## Passage I

An experiment was carried out to determine the effect of temperature on the heart rate of frogs. In the experiment, 100 frogs were removed from a large 25°C enclosure and separated randomly into four equal groups: A, B, C, and D. Each group was maintained in a separate container at a different constant temperature: Group A at 5°C; Group B at 15°C; Group C at 25°C; and Group D at 35°C. All other conditions, such as the size, type, age, and number of the frogs, as well as the size of the container and the amount of light, were the same for all groups of frogs.

## Passage II

Sodium chloride (table salt) is a crystalline solid made up of sodium ions ($Na^+$) and chloride ions ($Cl^-$). Ions are atoms that are electrically charged. When sodium chloride is dissolved in water, it separates into its ions. The sodium ions and chloride ions are released from their positions in the crystal pattern, and they move about freely. Some substances, such as sugar, do not ionize when dissolved in water. These substances are called non-electrolytes. When substances react with water to form ions, they are said to be ionized. The charged ions in the water are responsible for the conduction of electricity. Substances that conduct an electrical current when dissolved are called electrolytes. Substances that do not conduct an electrical current are called non-electrolytes.

To study the electrical conductivity of sodium chloride, an apparatus that measures the ability of substances to conduct electricity was used.

### *Experiment 1*

Solid sodium chloride was tested and found to be a non-conductor. Pure water was also tested and found to be a non-conductor. When a teaspoon of sodium chloride was added to 50 mL of water, the solution was found to be a good conductor of electricity. Sugar did not conduct electricity as a solid or when dissolved in water.

### *Experiment 2*

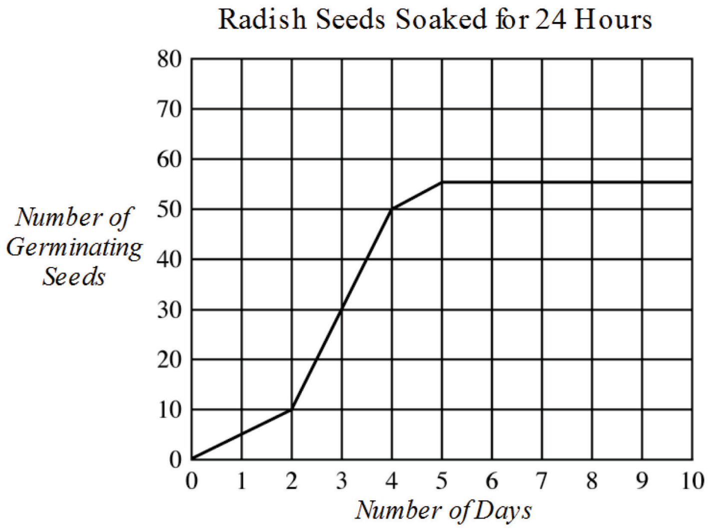
When a few crystals of sodium chloride were added to 50 mL of water, the solution showed a weak conduction of electricity. As additional sodium chloride was added, the ability of the solution to conduct electricity increased. After a certain point, adding more sodium chloride to the solution did not change the conduction of electricity.

## Passage III

Germination is the beginning of the growth of a seed after a period of inactivity. The following experiments were designed to compare the amount of time it takes for seeds of different vegetables to germinate.

### *Experiment 1*

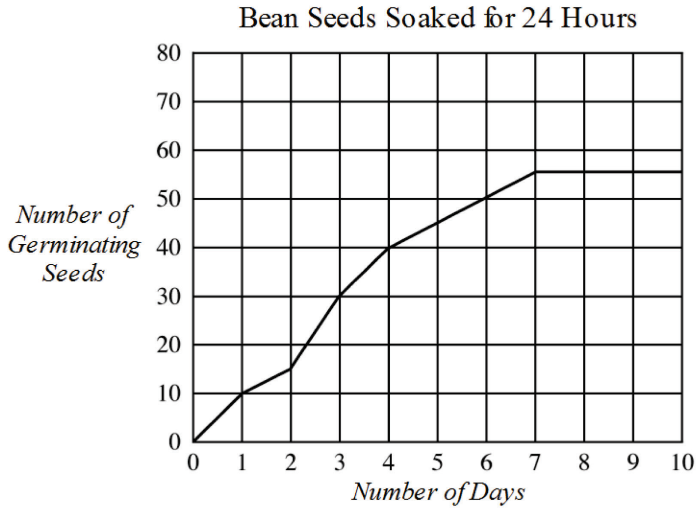
Radish seeds were soaked in water for 24 hours and then planted and kept at 25°C for 10 days. Each day the experimenters counted the total number of seeds that had germinated. The results are shown in Graph 1.



Graph 1

### *Experiment 2*

Bean seeds were soaked in water for 24 hours and then planted and kept at 25°C for 10 days. Each day the experimenters counted the total number of seeds that had germinated. The results are shown in Graph 2.



Graph 2

## Passage IV

When one end of a cord under tension is disturbed, the displacement moves down the cord in the form of a *transverse wave.* If the other end of the cord is fixed, the wave is reflected and moves back in the opposite direction encountering other waves moving toward the fixed point. Certain frequencies produce *standing waves*, which are characterized by motionless nodes separating oscillating segments of cord (see Figure 1). For a cord of a given length and density, only certain frequencies will produce standing waves.

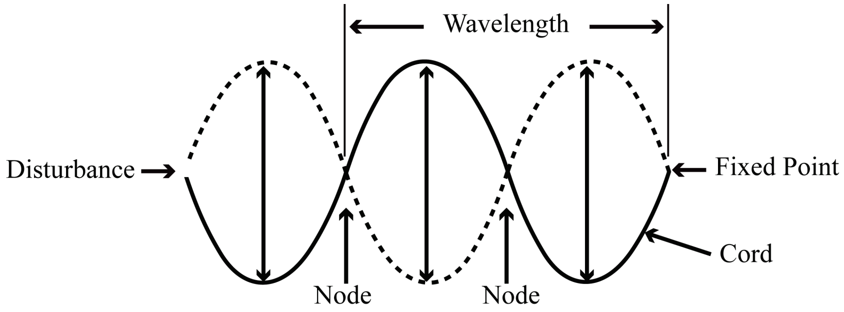


Figure 1

A group of students performed three investigations using the setup shown in Figure 2. One end of a cord was fastened to the reciprocating blade of a jig saw and the other was hung over a pulley and attached to a block. A stroboscope measured the frequency of the vibrations in the cord. The length of the cord from the jig saw blade to the pulley was 2 meters, and the length of the standing waves was measured using the meter stick attached to the lab table.

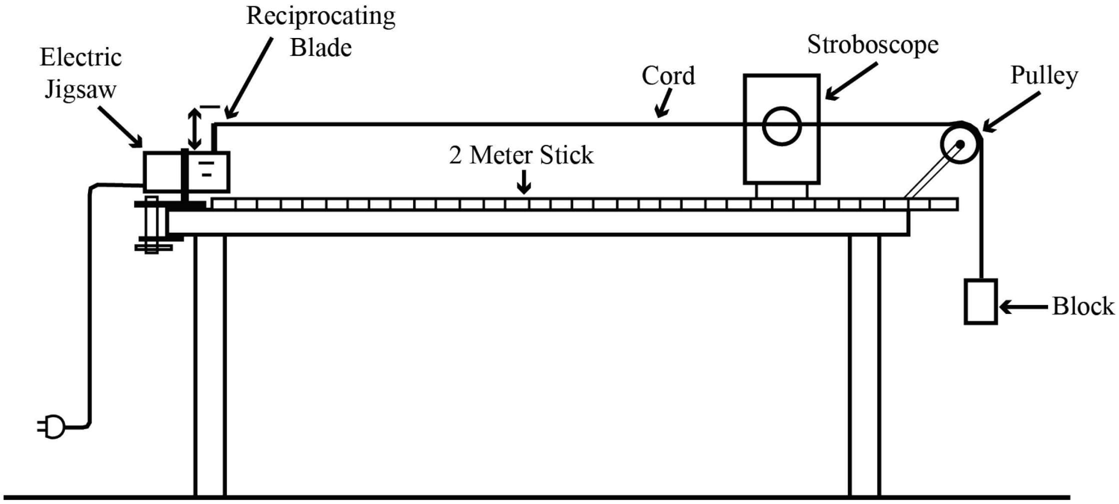


Figure 2

### *Experiment 1*

The students conducted five trials using the same cord of density 0.0076 kilograms per meter and block while adjusting the frequency to produce standing waves at pre-determined wavelengths. The cord tension in all five trials was 2 newtons. They recorded the length and frequency of the waves (see Table 1).

| Table 1 | | |
|---|---|---|
| Trial | Wavelength (meters) | Frequency (hertz) |
| 1 | 4 | 4.05 |
| 2 | 2 | 8.05 |
| 3 | 1.3 | 12.33 |
| 4 | 1 | 16.3 |
| 5 | 0.8 | 20.25 |

### *Experiment 2*

Using the same cord, the students decreased the tension to 1 newton and conducted five more trials, adjusting the frequency to produce standing waves at pre-determined wavelengths (see Table 2).

| Table 2 | | |
|---|---|---|
| Trial | Wavelength (meters) | Frequency (hertz) |
| 1 | 4 | 2.87 |
| 2 | 2 | 5.74 |
| 3 | 1.3 | 8.62 |
| 4 | 1 | 11.47 |
| 5 | 0.8 | 14.34 |

### *Experiment 3*

The students kept the tension at 1 newton but used five different cords of different densities. Again, they conducted five trials, adjusting the frequency to produce standing waves at pre-determined wavelengths and then recording the lengths of the waves and the frequencies (see Table 3).

| Table 3 | | | |
|---|---|---|---|
| Trial | Cord Density (kilogram per meter) | Wavelength (meters) | Frequency (hertz) |
| 1 | 0.0076 | 4 | 2.87 |
| 2 | 0.011 | 2 | 4.77 |
| 3 | 0.018 | 1.3 | 5.60 |
| 4 | 0.025 | 1 | 6.32 |
| 5 | 0.032 | 0.8 | 6.99 |

## Passage V

A projectile is any object that is thrown or otherwise projected into the air. Once in the air, the only force assumed to be acting on the projectile is gravity. The effect of air resistance is assumed to be negligible. The path followed by a projectile is the trajectory.

A student performs a series of experiments using a spring launch (see Figure 3).

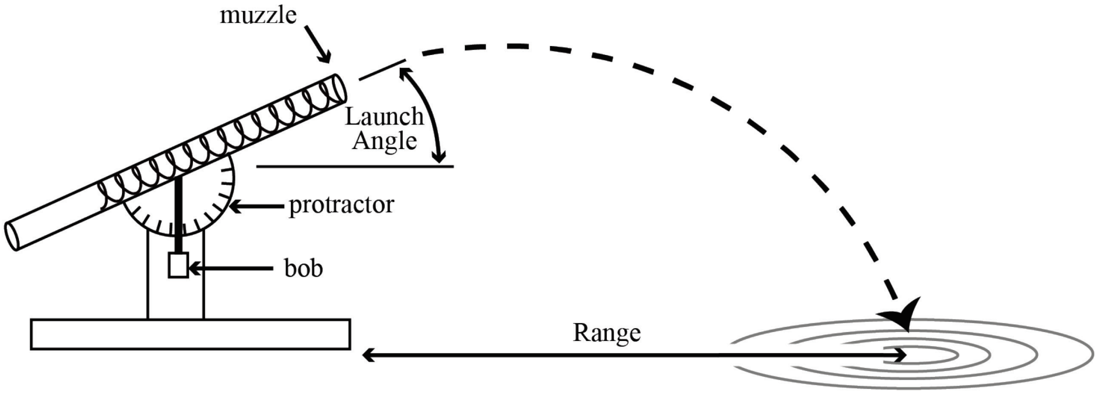


Figure 3

### *Experiment 1*

The student launched the projectile at various angles, using the protractor to measure the angle degree, while the muzzle velocity of the projectile was held constant at 10.0 meters per second (m/s). Both the spring launch and the point of impact of the projectile were at ground level. The horizontal distance covered, or range, was measured. The results are given in Table 4.

Table 4

| Launch Angle (degrees above horizontal) | Range (m) |
|---|---|
| 10° | 3.5 |
| 20° | 6.6 |
| 30° | 8.8 |
| 45° | 10.2 |
| 60° | 8.8 |
| 70° | 6.6 |
| 80° | 3.5 |

### *Experiment 2*

In a second experiment, the student varied the muzzle velocity while keeping the angle of launch constant at 45°. The results are given in Table 5.

Table 5

| Muzzle Velocity (m/s) | Range (m) |
|---|---|
| 10 | 10.2 |
| 15 | 23.0 |
| 20 | 40.8 |
| 25 | 63.8 |

### *Experiment 3*

The student launched projectiles with the spring launch positioned at different heights above the ground while keeping the angle of launch at 45° and the muzzle velocity at 10 m/s. The range was measured horizontally from a point at ground level directly below the spring launch to the point of impact at ground level. The results are given in Table 6.

Table 6

| Height above ground (m) | Range (m) |
|---|---|
| 1 | 11.1 |
| 2 | 11.9 |
| 3 | 12.6 |
| 4 | 13.3 |

## Passage VI

The energy, as measured in joules (J), that an object has by virtue of its position with respect to nearby masses is called *gravitational potential energy* (GPE), while energy of motion is called *kinetic energy* (KE). An object falling toward the earth has both gravitational potential energy and kinetic energy. An object's *total mechanical energy* (TME) is the sum of GPE and KE. Objects in motion lose total mechanical energy because of friction.

### *Experiment 1*

A steel marble weighing 1 kilogram (kg) was placed on a track and allowed to roll as shown in Figure 4. A series of photogates (timing devices useful for measuring events which happen faster than can be timed by hand) were used to determine the speed of the marble at various positions on the track. The speed of the marble was used to calculate its kinetic energy. The results are given in Table 7.

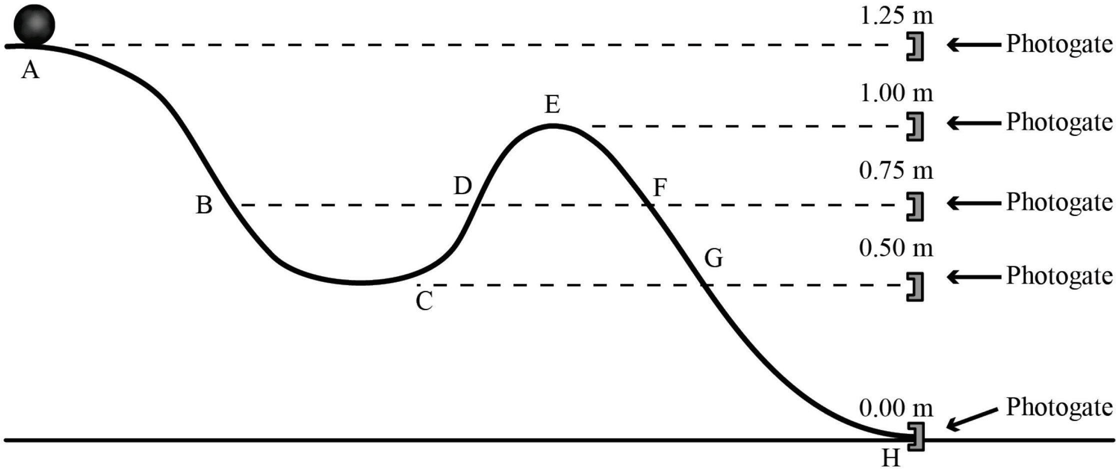


Figure 4

| Table 7 | | | | |
|---|---|---|---|---|
| | Height (m) | GPE (J) | KE (J) | TME (J) |
| A | 1.25 | 12.25 | 0.0 | 12.25 |
| B | 0.75 | 7.35 | 4.8 | 12.15 |
| C | 0.50 | 4.90 | 7.2 | 12.10 |
| D | 0.75 | 7.35 | 4.5 | 11.85 |
| E | 1.00 | 9.80 | 1.9 | 11.70 |
| F | 0.75 | 7.35 | 4.3 | 11.65 |
| G | 0.50 | 4.90 | 7.2 | 12.10 |
| H | 0.00 | 0.00 | 11.5 | 11.50 |

### *Experiment 2*

Students constructed a pendulum by hanging a 1 kg mass ("pendulum bob") from the end of a cord 2 meters long. The bob was pulled to the side and released at a height of 0.2 meters. The students allowed the bob to swing through ten cycles before stopping its motion. Using a photogate and timer, the students determined the speed of the bob at five selected points along its path for both the first (Figure 5) and tenth swings.

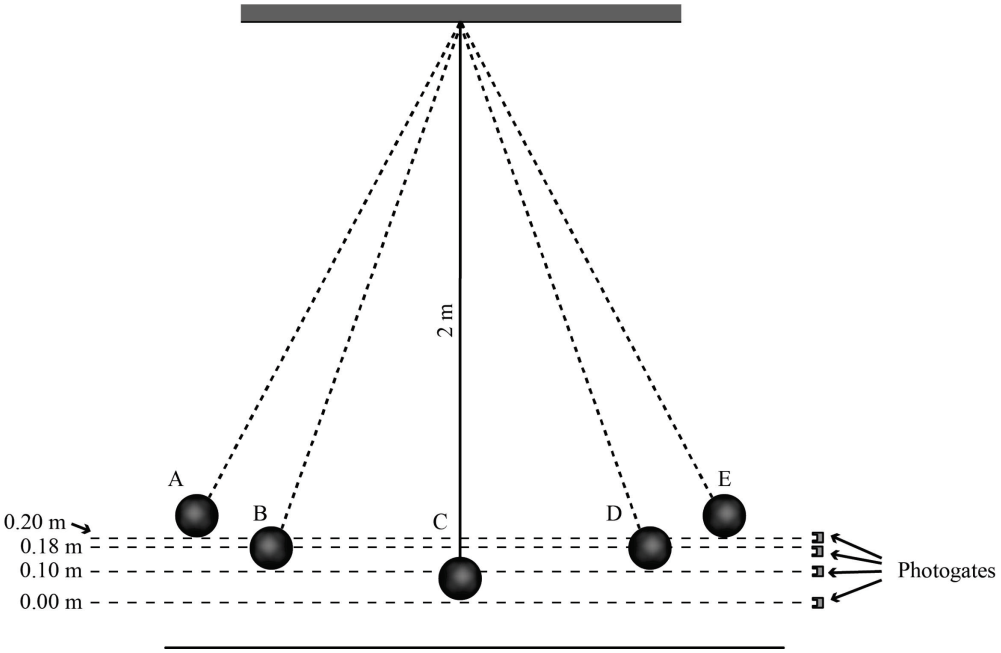


Figure 5

Note: Points A and E are the end points of the swing of the pendulum where height (*h*) has its maximum value. As the pendulum continues to swing, *h* values for points A and E will decrease because of frictional effects.

| Table 8 | | | | |
|---|---|---|---|---|
| **First Swing of Pendulum** | | | | |
| | Height (m) | GPE (J) | KE (J) | TME (J) |
| A | 0.2 | 1.96 | 0.00 | 1.96 |
| B | 0.1 | 0.98 | 0.98 | 1.96 |
| C | 0.0 | 0.00 | 1.96 | 1.96 |
| D | 0.1 | 0.98 | 0.98 | 1.96 |
| E | 0.2 | 1.96 | 0.00 | 1.96 |
| **Tenth Swing of Pendulum** | | | | |
| | Height (m) | GPE (J) | KE (J) | TME (J) |
| A | 0.18 | 1.76 | 0.00 | 1.76 |
| B | 0.10 | 0.98 | 0.78 | 1.76 |
| C | 0.00 | 0.00 | 1.76 | 1.76 |
| D | 0.10 | 0.98 | 0.78 | 1.76 |
| E | 0.18 | 1.76 | 0.00 | 1.76 |

## Passage VII

A Hertzsprung-Russell (H-R) diagram is used to plot the luminosity (or true brightness) of a star versus its surface temperature. Luminosity is typically expressed in relation to the luminosity of the Sun (solar units). For example, a star with a luminosity of 2 solar units would emit twice as much energy as does our Sun. Surface temperatures of stars are expressed in kelvins (K).

Stars plotted on an H-R diagram generally fall into four main regions: main sequence, red giants, supergiants, and white dwarfs. All main sequence stars (which comprise approximately 90% of all stars) undergo hydrogen fusion in their cores. The heat and pressure created by fusion prevent gravitational forces acting inward from crushing the star.

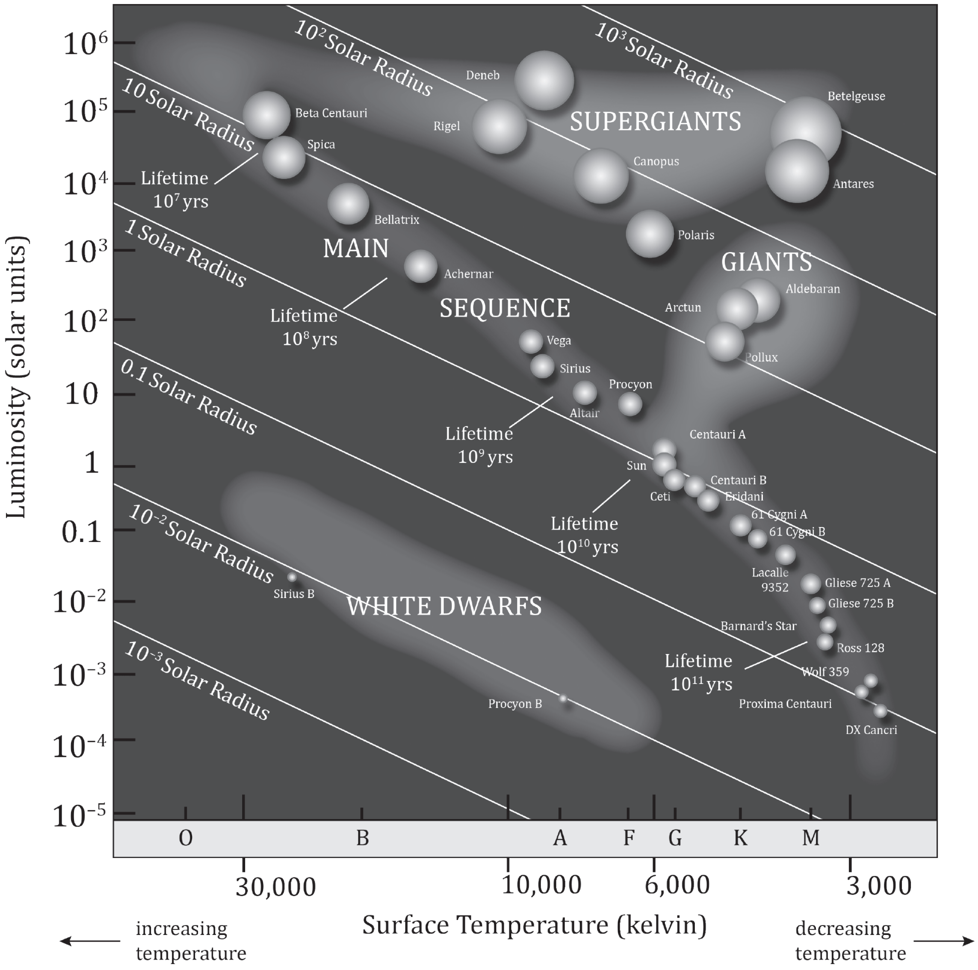


Figure 6

The evolutionary fate of main sequence stars depends on their mass. When mid-mass main sequence stars, such as the Sun, run out of hydrogen in their cores, other fusion reactions occur; and the stars expand to become red giants. When fusion stops altogether, after a brief transitory phase called a planetary nebula, the cores of mid-size stars remain as planet-sized, very hot objects called white dwarfs. From birth to death, mid-mass stars exist on the order of billions of years.

Main sequence stars with much more mass than the Sun appear in the upper left of the H-R diagram. When hydrogen fusion ceases in the cores of these rare stars, other fusion reactions support the star, and they evolve into red supergiants. Eventually, when fusion reactions in their cores cease altogether, gravity begins to crush the stars and runaway thermonuclear reactions cause the outer layers to explode in an event called a supernova. The spent cores of these stars become either neutron stars or black holes. Neither neutron stars nor black holes appear on the H-R diagram. Large mass stars exist for the shortest amount of time—just millions of years—because they burn through their fuel quickly.

Finally, the majority of all main sequence stars have much less mass than the Sun. Fusion reactions in their cores take place at a much slower rate. In fact, these stars will remain on the main sequence for trillions of years. Since the universe is only 13.8 billion years old, not a single low-mass star has yet to evolve off the main sequence.

The diagram below shows the Sun's future evolutionary journey on the H-R diagram.

H-R Diagram - Sun's Evolutionary Track

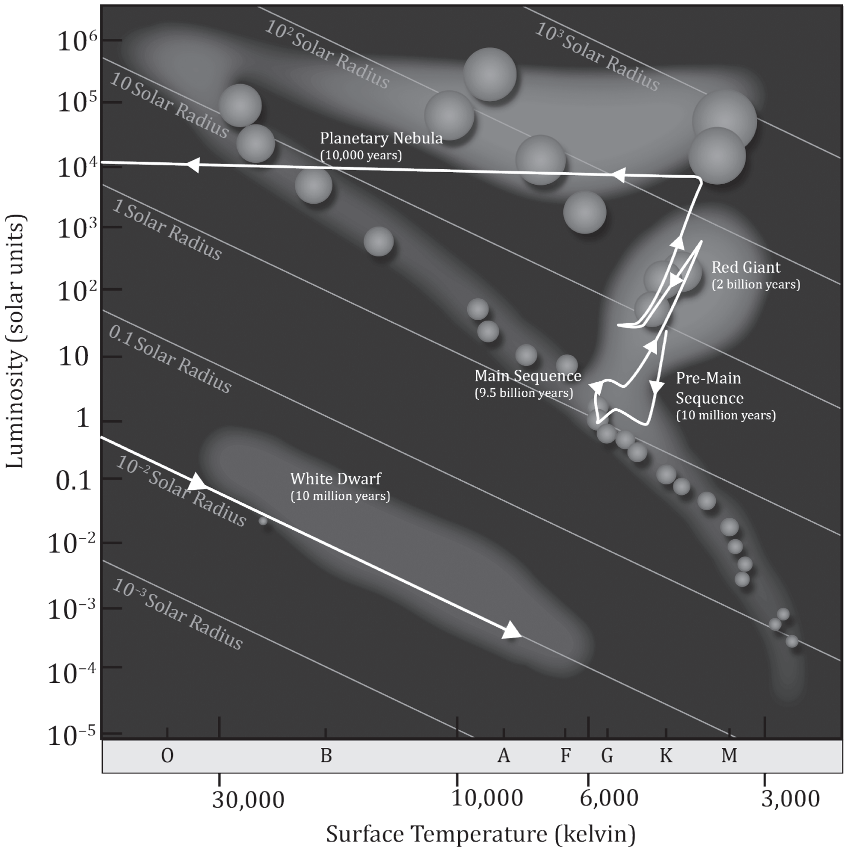


Figure 7

## Passage VIII

When an object from space strikes the surface of a solid planet or moon, the result is a crater. The edges of the crater are called the rim of the crater. Surrounding the crater is material called ejecta, which is thrown from the point of impact by the impactor (object striking the surface) (see Figure 8). The size of the crater is a function of both the velocity and mass of the impactor.

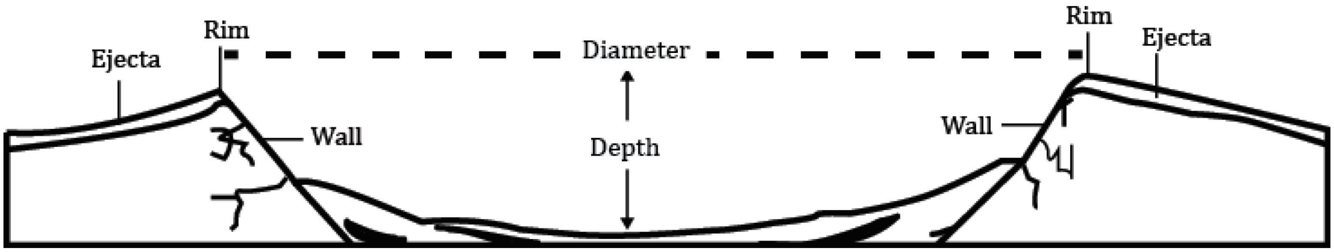

Cross-Sectional View of a Crater

Figure 8

A team of students conducted experiments to determine how mass and velocity affect crater formation.

### *Experiment 1*

The students filled a box with sand. They then dropped smooth spheres made of different materials but with identical diameters into the box. The objects were all dropped from a height of 1.0 meter and therefore had approximately the same velocity upon impact with the sand. (The effect of air resistance is assumed to be negligible.) The students measured the diameter of each crater formed in the sand from rim to rim. The students conducted multiple trials for each sphere, leveling the sand after each trial, and recorded the data in Table 9.

Table 9

| Material/ Mass of Impactor (grams) | Crater Diameter (centimeters) | | | | |
|---|---|---|---|---|---|
| | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Average |
| Cork (1.8 g) | 3.8 | 3.7 | 3.9 | 3.8 | 3.8 |
| Wood (5.7 g) | 5.1 | 5.1 | 5.4 | 4.7 | 5.1 |
| Glass (21.4 g) | 6.2 | 6.3 | 6.1 | 6.5 | 6.3 |
| Aluminum (27.1 g) | 6.5 | 6.1 | 6.5 | 6.4 | 6.4 |
| Steel (64.1 g) | 8.0 | 8.6 | 8.5 | 8.6 | 8.4 |

### *Experiment 2*

To determine how velocity affects crater diameter, the students used only the steel sphere, dropped from four different heights. The velocity of the sphere at each height was determined using the equation:

$$v = \sqrt{2gh} \qquad \text{Equation 1}$$

where $v$ is the velocity of the impactor in meters/second as it hits the sand, $g$ is the acceleration due to gravity (9.8 meters/second-squared) and $h$ is the drop height in meters. The data from this experiment are recorded in Table 10.

Table 10

| Drop Height (meters) | Velocity of Impactor (meters/second) | Crater Diameter (centimeters) | | | | |
|---|---|---|---|---|---|---|
| | | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Average |
| 0.5 | 3.1 | 5.4 | 5.6 | 5.5 | 5.5 | 5.5 |
| 1.0 | 4.4 | 8.4 | 8.6 | 8.1 | 8.5 | 8.4 |
| 1.5 | 5.4 | 10.1 | 9.3 | 9.9 | 9.9 | 9.8 |
| 2.0 | 6.3 | 11.0 | 11.3 | 10.9 | 10.9 | 11.0 |

## Passage IX

A team of safety experts conducted experiments to determine the distance required to stop a vehicle traveling at different speeds. The experiments were all conducted along a stretch of flat, straight, paved roadway. A series of traffic signals was set up near the middle of the roadway. At the start of each experiment, the vehicle accelerated until it reached a pre-determined speed. The driver then continued traveling at that speed until one of the traffic signals was triggered. (The timing for the trigger was not known by the driver).

A driver always takes a small amount of time to react to seeing a traffic light before applying the brakes. The distance the car traveled during this interval is called the reaction distance. In the experiments, the team measured the reaction distance by recording the position of the vehicle when the traffic light was triggered and the position of the car when a sensor attached to the brakes indicated that the brakes had been applied. The team measured the additional distance the car traveled until it reached a full stop.

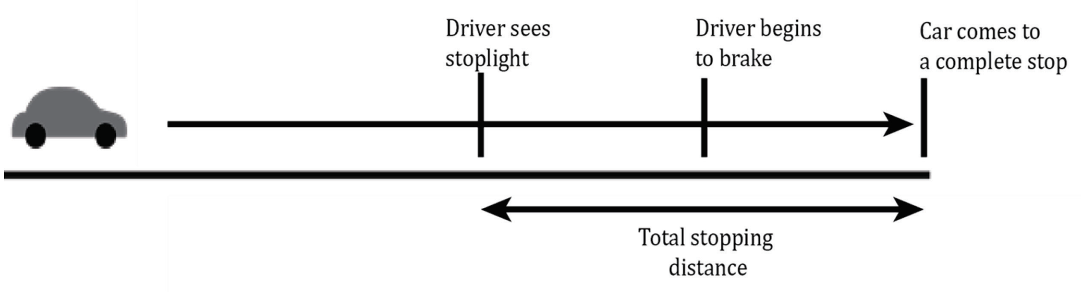


Figure 9

The team conducted seven runs on dry pavement and recorded their findings in Table 11.

Table 11: Stopping Distance on Dry Pavement

| Initial Speed (miles per hour) | Reaction Distance (feet) | Braking Distance (feet) | Total Stopping Distance (feet) |
|---|---|---|---|
| 20 | 20 | 20 | 40 |
| 30 | 30 | 45 | 75 |
| 40 | 40 | 80 | 120 |
| 50 | 50 | 125 | 175 |
| 60 | 60 | 180 | 240 |
| 70 | 70 | 245 | 315 |
| 80 | 80 | 320 | 400 |

Next, the team soaked the entire course with ordinary water using a fire hose. They conducted seven runs on wet pavement and recorded their findings in Table 12.

| Table 12: Stopping Distance on Wet Pavement | | | |
|---|---|---|---|
| Initial Speed (miles per hour) | Reaction Distance (feet) | Braking Distance (feet) | Total Stopping Distance (feet) |
| 20 | 20 | 40 | 60 |
| 30 | 30 | 90 | 120 |
| 40 | 40 | 160 | 200 |
| 50 | 50 | 250 | 300 |
| 60 | 60 | 360 | 420 |
| 70 | 70 | 490 | 560 |
| 80 | 80 | 640 | 720 |

## Passage X

The ocean is salty because of the gradual concentration of dissolved chemicals eroded from Earth's crust and washed into the ocean. Solid and gaseous ejections from volcanoes, suspended particles swept to the ocean from the land by onshore winds, and materials dissolved from sediments deposited on the ocean floor also contribute salts.

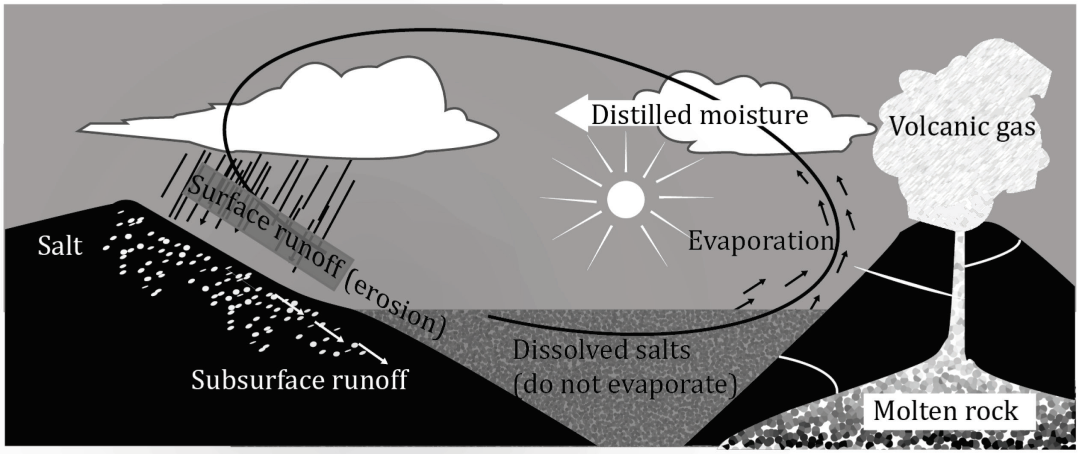


Figure 10

Salts become concentrated in the ocean because the Sun's heat distills or vaporizes almost pure water from the surface of the ocean, leaving the salts behind. In the hydrologic cycle (see Figure 10), water vapor rises from the ocean surface and is carried landward by the winds. When the vapor collides with a colder mass of air, it condenses (changes from a gas to a liquid) and falls to Earth as rain. The rain runs off into streams which in turn transport water to the ocean. Evaporation from both the land and the ocean again causes water to return to the atmosphere as vapor and the cycle starts anew. Because salts are continually added to the ocean basic and do not evaporate, the salinity of ocean water has increased over time.

Oceanographers report salinity (total salt content) and the concentrations of individual chemical constituents in seawater— for example, chloride, sodium, or magnesium—in parts per thousand (‰). That is, a salinity of 35 ‰ means 35 units of salt per 1,000 units of seawater. Similarly, a sodium concentration of 10 ‰ means 10 units of sodium per 1,000 units of seawater.

The salinity of surface seawater varies from one location to another in the world's oceans. The average salinity of surface seawater worldwide is 35 ‰, a value found at the equator. Maximum salinity values are found near the Tropics of Cancer and Capricorn (23.5° N and 23.5° S, respectively). As shown in Figure 11, at these locations, evaporation rates are higher and precipitation amounts are less than those found at the equator. High winds and high temperatures are responsible for the higher evaporation rates at these latitudes.

At still higher latitudes (45° N and 45° S), surface salinity values lower than average are found (34–34.5 ‰) because cooler temperatures result in much lower evaporation rates. Figure 11 does not show salinity values for polar waters (found at latitudes 60° N and 60° S and all locations poleward). At these locations, surface salinity values undergo significant seasonal variations. Values are higher in the autumn as sea ice forms (a process that removes water from seawater). In the spring, the melting of sea ice lowers salinity values as freshwater is once again added to the oceans (see Figure 11).

Longitudinal Variations in Evaporation and Precipitation

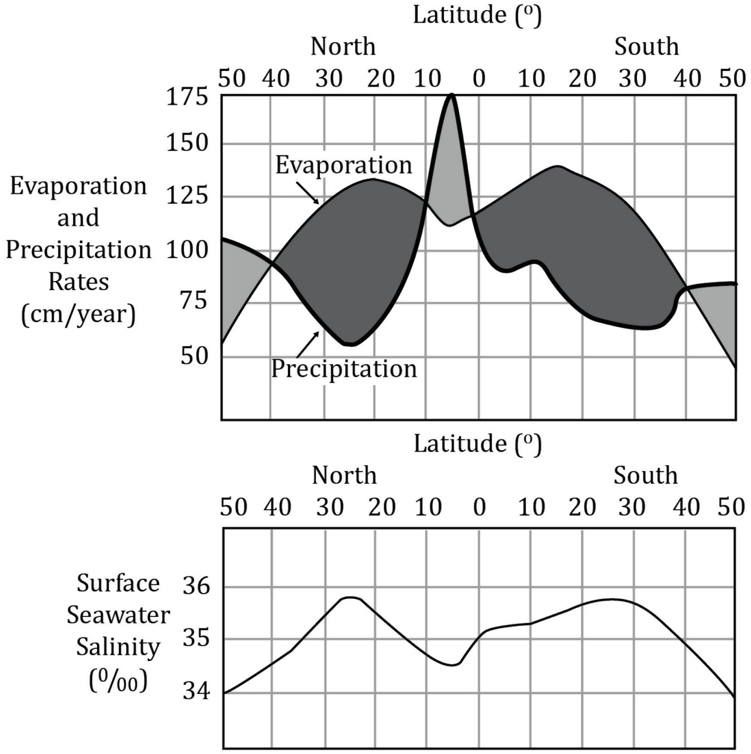


Figure 11

| Table 13: Principal Constituents of Seawater | |
|---|---|
| Chemical Constituent | Concentration (parts per thousand) |
| Calcium (Ca) | 0.419 |
| Magnesium (Mg) | 1.304 |
| Sodium (Na) | 10.710 |
| Potassium (K) | 0.390 |
| Bicarbonate ($HCO_3$) | 0.146 |
| Sulfate ($SO_4$) | 2.690 |
| Chloride (Cl) | 19.350 |
| Bromide (Br) | 0.070 |
| Total dissolved solids (salinity) | 35.079 |

| Table 14: Comparison between Seawater and River Water | | |
|---|---|---|
| Chemical Constituent | Percentage of Total Salt Content | |
| | Seawater | River Water |
| Silica ($SiO_2$) | — | 14.51 |
| Iron (Fe) | — | 0.74 |
| Calcium (Ca) | 1.19 | 16.62 |
| Magnesium (Mg) | 3.72 | 4.54 |
| Sodium (Na) | 30.53 | 6.98 |
| Potassium (K) | 1.11 | 2.55 |
| Bicarbonate ($HCO_3$) | 0.42 | 31.90 |
| Sulfate ($SO_4$) | 7.67 | 12.41 |
| Chloride (Cl) | 55.16 | 8.64 |
| Nitrate ($NO_3$) | — | 1.11 |
| Bromide (Br) | 0.20 | — |
| Total | 100.00 | 100.00 |