Measuring Time Through the Ages

A. Fill in the Blanks

1. A sundial measures time using the shadow cast by a central pointer called a _____.
2. The regular swing of a _____ was the key to creating the first highly accurate mechanical clocks.
3. Modern digital watches and clocks rely on the vibrations of a _____ crystal.
4. The most precise timekeeping devices ever created are _____ clocks.
5. The mechanism in a mechanical clock that controls the release of energy from the spring or weight is called the _____.

B. Match the Following;

Match the timekeeping device or concept in Column A with its correct description or principle in Column B.

Column A	Column B
1. Sundial	A. Uses the controlled flow of a liquid to measure time intervals.
2. Clepsydra	B. Relies on the piezoelectric effect of a vibrating crystal.
3. Pendulum Clock	C. The most precise clock; uses the frequency of atomic transitions.
4. Quartz Clock	D. Uses the position of a shadow cast by the sun.
5. Atomic Clock	E. A mechanism that translates continuous force into periodic ticks.
6. Escapement	F. Uses the regular, gravity-driven swing of a weight to keep time.

C. Practice Problems

Answer the following questions in more detail. Show your work for any calculations.

1. Explain the basic scientific principle behind a water clock (clepsydra).

2. Why was the invention of the pendulum clock by Christiaan Huygens in the 17th century such a significant improvement over earlier clocks?
3. List two advantages and two disadvantages of an hourglass compared to a sundial.
    - Advantage 1: _____
    - Advantage 2: _____
    - Disadvantage 1: _____
    - Disadvantage 2: _____
4. What is the "escapement mechanism" in a mechanical clock, and why is it essential?
5. What is the scientific phenomenon that allows a quartz watch to keep time so accurately?
6. List these timekeeping devices in chronological order, from oldest to newest: Atomic Clock, Pendulum Clock, Sundial, Quartz Clock
7. A simple candle clock is marked to show that every inch that burns represents one hour. If the candle is 8 inches long, how long can it measure time for?
8. Why are atomic clocks considered the "gold standard" of timekeeping today?
9. What is the difference between how a sundial measures time and how an hourglass measures time?
10. If a mechanical clock gains 2 minutes every day, how many minutes fast will it be after two weeks?

D. Warm-up Questions

Answer the following questions with a brief sentence or two.

1. What is the most basic way early humans could tell it was daytime or nighttime?
2. Name one ancient device used for measuring time.
3. What is the main weakness of using a sundial to tell time?
4. How many minutes are in one hour?
5. What natural cycle defines one year on Earth?

E. Challenge Questions

These questions require critical thinking and application of scientific principles.

1. Galileo supposedly realized the principle of the pendulum by watching a chandelier swing in a cathedral. He noticed that each swing took the same amount of time, regardless of how wide the swing was. How could you design a simple experiment using a string and a weight to test this principle of isochronism?
2. Imagine you are on a planet where the rotation is very irregular, making the length of a "day" unpredictable. However, the planet has a moon that orbits with extreme regularity. How could an advanced civilization on this planet create a reliable system for measuring time?

3. The modern scientific definition of a second is based on the vibrations of a cesium-133 atom, not on the Earth's rotation. Why do you think scientists preferred an atomic standard over an astronomical one? (Hint: Think about consistency).
4. A pendulum clock that is perfectly accurate in London is moved to the top of Mount Everest, where gravity is slightly weaker. Will the clock run faster, slower, or at the same speed? Explain your reasoning.
5. GPS satellites orbit the Earth at very high speeds and are in a weaker gravitational field. Both of these factors, according to Einstein's theory of relativity, affect time. Why is it crucial for the clocks on GPS satellites to be constantly adjusted to match time on Earth?

F. Word Problems & Application

1. An ancient Roman clepsydra is designed to let 200 mL of water flow out every 30 minutes. If the main basin holds 1,000 mL of water, how long can it measure time before it needs to be refilled?
2. A sailor uses a 30-minute hourglass to time his 4-hour watch duty. How many times must he flip the hourglass to complete his entire watch?
3. Our modern calendar adds a leap day every 4 years because a year is not exactly 365 days long. If the Earth's revolution around the sun takes approximately 365.25 days, how many full days "off" would our calendar be after 100 years without leap years?
4. A high-end quartz watch is accurate to within +/- 10 seconds per year. An older mechanical watch is accurate to within +/- 5 minutes per month. Which clock is more accurate, and by how much over the course of one year?
5. The gnomon (the part that casts the shadow) on a sundial is broken. At noon, a 1-meter tall stick placed vertically in the ground casts a shadow that is 0.5 meters long. At 3 PM, the same stick casts a shadow that is 1.5 meters long. Could you use this information to create a temporary time-telling device? Explain how.

G. True or False

1. A water clock would work just as well in the freezing arctic as it would in a temperate climate. _____
2. The time it takes for a pendulum to complete one swing depends primarily on its weight. _____
3. A year is defined as the time it takes for the Moon to orbit the Earth. _____
4. An hourglass can be used to measure any length of time you want. _____
5. The invention of the mechanical clock made it possible to know the time at night and on cloudy days. _____