. In turn, the siphon outflow worked a waterwheel which, each day, rotated the cylinder very slowly, making one complete rotation in a year. The markings of the cylinder were ingeniously adapted to the varying lengths of the hours throughout the seasons. (Diagrammatic reconstruction by J. F. Horrabin)*

AN HOUR CANDLE, *the simplest form of the fire clock, and a* SANDGLASS the inaccuracies of the clepsydra. Evaporation and rain made the clepsydra innaccurate.

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Clockmakers had to add something to the clock that would do this process of interrupting constantly. It was known as a verge escapement. The verge escapement stopped the drum and gears for a split second, and then let it start again. It repeated this action the whole time the clock was running.

During the 1700's, the pendulum was added to the clock (see inventions), invented by Christiaan Huygens (see scientists). This was the first mechanism that gave each individual second to the clock.

Another breakthrough in clockmaking was the anchor escapement. A metal anchor was made to interrupt the escape wheel by alternately slipping a hooked shaped pallet between the wheel's teeth.

With these improvements came, besides the tick of the clock, the "sight of each second", by the pendulum. They divided their 60 minutes by 60 seconds. They used 60 for the same reasons that the Babylonians used their numbers: it was divisible by so many numbers--1, 2, 3, 4, 5, 6, 10, 12, 15, 20, 30, and 60.

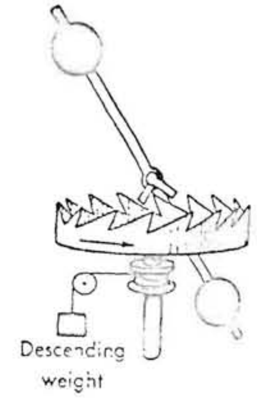
3. Other Problems

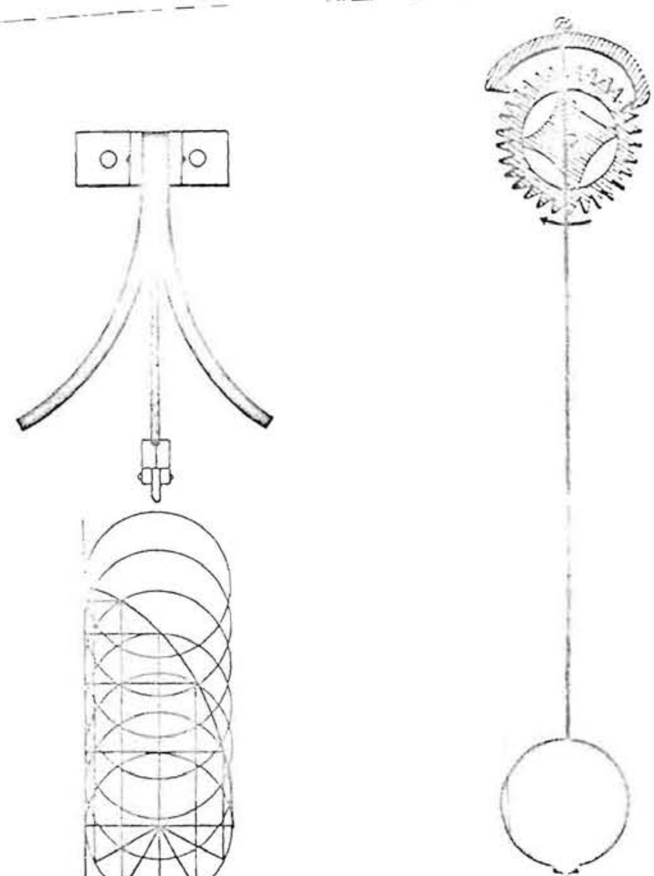
Now clocks were everywhere. All homes had them. A coiled spring replaced the weights of a clock, so clocks could be smaller. Watches came into being.

Good

There was still a problem. What ever happened to the equinoxes and uneven number of days in the year? How could a mechanical clock change with the seasons as the clepsydra could do? Variations on the clock and the sun were sometimes up to sixteen minutes. What they did was take an average

DIAGRAM OF A VERGE ESCAPEMENT





(*Left*) A CYCLOID. *Above the figure is a drawing of Huygens' cycloidal suspension. As the pendulum swung, the bob described a cycloid because the pendulum rod, flexible at the top, was forced to bend first one way, then the other, by curved "jaws."*

(*Right*) AN ANCHOR ESCAPEMENT AND PENDULUM of all the days of the year. So each clock would run uniformly as if each day were exactly 24 hours long.

Where it is one o'clock at night at a given place, somewhere else on earth, at the same time , it was one o'clock in the afternoon. What could be done? How could it be the same time at a different time? The people agreed there must be one point where the center of time was. All other places, depending upon how far away from this point they were, would have the same relative time. Greenwich, England was chosen for this point. They made 24 time zones--12 to the east and 12 to the west of Greenwich. Each zone was on a 15 degree longitudinal. And each time zone was separated by one hour.

After Franklin's discovery of electricity, everyone was experimenting with electricity. Alexander Bain was a Scottish clockmaker who made the first electrical clock in 1840 (see inventions).

B. Changes in Lifestyle

Time is what we need to exist. Without it, the universe would not be. The clock has helped man to determine time. With the development of the clock, people can record information on the specific time that an event takes place. We have specific times for working, playing, sleeping, and everything else we do:

"So I'll see you at 4:30."

"9:00 at your place."

With the growth, and near perfection of the clock, man can determine who won the race, how many minutes the Knicks have to strike back, or at what time the Sabbath comes.

In the distant future, maybe man will have a built-in body clock. Then conventional clocks will become obsolete. But until then, we can marvel at their beauty and how they aid our growing society.

C. Ecology

Man has polluted the air, land and water by using the oils that are needed in the making of plastics. Most new clocks and clock radios have a plastic cabinet.

Plastics are made of oil and other natural resources which are being used too carelessly. Also, electricity is used by most clocks now. The making of electricity pollutes the environment. Nuclear energy, which is sometimes used for clocks, gives off radiation. It disturbs nature by corroding land, and ruining water.

II. Inventions

A. Two Major Inventions & B. Scientific Principles

1. Pendulum

Galileo, an Italian astronomer, was once in church with the door open. As wind blew in the door, the chandelier on the ceiling swung back and forth. Distracting him from praying, he noticed that no matter how fast the chandelier swung, it used precisely the same amount of time. He checked this by noticing the rhythm of the chandelier with the rhythm of his pulse. When there was a little draft, it swung only a few inches. When a strong wind arose, it swung nearly a foot. But in every attempt to prove himself wrong, he found that it always took the same time to swing back and forth.

He discovered that the combination of acceleration and inertia was used. There was inertia as the chandelier started to swing. And then acceleration took over as it neared the bottom of the arc. Then inertia was used again as it went up to the other side of the arc.

His discovery became known as the "isochronism" of the pendulum. This idea could control escapement better than any verge could.

Galileo performed experiments with timepieces, using this idea, and developed the first accurate mechanical clock.

2. Electric Clock

Alexander Bain, a Scottish clockmaker, asked himself, "Why can't we make a battery driven clock?" (This was the only means for electricity). So he experimented with the idea.

"A magnet has two poles--north an d south. Opposite poles attract and similar poles repel. If I could place a permanent magnet at the end of the pendulum, and make it swing between two electromagnets so that the south pole on the magnet would go toward the south pole on the electromagnet. These would repel each other, so the north pole would go towards the electromagnet with its north pole facing the pendulum, and thus repel each other also!"

The pendulum would oscilate between the electromagnets as long as there was a device to turn the electromagnets on

and off at the correct time.
This principle of electric clocks is still in use today, though there have been many changes in the sources of electricity. Also, the movement has gone from the pendulum to the hands of the clock.

Between 1840 and 1852, Bain made many experiments with his new clock. He reversed the electromagnets with the permanent magnets. His first truly electrical clock, or Master Clock, had an electric pendulum, which, in its vibrations, produced an impulse which was transmitted to an ordinary clock to turn its hands. Bain has been credited with the invention of the electrical clock.

C. Newspaper Article

Henlein Makes Coiled Driven Timepiece

date

Peter Henlein, a Nuremberg locksmith, has invented a timepiece with a coiled spring instead of a pendulum. The clock is of normal size, but Henlein hopes to shrink his clock down to a much smaller size in the near future.

Henlein said,"The clock-watch is very versatile, for it does not rely on gravity. Another thing,I hope to make my invention more exotic. Maybe precious jewels, or even a music box built-in. And bells that tell the hour on the hour. The only drawback is that my clock-watch has to be wound by a separate key." (The first self-winding clock was made in 1750).

excellent

Henlein's invention will be on sale next week at only the finest jewelry stores throughout Nuremberg.

D. Futuristic Invention

In the year 2000, every house will have a clock (indicator) in every room. Each indicator will be run by the Central Time System Building in the heart of every city 500 miles apart. Each digital indicator absorbs wave impulses sent out by the C.T.S. The system is run by one pendulum travelling perpendicular through two beams of light. When the beam of light is broken, it sends waves through the air to all the indicators within a 500 mile radius.

how does the pendulum travel
I don't understand

The waves would take too long to go to a house 500 miles away, when at the same time, waves are going to a house 3 miles away. So, the waves will travel at different speeds and frequencies. A C.T.S. serviceman will come and set up an antenna to attract the frequency that you need. No one will have the wrong time when travelling, because you can always buy "wrist indicators" which have an automatic scanning device to pick up the correct frequencies whether you are one or 500 miles away from the nearest C.T.S. building. Time will be perfect!!

E. Fiction Story

Dorris Dorfman, a model, just come home from her father's house, a 25 minute drive. She got home to realize that she forgot her purse at her father's home. She drove back at 8:45 and found her father dead with blood stains all over him.

She immediately went into a panic, but calming down, she called the police.

The police came, looked around the house officially. They took some fingerprints, and then said,"This must be the time of the murder--7:45. In the scuffle, Mr. Dorfman must have tripped and disconnected the clock. Hmm."

"No, I was here at 7:45!" Dorris interrupted,"everything was fine! I went home, and noticed that I left my purse here, so I--"

"That's enough, ma'am."

Just then, a knock came at the door. It was a new next door neighbor, Mr. Lerner. "What's goin' on here? Can't a guy watch some TV in pri--"

"What's your name, sir?"

"Samuel H. Lerner, at your service, officer," he said seriously.

"Hmm, that name sounds familiar," said the head officer to himself. Just then, the rookie cop dropped the clock and just about every chance they had for catching the murderer.

"What happened, officer Butterman?" asked the senior officer.

"I don't know, chief", he yelled back,"it just fell. Don't expect me to--"

Good imagination & humor

"Wait a minute, what did you say your name--yes! Samuel Harvey Lerner! I read about you escaping from the mental institution in Watertown. You impersonated famous killers of the past. Lock 'im up!", said the senior officer, proudly.

"But how can you be sure, chief?"

"Look at the clock--7:45, upside down, as it fell on the floor. That's SHL--Lerner's initials!-- He was impersonating the notorious killer who always left his initials hidden somewhere after the murder--Simon Ethan Xavier: S.E.X.!"

III. Scientists

A. History of Life

B. History of Inventions

C. Problems Faced

D. Accuracy of Work

1. Christiaan Huygens

Christiaan Hu ygens was born at The Hague in Holland. He was a well educated Dutchman from a prominent family. From 1645 to 1647 he studied law and mathematics at the University of Leiden. From 1647 to 1649 he studied law at Collegium Arausiacum at Breda. Then, not electing a career, he lived at home until 1666, where he studied nature for sixteen years.

At first he concentrated on mathematics: quadratures and cubatures, and algebraic problems. In 1655 he discovered the rings of Saturn. Then, in 1656 he invented the pendulam clock. In 1569 he elaborated on the study of centrifigal force.

Then, in 1664, he accpeted a job at the Academy in Paris. His stay lasted until 1681, when he went home because of illness.

In his last years he wrote books, made clocks and conducted many experiments. He died in 1695.

In 1659, In a study on the basic pendulum, Huygens derived a relationship between the period and the time of free-fall from rest along the length of the pendulum. His equation for this was $T = 2\pi\sqrt{l/g}$

Another discovery was 'The shorter the pendulum, the faster it will swing back and forth.' But all this depends on the curve that the pendulum swings in. With these two scientific laws in mind he went to work to produce an accurate pendulum clock. Years past and the wrold lost hope for an accurate time piéce. Then finally, in 1657, he come corward with the first pendulum clock. He developed seconds on the clock because of the tick of the pendulum. There was only one problem -- the pendulum could not keep time on a ship because it had to be on stable ground to operate correctly. To please every sailor on earth, he devised a clock that was much like the one of Peter Henlein. It relied on a coiled spring. Christiaan Huygens contributed much to the clock, and should be more famous than he is today.

The only obstacle Christiaan Huygens had to overcome was his illness that plagued him for months at a time.

2. Galileo

Galileo was born in 1564 in Italy. He made the first practical use of the telescope. He also discovered the law of falling bodies. He is also credited with the invention of a hydrostatic balance for finding the specific gravity of objects. He improved telescopes and discovered the law of the pendulum.

As a child, Galileo was a good musician and showed a talent for building. He was also a good artist.

He went to school to study medicine and philosophy at the University of Pisa. At age 20, after the discovery of the law of the pendulum, he suggested to use the pendulum to time the pulses of medical patients.

He left the University because of financial problems in 1585. He decided to enter the field of mathematics. But then, he returned to the University at the age of 25, and discovered the law of falling bodies. He was ridiculed about his idea, and was forced to leave the University.

Galileo taught for the next 18 years and then became interested in astronomy. He observed the moon, found 4 of Jupiter's moons, discovered Saturn, and discovered the phases of Venus and Mars.

The church court was shocked by his beliefs and confined him to his home indefinately. Galileo wrote books until his death in 1642.

He will always be respected as one of the greatest scientists that ever lived.

E. Specialists

I would consider the specialists in the area of clocks, those men who discovered the physical laws pertaining to the mechanisms used to measure time.

Some of the most famous of these men are: Christiaan Huygens, Henry DeVick, Alexander Bain, Daniel Quare, and Galileo. These men are usually called physicists or scientists.

F. Letter To A Friend

Dear James,

I have been doing what you suggested about the cows. It's working! But the real reason I'm writing you is to tell you about my new invention. You have probably heard about it in the paper. I have invented an <u>electric</u> clock using a magnetic bob and two electromagnets!

Last week I figured it out. I knew about the new invention of a battery, so I tried to harness it on to a clock. It worked! Now the pendulum can go without winding everyday.

I plan on making a formal exhibit at the museum in Glasgow, the day after tomorrow. Hope to see you there! excellent

Hopefully,

Alexander (Bain)

IV. Energy Terms

A. Definitions

1. Friction--The rubbing of one body against another.
2. Inertia--The tendency of matter to remain at rest, if at rest.
3. Transistor--A minute electronic device which controls current flow, without employing a vacuum.
4. Electromagnet--A core of magnetizable substance, placed within a coil or helix of wire, through which an electric current is passed.
5. Technology--The science or study of practical or industrial arts.

Short but to the point excellent

6. Frequency--The number of vibrations or cycles per unit of time.

B. Relations

1. Friction is used to stop a pendulum from swinging too far.
2. Inertia is used to keep a pendulum swinging when ascending up the arc.
3. A transistor is used in electrical clocks to control the flow of electricity excellent
4. Electromagnets were used in the first electrical clocks.
5. Technology is needed to make, put together, and use all the different parts of a clock.
6. Frequencies are used in digital clocks for the process of the counting off of the seconds.

C. Five New Words

1. Definitions

1. Pendulum--A body so suspended from or supported at a fixed point as to swing freely to and fro under the combined forces of gravity and momentum.
2. Gear--In mechanics, a system of two or more toothed wheels meshed together so that the motion of one is passed on to the others.
3. Weight--Any block or mass of material used for it's heaviness
4. Escapement--The part in a clock or watch that controls the speed and regularity of the balance wheel or pendulam of a clock.

5. Clepsydra--A device for measuring time by marking the gradual flow of liquid through a small opening.

2. Relations

1. The pendulum was used in the first electric clock, and was invented by Christiaan Huygens for the clock.
2. Gears were and are used in clocks to transfer the source of movement.
3. Weights were used in the first pendulum clocks.
4. The escapement controls the speed at which the weights fall.
5. The clepsydra was the first mechanical clock.