# تجميعة أسئلة الدروس وفق الهيكل الوزاري منهج انسبلير بدون الحل

# Grade 9

# EOT – Term 3 - 2024-2025

# Written Part

| Q1 | Part A: Determine the free-fall acceleration of objects on the surface of the Earth and at higher altitudes.<br><br>Part B: Calculate the orbital speed of a satellite. | Student Book<br><br>Figure 6; Get It: Calculate & Get It: Explain; Q.(18 – 20)<br><br>Q.(14 – 17); Q.21 | P.163<br>P. 169<br><br>P.163; P.(171 - 173); P.176<br>P.170; P.176 |
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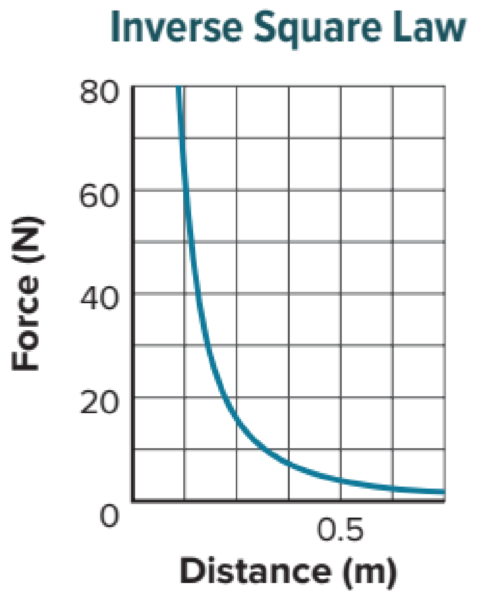


**Figure 6** This is a graphical representation of the inverse square relationship.

**Get It?**

**Calculate** how much force is acting on a 75.0-kg astronaut that is 405 km above Earth's surface, assuming $g = 8.7$ N/kg.

**Get It?**

**Explain** the concept that is used to explain forces at a distance.

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|---|---|---|---|
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18. **Earth and Moon** The Moon is $3.9\times10^5$ km from Earth's center and Earth is $14.96\times10^7$ km from the Sun's center. The masses of Earth and the Sun are $5.97\times10^{24}$ kg and $1.99\times10^{30}$ kg, respectively. During a full moon, the Sun, Earth, and the Moon are in line with each other, as shown in **Figure 17.**

a. Find the ratio of the gravitational fields due to Earth and the Sun at the center of the Moon.

b. What is the net gravitational field due to the Sun and Earth at the center of the Moon?

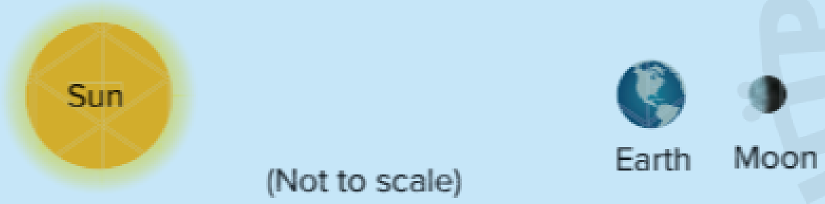


**Figure 17**

19. **Apparent Weightlessness** Chairs in an orbiting spacecraft are weightless. If you were on board such a spacecraft and you were barefoot, would you stub your toe if you kicked a chair? Explain.

20. **Gravitational Field** The mass of the Moon is $7.3\times10^{22}$ kg and its radius is 1738 km. What is the strength of the gravitational field on the surface of the Moon?

21. **Orbital Period and Speed** Two satellites are in circular orbits about Earth. One is 150 km above the surface, the other is 160 km.

a. Which satellite has the larger orbital period?

b. Which has the greater speed?

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|---|---|---|---|
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## PRACTICE Problems

ADDITIONAL PRACTICE

Assume a circular orbit for all calculations.

**14.** Suppose that the satellite in Example Problem 2 is moved to an orbit that is 24 km larger in radius than its previous orbit. What is its speed? Is this faster or slower than its previous speed? Explain.

**15.** Uranus has 27 known moons. One of these moons is Miranda, which orbits at a radius of $1.29\times10^{8}$ m. Uranus has a mass of $8.68\times10^{25}$ kg. Find the orbital speed of Miranda. How many Earth days does it take Miranda to complete one orbit?

**16.** Use Newton's thought experiment on the motion of satellites to calculate the speed that a satellite shot from a cannon must have to orbit Earth 150 km above its surface. How long, in seconds and minutes, would it take for the satellite to complete one orbit and return to the cannon?

**17. CHALLENGE** Use the data for Mercury in **Table 1** to find the speed of a satellite that is in orbit 260 km above Mercury's surface and the period of the satellite.

| | | | |
|---|---|---|---|
| Q2 | 1. State and explain the law of conservation of energy<br>2. Define mechanical energy as the sum of all kinetic and potential energies of the system; ME=KE+PE.<br>3. Apply the law of conservation of mechanical energy ($KE_i+PE_i=KE_f+PE_f$) to solve problems on different physical situations like roller coaster rides, skiing on ski slopes, motion on inclined planes/ hills, motion of pendulums, or others. | Student Book | P.(202 - 206) |
| | | Q.(39 – 43); Q.(44 - 53) | P.207; P.211 |

## PRACTICE Problems

**39.** A bike rider approaches a hill at a speed of 8.5 m/s. The combined mass of the bike and the rider is 85.0 kg. Choose a suitable system. Find the initial kinetic energy of the system. The rider coasts up the hill. Assuming friction is negligible, at what height will the bike come to rest?

**40.** Suppose that the bike rider in the previous problem pedaled up the hill and never came to a stop. In what system is energy conserved? From what form of energy did the bike gain mechanical energy?

**41.** A skier starts from rest at the top of a hill that is 45.0 m high, skis down a 30° incline into a valley, and continues up a hill that is 40.0 m high. The heights of both hills are measured from the valley floor. Assume that friction is negligible and ignore the effect of the ski poles.

**a.** How fast is the skier moving at the bottom of the valley?

**b.** What is the skier's speed at the top of the second hill?

**c.** Do the angles of the hills affect your answers?

| | | | |
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**42.** In a belly-flop diving contest, the winner is the diver who makes the biggest splash upon hitting the water. The size of the splash depends not only on the diver's style, but also on the amount of kinetic energy the diver has. Consider a contest in which each diver jumps from a 3.00-m platform. One diver has a mass of 136 kg and simply steps off the platform. Another diver has a mass of 100 kg and leaps upward from the platform. How high would the second diver have to leap to make a competitive splash?

**43. CHALLENGE** The spring in a pinball machine exerts an average force of 2 N on a 0.08-kg pinball over 5 cm. As a result, the ball has both translational and rotational kinetic energy. If the ball is a uniform sphere $\left(I = \frac{5}{2}mr^2\right)$, what is its linear speed after leaving the spring? (Ignore the table's tilt.)

| | | | |
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**44.** An 8.00-g bullet is fired horizontally into a 9.00-kg block of wood on an air table and is embedded in it. After the collision, the block and bullet slide along the frictionless surface together with a speed of 10.0 cm/s. Find the initial speed of the bullet.

**45.** A 91.0-kg hockey player is skating on ice at 5.50 m/s. Another hockey player of equal mass, moving at 8.1 m/s in the same direction, hits him from behind. They slide off together.

**a.** What are the total mechanical energy and momentum of the system before the collision?

**b.** What is the velocity of the two hockey players after the collision?

**c.** How much was the system's kinetic energy decreased in the collision?

**46. CHALLENGE** A 0.73-kg magnetic target is suspended on a string. A 0.025-kg magnetic dart, shot horizontally, strikes the target head-on. The dart and the target together act like a pendulum and swing 12.0 cm above the initial level before instantaneously coming to rest.

**a.** Sketch the situation and choose a system.

**b.** Decide what is conserved in each step of the process and explain why.

**c.** What was the initial velocity of the dart?

| | | | |
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47. **Energy Diagrams** A child jumps on a trampoline. Draw energy bar diagrams to show the forms of energy in the following situations.
    a. The child is at the highest point.
    b. The child is at the lowest point.
48. **Energy** Explain why energy is considered a single quantity.
49. **Kinetic Energy** Suppose a glob of chewing gum and a small, rubber ball collide head-on in midair and then rebound apart. Would you expect kinetic energy to be conserved? If not, what happens to the energy?
50. **Potential Energy** A rubber ball drops from a height of 8.0 m onto a concrete floor and bounces repeatedly. Each time it hits the floor, the ball-Earth system loses $\frac{1}{5}$ of its *ME*. How many times will the ball bounce before it bounces back up to a height of only 4 m?

| | | | |
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51. **Energy** In **Figure 27,** a child slides down a playground slide. At the bottom, she is moving at 3.0 m/s. How much energy was transformed by friction as she slid down the slide?


Figure 27

52. **Conservation of Energy** Your friend wants to solve the world's energy problems by inventing a device that will deliver ten times more energy than put into the device. Can this device work? Explain.

53. **Critical Thinking** A ball drops 20 m. When it has fallen 10 m, half of the energy is potential energy and half is kinetic energy. When the ball has fallen for half the amount of time it takes to fall, will more, less, or exactly half of the energy be potential energy?

| Q3 | 1. Apply the relationship between a force F and the work done on a system by the force when the system undergoes a displacement d: W=Fd cosθ, where θ is the angle between the direction of the force and the direction of displacement.<br>2. Determine graphically the work done by a force from the area of force versus displacement graph.<br>3. Apply the work–energy theorem to relate the net work done on a system and the resulting change in kinetic energy. | Student Book | P.(182 - 190) |
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| | | Q.(1 - 13) | P.(182 - 190) |

## PRACTICE Problems

ADDITIONAL PRACTICE

1. Refer to Example Problem 1 to solve the following problem.
   - **a.** If the hockey player exerted twice as much force (9.00 N) on the puck over the same distance, how would the amount of work the stick did on the puck be affected?
   - **b.** If the player exerted a 9.00-N force, but the stick was in contact with the puck for only half the distance (0.075 m), how much work does the stick do on the puck?
2. Together, two students exert a force of 825 N in pushing a car a distance of 35 m.
   - **a.** How much work do the students do on the car?
   - **b.** If their force is doubled, how much work must they do on the car to push it the same distance?
3. A rock climber wears a 7.5-kg backpack while scaling a cliff. After 30.0 min, the climber is 8.2 m above the starting point.
   - **a.** How much work does the climber do on the backpack?
   - **b.** If the climber weighs 645 N, how much work does she do lifting herself and the backpack?
4. **CHALLENGE** Marisol pushes a 3.0-kg box 7.0 m across the floor with a force of 12 N. She then lifts the box to a shelf 1 m above the ground. How much work does Marisol do on the box?

| | | | |
|---|---|---|---|
| Q3 | 1. Apply the relationship between a force F and the work done on a system by the force when the system undergoes a displacement d: $W=Fd\cos\theta$, where $\theta$ is the angle between the direction of the force and the direction of displacement.<br>2. Determine graphically the work done by a force from the area of force versus displacement graph.<br>3. Apply the work–energy theorem to relate the net work done on a system and the resulting change in kinetic energy. | Student Book | P.(182 - 190) |
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## PRACTICE Problems

5. If the sailor in Example Problem 2 pulls with the same force through the same displacement but at an angle of 50.0°, how much work is done on the boat by the rope?
6. Two people lift a heavy box a distance of 15 m. They use ropes, each of which makes an angle of 15° with the vertical. Each person exerts a force of 225 N. Calculate the work done by the ropes.
7. An airplane passenger carries a 215-N suitcase up the stairs, a displacement of 4.20 m vertically and 4.60 m horizontally.
   - **a.** How much work does the passenger do on the suitcase?
   - **b.** The same passenger carries the same suitcase back down the same set of stairs. How much work does the passenger do on the suitcase to carry it down the stairs?

| Q3 | 1. Apply the relationship between a force F and the work done on a system by the force when the system undergoes a displacement d: W=Fd cosθ, where θ is the angle between the direction of the force and the direction of displacement.<br>2. Determine graphically the work done by a force from the area of force versus displacement graph.<br>3. Apply the work–energy theorem to relate the net work done on a system and the resulting change in kinetic energy. | Student Book | P.(182 - 190) |
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| | | Q.(1 - 13) | P.(182 - 190) |

**8.** A rope is used to pull a metal box a distance of 15.0 m across the floor. The rope is held at an angle of 46.0° with the floor, and a force of 628 N is applied to the rope. How much work does the rope do on the box?

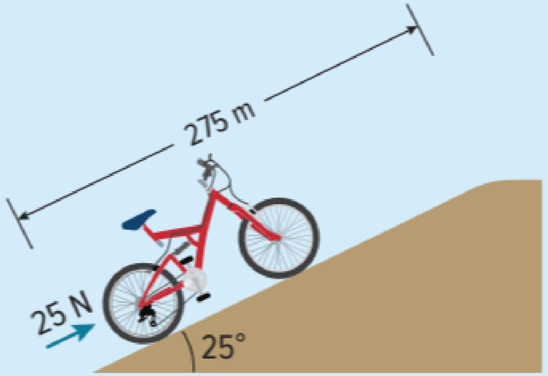


**Figure 5**

**9. CHALLENGE** A bicycle rider pushes a 13-kg bicycle up a steep hill. The incline is 25° and the hill is 275 m long, as shown in **Figure 5.** The rider pushes the bike parallel to the road with a force of 25 N.

**a.** How much work does the rider do on the bike?

**b.** How much work is done by the force of gravity on the bike?

| | | | |
|---|---|---|---|
| Q3 | 1. Apply the relationship between a force F and the work done on a system by the force when the system undergoes a displacement d: W=Fd cosθ, where θ is the angle between the direction of the force and the direction of displacement.<br>2. Determine graphically the work done by a force from the area of force versus displacement graph.<br>3. Apply the work–energy theorem to relate the net work done on a system and the resulting change in kinetic energy. | Student Book | P.(182 - 190) |
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## PRACTICE Problems

ADDITIONAL PRACTICE

**10.** A catamaran with a mass of $5.44\times10^3$ kg is moving at 12 knots. How much work is required to increase the speed to 16 knots? (One knot = 0.51 m/s.)

**11.** A 52.0-kg skater moves at 2.5 m/s and stops over a distance of 24.0 m. Find the skater's initial kinetic energy. How much of her kinetic energy is transformed into other forms of energy by friction as she stops? How much work must she do to speed up to 2.5 m/s again?

**12.** An 875.0-kg car speeds up from 22.0 m/s to 44.0 m/s. What are the initial and final kinetic energies of the car? How much work is done on the car to increase its speed?

**13.** **CHALLENGE** A comet with a mass of $7.85\times10^{11}$ kg strikes Earth at a speed of 25.0 km/s. Find the kinetic energy of the comet in joules, and compare the work that is done by Earth in stopping the comet to the $4.2\times10^{15}$ J of energy that was released by the largest nuclear weapon ever exploded.

| | | | |
|---|---|---|---|
| Q4 | 1. Analyze the forces acting on an object immersed in a fluid and calculate the net force ($F_{net}= F_g-F_{buoyant}$) to predict whether it will float, sink, or remain in its place (neutral buoyancy).<br>2. Explain why some objects float while others sink by comparing the density of an object and the density of the fluid in which it is placed. | Student Book | P.(241 - 239) |
| | | Q.(27 - 31) | P.241 |

## PRACTICE Problems

ADDITIONAL PRACTICE

**27.** Common brick is about 1.8 times denser than water. What is the net force on a 0.20 $m^3$ block of bricks under water?

**28.** A girl is floating in a freshwater lake with her head just above the water. If she weighs 610 N, what is the volume of the submerged part of her body?

**29.** What is the tension in a wire supporting a 1250-N camera submerged in water? The volume of the camera is $16.5\times10^{-3}$ $m^3$.

**30.** Plastic foam is about 0.10 times as dense as water. What weight of bricks could you stack on a 1.0-m × 1.0-m × 0.10-m slab of foam so that the slab of foam floats in water and is barely submerged, leaving the bricks dry?

**31.** **CHALLENGE** Canoes often have plastic foam blocks mounted under the seats for flotation in case the canoe fills with water. What is the approximate minimum volume of foam needed for flotation for a 480-N canoe?

| Q5 | Part A:<br>Clarify the meaning of the important terms and concepts contained in the GRAVITATION Module.<br><br>Part B:<br>Define kinetic energy and apply the relationship between a particle's kinetic energy, mass, and speed (KE=1/2 mv$^2$). | Student Book | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194 |
|---|---|---|---|
| | | All Terms / Concepts<br>Get It: Explain; Q.(10 – 13) | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194; P.190 |

## Kepler's Laws

In 1600 Tycho moved to Prague where Johannes Kepler, a 29-year-old German, became one of his assistants. Kepler analyzed Tycho's observations. After Tycho's death in 1601, Kepler continued to study Tycho's data and used geometry and mathematics to explain the motion of the planets. After seven years of careful analysis of Tycho's data on Mars, Kepler discovered the laws that describe the motion of every planet and satellite, natural or artificial. Here, the laws are presented in terms of planets.

**Kepler's first law** states that the paths of the planets are ellipses, with the Sun at one focus. An ellipse has two foci, as shown in **Figure 2**. Although exaggerated ellipses are used in the diagrams, Earth's actual orbit is very nearly circular. You would not be able to distinguish it from a circle visually.

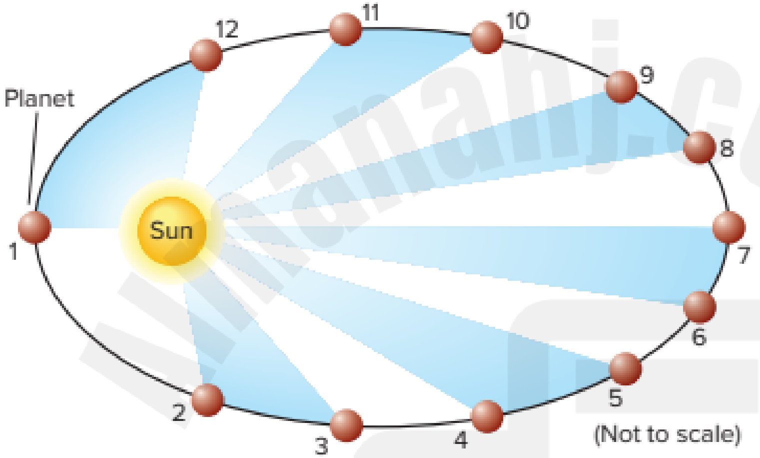



**Figure 3** Kepler found that elliptical orbits sweep out equal areas in equal time periods.

**Explain** *why the equal time areas are shaped differently.*

Kepler found that orbits might change due to gravitational effects from, or collisions with, other objects in the solar system. He also found that the planets move faster when they are closer to the Sun and slower when they are farther away from the Sun. **Kepler's second law** states that an imaginary line from the Sun to a planet sweeps out equal areas in equal time intervals, as illustrated in **Figure 3.**

A period is the time it takes for one revolution of an orbiting body. Kepler also discovered a mathematical relationship between periods of planets and their mean distances away from the Sun.

**Kepler's third law** states that the square of the ratio of the periods of any two planets revolving about the Sun is equal to the cube of the ratio of their average distances from the Sun. Thus, if the periods of the planets are $T_A$ and $T_B$ and their average distances from the Sun are $r_A$ and $r_B$, Kepler's third law can be expressed as follows.

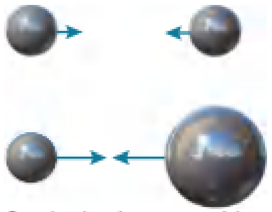
### Kepler's Third Law

The square of the ratio of the period of planet A to the period of planet B is equal to the cube of the ratio of the distance between the centers of planet A and the Sun to the distance between the centers of planet B and the Sun.

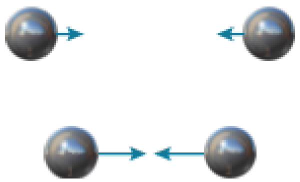
$$\left(\frac{T_A}{T_B}\right)^2 = \left(\frac{r_A}{r_B}\right)^3$$

| | | | |
|---|---|---|---|
| Q5 | **Part A:** Clarify the meaning of the important terms and concepts contained in the GRAVITATION Module. | Student Book | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194 |
| | **Part B:** Define kinetic energy and apply the relationship between a particle's kinetic energy, mass, and speed (KE=1/2 mv$^2$). | All Terms / Concepts<br>Get It: Explain; Q.(10 – 13) | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194; P.190 |

# Newton's Law of Universal Gravitation



Gravitation between objects depends on the product of the masses of the objects.



The gravitational force between objects is inversely proportional to the square of the distance between the objects.

**Figure 5** Mass and distance affect the magnitude of the gravitational force between objects.

In 1666, Isaac Newton began his studies of planetary motion. It has been said that seeing an apple fall made Newton wonder if the force that caused the apple to fall might extend to the Moon, or even beyond. He found that the magnitude of the force ($F_g$) on a planet due to the Sun varies inversely with the square of the distance ($r$) between the centers of the planet and the Sun. That is, $F_g$ is proportional to $\frac{1}{r^2}$. The force ($F_g$) acts in the direction of the line connecting the centers of the two objects, as shown in **Figure 5.**

Newton found that both the apple's and the Moon's accelerations agree with the $\frac{1}{r^2}$ relationship. According to his own third law, the force Earth exerts on the apple is exactly the same as the force the apple exerts on Earth. Even though these forces are exactly the same, you can easily observe the effect of the force on the apple because it has much lower mass than Earth. The force of attraction between two objects must be proportional to the objects' masses and is known as the **gravitational force.**

Newton was confident that the same force of attraction would act between any two objects anywhere in the universe. He proposed the **law of universal gravitation,** which states that objects attract other objects with a force that is proportional to the product of their masses and inversely proportional to the square of the distance between them. Newton's law of universal gravitation, shown below, provides the mathematical models to describe and predict the effects of gravitational forces between distant objects.

## Law of Universal Gravitation

The gravitational force is equal to the universal gravitational constant, times the mass of object 1, times the mass of object 2, divided by the distance between the centers of the objects, squared.

$$F_g = \frac{Gm_1m_2}{r^2}$$

| | | | |
|---|---|---|---|
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# Universal Gravitation and Kepler's Third Law

Newton stated the law of universal gravitation in terms that applied to the motion of planets about the Sun. This agreed with Kepler's third law and confirmed that Newton's law fit the best observations of the day.

Consider a planet orbiting the Sun, as shown in **Figure 7.** Newton's second law of motion, $F_{net} = ma$, can be written as $F_{net} = m_p a_c$, where $F_{net}$ is the magnitude of the gravitational force, $m_p$ is the mass of the planet, and $a_c$ is the centripetal acceleration of the planet. For simplicity, assume circular orbits. Recall from your study of uniform circular motion that for a circular orbit $a_c = \frac{4\pi^2 r}{T^2}$. This means that $F_{net} = m_p a_c$ may now be written $F_{net} = \frac{m_p 4\pi^2 r}{T^2}$. In this equation, $T$ is the time in seconds required for the planet to make one complete revolution about the Sun. If you set the right side of this equation equal to the right side of the law of universal gravitation, you arrive at the following result:

$$\frac{Gm_s m_p}{r^2} = \frac{m_p 4\pi^2 r}{T^2}$$

$$T^2 = \left(\frac{4\pi^2}{Gm_s}\right) r^3$$

$$T = \sqrt{\left(\frac{4\pi^2}{Gm_s}\right) r^3}$$

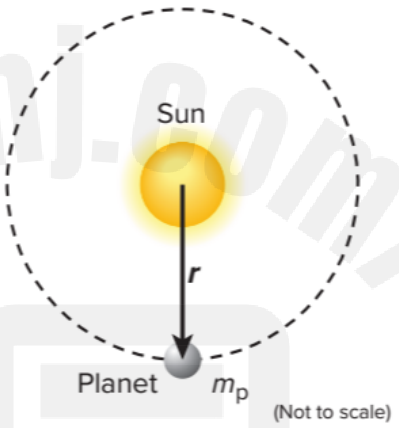


**Figure 7** A planet with mass $m_p$ and average distance from the Sun $r$ orbits the Sun. The mass of the Sun is $m_s$.

The period of a planet orbiting the Sun can be expressed as follows.

### Period of a Planet Orbiting the Sun

The period of a planet orbiting the Sun is equal to 2π times the square root of the average distance from the Sun cubed, divided by the product of the universal gravitational constant and the mass of the Sun.

$$T = 2\pi\sqrt{\frac{r^3}{Gm_s}}$$

| Q5 | Part A: Clarify the meaning of the important terms and concepts contained in the GRAVITATION Module. | Student Book | P.(159 – 165 & 168 – 173 & 175 - 176) P.194 |
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**A satellite's speed** A satellite in an orbit that is always the same height above Earth moves in uniform circular motion. Recall that its centripetal acceleration is given by $a_c = \frac{v^2}{r}$. Newton's second law, $F_{net} = ma_c$, can thus be rewritten $F_{net} = \frac{mv^2}{r}$. If Earth's mass is $m_E$, then this expression combined with Newton's law of universal gravitation produces the following equation:

$$\frac{Gm_Em}{r^2} = \frac{mv^2}{r}$$

Solving for the speed of a satellite in circular orbit about Earth ($v$) yields the following.

### Speed of a Satellite Orbiting Earth

The speed of a satellite orbiting Earth is equal to the square root of the universal gravitational constant times the mass of Earth, divided by the radius of the orbit.

$$v = \sqrt{\frac{Gm_E}{r}}$$

**A satellite's orbital period** A satellite's orbit around Earth is similar to a planet's orbit about the Sun. Recall that the period of a planet orbiting the Sun is expressed by the following equation:

$$T = 2\pi\sqrt{\frac{r^3}{Gm_S}}$$

Thus, the period for a satellite orbiting Earth is given by the following equation.

### Period of a Satellite Orbiting Earth

The period for a satellite orbiting Earth is equal to 2π times the square root of the radius of the orbit cubed, divided by the product of the universal gravitational constant and the mass of Earth.

$$T = 2\pi\sqrt{\frac{r^3}{Gm_E}}$$

## Free-Fall Acceleration

The acceleration of objects due to Earth's gravity can be found by using Newton's law of universal gravitation and his second law of motion. For a free-falling object of mass $m$, the following is true:

$$F = \frac{Gm_Em}{r^2} = ma, \text{ so } a = \frac{Gm_E}{r^2}$$

If you set $a = g_E$ and $r = r_E$ on Earth's surface, the following equation can be written:

$$g = \frac{Gm_E}{{r_E}^2}, \text{ thus, } m_E = \frac{g{r_E}^2}{G}$$

You saw above that $a = \frac{Gm_E}{r^2}$ for a free-falling object. Substitution of the above expression for $m_E$ yields the following:

$$a = G\frac{\left(\frac{g{r_E}^2}{G}\right)}{r^2}$$

$$a = g\left(\frac{r_E}{r}\right)^2$$

| Q5 | Part A: Clarify the meaning of the important terms and concepts contained in the GRAVITATION Module. | Student Book | P.(159 – 165 & 168 – 173 & 175 - 176) P.194 |
|---|---|---|---|
| | Part B: Define kinetic energy and apply the relationship between a particle's kinetic energy, mass, and speed (KE=1/2 mv$^2$). | All Terms / Concepts<br>Get It: Explain; Q.(10 – 13) | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194; P.190 |

## The Gravitational Field

spacecraft and eve
ating toward Earth
astronauts. That is
falling from benea

Recall from studying motion that many common forces are contact forces. Friction is exerted where two objects touch; for example, the floor and your chair or desk push on you when you are in contact with them. Gravity, however, is different. It acts on an apple falling from a tree and on the Moon in orbit. In other words, gravity acts over a distance. It acts between objects that are not touching or that are not close together. Newton was puzzled by this concept. He wondered how the Sun could exert a force on planet Earth, which is hundreds of millions of kilometers away.

**Field concept** The concept of a field was developed by Michael Faraday in the nineteenth century while he was studying the attraction between magnets. Fields, such as gravitational, electric, and magnetic, explain forces acting at a distance. These forces are between objects that transfer energy through space. How does this apply to gravitational forces?

Any object with mass is surrounded by a gravitational field, which exerts a force that is directly proportional to the mass of the object and inversely proportional to the square of the distance from the object's center. Another object experiences a force due to the interaction between its mass and the gravitational field ($g$) at its location. The direction of $g$ and the gravitational force is toward the center of the object producing the field. Gravitational field strength is expressed by the following equation.

### Gravitational Field

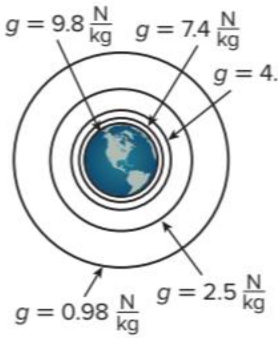
The gravitational field strength produced by an object is equal to the universal gravitational constant times the object's mass, divided by the square of the distance from the object's center.

$$g = \frac{Gm}{r^2}$$

Suppose the gravitational field is created by the Sun. Then a planet of mass $m$ in the Sun's gravitational field has a force exerted on it that depends on its mass and the magnitude of the gravitational field at its location. That is, $F_g = mg$, toward the Sun. The force is caused by the interaction of the planet's mass with the gravitational field at its location, not with the Sun millions of kilometers away. To find the gravitational field caused by more than one object, calculate all gravitational fields and add them as vectors.

The gravitational field is measured by placing an object with a small mass ($m$) in the gravitational field and measuring the force ($F_g$) on it. The gravitational field is calculated using $g = \frac{F_g}{m}$ The gravitational field is measured in units of newtons per kilogram (N/kg).

On Earth's surface, the strength of the gravitational field is 9.8 N/kg, and its direction is toward Earth's center. The field can be represented by a vector of length $g$ pointing toward the center of the object producing the field. You can picture the gravitational field produced by Earth as a collection of vectors surrounding Earth and pointing toward it, as shown in **Figure 13.** The strength of Earth's gravitational field varies inversely with the square of the distance from Earth's center. Earth's gravitational field depends on Earth's mass but not on the mass of the object experiencing it.



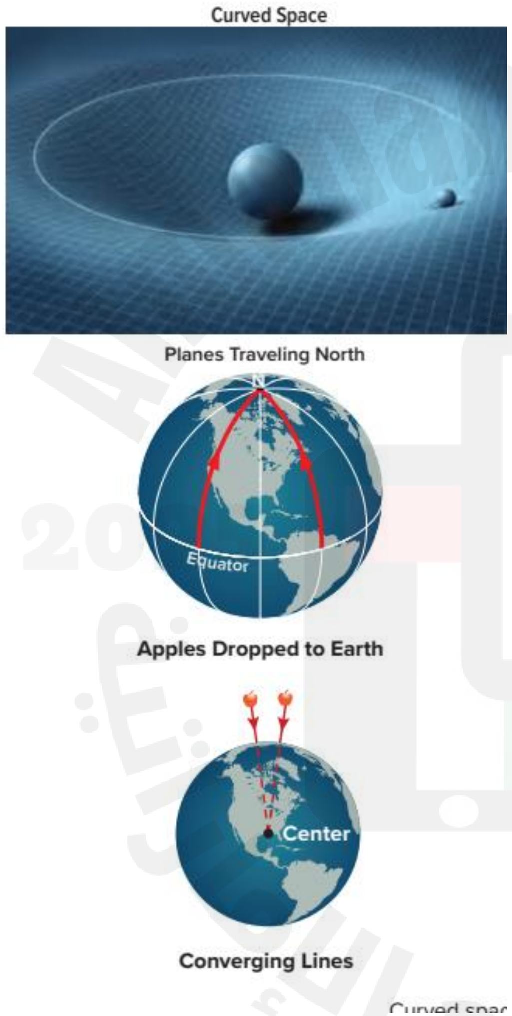
| | | | |
|---|---|---|---|
| Q5 | **Part A:** Clarify the meaning of the important terms and concepts contained in the GRAVITATION Module. | Student Book | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194 |
| | **Part B:** Define kinetic energy and apply the relationship between a particle's kinetic energy, mass, and speed (KE=1/2 mv$^2$). | All Terms / Concepts<br>Get It: Explain; Q.(10 – 13) | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194; P.190 |

## Einstein's Theory of Gravity

Newton's law of universal gravitation allows us to calculate the gravitational force that exists between two objects because of their masses. Newton was puzzled, however, as to how two objects could exert forces on each other if those two objects were millions of kilometers away from each other. Albert Einstein proposed that gravity is not a force but rather an effect of space itself. According to Einstein's explanation of gravity, mass changes the space around it. Mass causes space to be curved, and other bodies are accelerated because of the way they follow this curved space.

**Curved space** One way to picture how mass affects space is to model three-dimensional space as a large, two-dimensional sheet, as shown in the top part of **Figure 15.** The large blue ball on the sheet represents a massive object. The ball forms an indentation on the sheet. A small blue ball rolling across the sheet simulates the motion of an object in space. If the small ball moves near the sagging region of the sheet, it will be accelerated. In a similar way, Earth and the Sun are attracted to each other because of the way space is distorted by the two objects.

**Planes traveling north** The following is another analogy that might help you understand the curvature of space. Suppose you watch from space as two planes travel due north from the equator. At the equator, the planes are separated by 4000 km. As they approach the North Pole, the distance decreases to 1 km. To the pilots, their paths are straight lines, but because of Earth's curvature, they travel in a curve, as viewed far from Earth's surface, as in Figure 15.




**Converging lines** Consider a similar motion. Two apples are dropped to Earth, initially traveling in parallel paths, as in **Figure 15.** As they approach Earth, they are pulled toward Earth's center. Their paths converge. This convergence can be attributed to the curvature of space near Earth. Far from any massive object, such as a planet or star, space is flat, and parallel lines remain parallel. Then they begin to converge. In flat space, the parallel lines would remain parallel. In curved space, the lines converge.

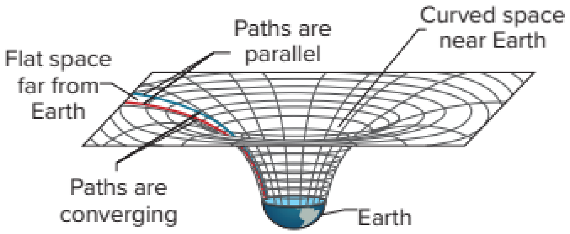



**Figure 15** Visualizing how space is curved is difficult. Analogies can help you understand difficult concepts.

Einstein's theory or explanation, called the general theory of relativity, makes many predictions about how massive objects affect one another. In every test conducted to date, Einstein's theory has been shown to give the correct results.

| Q5 | **Part A:** Clarify the meaning of the important terms and concepts contained in the GRAVITATION Module. | Student Book | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194 |
|---|---|---|---|
| | **Part B:** Define kinetic energy and apply the relationship between a particle's kinetic energy, mass, and speed ($KE=1/2\ mv^2$). | All Terms / Concepts<br>Get It: Explain; Q.(10 – 13) | P.(159 – 165 & 168 – 173 & 175 - 176)<br>P.194; P.190 |

**Deflection of light** Einstein's theory predicts that massive objects deflect and bend light. Light follows the curvature of space around the massive object and is deflected, as shown in **Figure 16.** In 1919, during an eclipse of the Sun, astronomers found that light from distant stars that passed near the Sun was deflected an amount that agreed with Einstein's predictions.

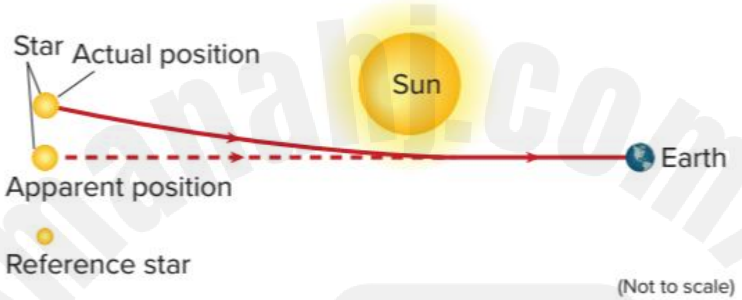



**Figure 16** Light is bent around massive objects in space, altering the apparent position of the light's source.

**Describe** *how this effect contradicts your experience of light's behavior.*

Another result of general relativity is the effect of gravity on light from extremely massive objects. If an object is massive and dense enough, the light leaving it is totally bent back to the object. No light ever escapes the object. Objects such as these, called black holes, have been identified as a result of their effects on nearby stars. Black holes have been detected through the radiation produced when matter is pulled into them.

### Get It?

**Explain** Using the equation for translational kinetic energy, show why a car moving at 20 m/s has four times the translational kinetic energy of the same car moving at 10 m/s.

# McQ’s Part

| | | | |
|---|---|---|---|
| 1 | Explain Kepler's Second Law which states that an imaginary line from the Sun to a planet sweeps out equal areas in equal time intervals. | Student Book | P.(160 - 161) |
| | | Q.(1 - 7) | P.162 |
| 2 | Explain Kepler's Third Law which states that the square of the ratio of the periods of any two planets revolving about the Sun is equal to the cube of the ratio of their average distances from the Sun and write it in equation form $((T_A/T_B)^2=(r_A/r_B)^3)$. | Student Book | P.(160 - 161) |
| | | Q.(1 - 7) | P.162 |

**PRACTICE Problems** ADDITIONAL PRACTICE

1. If Ganymede, one of Jupiter's moons, has a period of 32 days, how many units is its orbital radius? Use the information given in Example Problem 1.
2. An asteroid revolves around the Sun with a mean orbital radius twice that of Earth's. Predict the period of the asteroid in Earth years.
3. Venus has a period of revolution of 225 Earth days. Find the distance between the Sun and Venus as a multiple of Earth's average distance from the Sun.

| | | | |
|---|---|---|---|
| 1 | Explain Kepler's Second Law which states that an imaginary line from the Sun to a planet sweeps out equal areas in equal time intervals. | Student Book | P.(160 - 161) |
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| | | Q.(1 - 7) | P.162 |

**4.** Uranus requires 84 years to circle the Sun. Find Uranus's average distance from the Sun as a multiple of Earth's average distance from the Sun.

**5.** From **Table 1** you can find that, on average, Mars is 1.52 times as far from the Sun as Earth is. Predict the time required for Mars to orbit the Sun in Earth days.

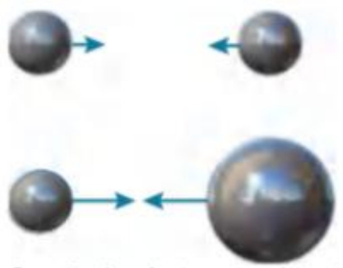
**6.** The Moon has a period of 27.3 days and a mean distance of $3.9\times10^5$ km from its center to the center of Earth.

a. Use Kepler's laws to find the period of a satellite in orbit $6.70\times10^3$ km from the center of Earth.

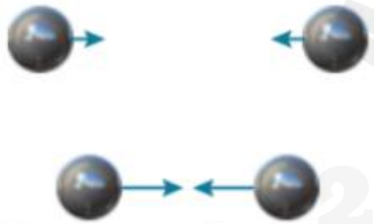
b. How far above Earth's surface is this satellite?

**7.** **CHALLENGE** Using the data in the previous problem for the period and radius of revolution of the Moon, predict what the mean distance from Earth's center would be for an artificial satellite that has a period of exactly 1.00 day.

| 3 | Explore the gravitational force between objects and the parameters affecting that force, and explain the insignificance of such force between objects. | Student Book | P.163 |
|---|---|---|---|
| | | Figure 5 | P.163 |



Gravitation between objects depends on the product of the masses of the objects.



The gravitational force between objects is inversely proportional to the square of the distance between the objects.

**Figure 5** Mass and distance affect the magnitude of the gravitational force between objects.


جسمان A وB مختلفان في الكتلة وضعا على مسافة من بعضهما البعض كما هو مبين في الشكل. وفقاً لقانون الجذب العام يؤثر كل من الجسمين على الآخر بقوة جاذبية. إذا كان A يؤثر على B بقوة مقدارها F، ما مقدار القوة التي يؤثر بها B على A؟

Two objects A and B with different masses are placed at a distance from each other as shown in the figure. According to the law of universal gravitation, each object exerts a gravitational force on the other. If A exerts a force F on B, **what is the force that B exerts on A?**

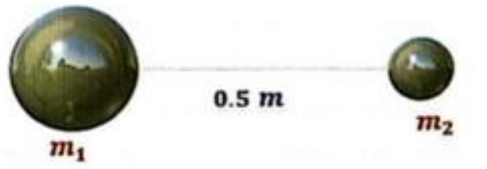
استخدم الثوابت والمعادلات الآتية حيثما يلزم

**Use the following constants and formulas when required**

| Module (6) ( Motion in Two Dimensions ) | | | | |
|---|---|---|---|---|
| $a_c = \frac{v^2}{r}$ | $F_{net} = ma_c$ | $v = \frac{2\pi r}{T}$ | $a_c = \frac{4\pi^2 r}{T^2}$ | $v_{a/b} + v_{b/c} = v_{a/c}$ |
| **Module (7) ( Gravitation )** | | | | |
| $G = 6.67 \times 10^{-11}\ N \cdot m^2/kg$ | $F_g = G\frac{m_1 m_2}{r^2}$ | $T = 2\pi\sqrt{\frac{r^3}{Gm}}$ | | |

1. F
2. 2F
3. $\frac{F}{2}$
4. 3F

| 3 | Explore the gravitational force between objects and the parameters affecting that force, and explain the insignificance of such force between objects. | Student Book | P.163 |
|---|---|---|---|
| | | Figure 5 | P.163 |




a. يوضح الشكل جسمين كرويين لهما كتلتين مختلفتين :

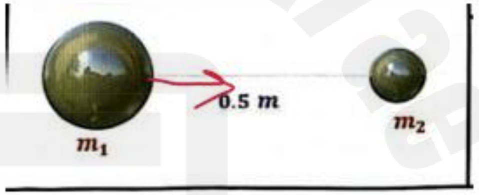
$$m_1 = 15.0\ kg, m_2 = 5.0\ kg$$

The Figure shows two objects with different masses:

$$m_1 = 15.0\ kg, m_2 = 5.0\ kg$$

a. احسب قوة الجاذبية بين الجسمين $m_1$ و $m_2$.

Calculate the gravitational force between $m_1$ and $m_2$.




b. ارسم على الشكل متجهاً (سهماً) يبين اتجاه قوة الجاذبية المؤثرة على الكتلة $m_1$.

Draw a vector (an arrow) to show the direction of the gravitational force on the mass $m_1$.

c. ماذا يحدث لقوة الجاذبية المتبادلة بين الكتلتين إذا:

What happens to the gravitational force between the two masses if:

1. أنقصت المسافة (r) بينهما إلى النصف لتصبح $(\frac{r}{2})$؟

The distance (r) between them is halved to $(\frac{r}{2})$?

تزيد القوة أربع أضعاف

2. زيدت الكتلة $m_2$ إلى مثلي ما كانت عليه لتصبح $2m_2$؟

The mass $m_2$ is doubled to $2m_2$?

تزيد القوة الضعف (اكبر مرتين)

| | | | |
|---|---|---|---|
| 4 | Define gravitational force as the force of attraction between two or more objects with given masses, with an explanation of the law of universal gravitation as a form of Newton's second law, and writing it in the form of an equation ($F_g=(Gm_1 m_2)/r^2$). | Student Book | P.163 |
| | | Figure 6; Q.9 | P.163; P.167 |

9. **Mathematical Representations** Predict the gravitational force between two 15-kg balls whose centers are 35 cm apart. What fraction is this of the weight of one ball?

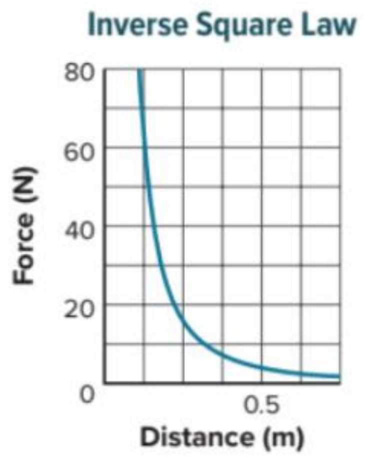



**Figure 6** This is a graphical representation of the inverse square relationship.

**Law of Universal Gravitation**

The gravitational force is equal to the universal gravitational constant, times the mass of object 1, times the mass of object 2, divided by the distance between the centers of the objects, squared.

$$F_g = \frac{Gm_1m_2}{r^2}$$

According to Newton's equation, *F* is directly proportional to $m_1$ and $m_2$. If the mass of a planet near the Sun doubles, the force of attraction doubles. Use the Connecting Math to Physics feature on the next page to examine how changing one variable affects another. **Figure 6** illustrates the inverse square relationship graphically. The term G is the universal gravitational constant and will be discussed on the following pages.

| | | | |
|---|---|---|---|
| 5 | Explain Kepler's First Law which states that the planets follow elliptical paths with the sun at one focus. | Student Book | P.160 |
| | | Get It: Describe, Figure 2 | P.160 |

## Get It?

**Describe** the common feature that Kepler's first law found concerning the paths of orbiting objects around the Sun.

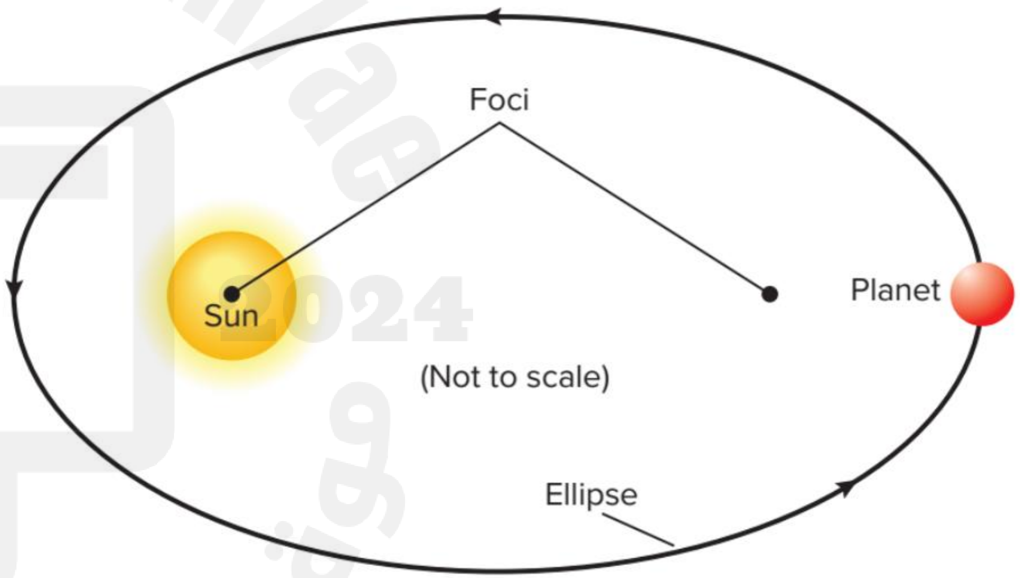



**Figure 2** The orbit of each planet is an ellipse, with the Sun at one focus.

| | | | |
|---|---|---|---|
| 6 | 1. Show that work is done when a force is applied through a displacement.<br>2. Recall that a perpendicular force (perpendicular to the direction of motion) does no work, but only changes the direction of motion of an object. | Student Book | P.(182 – 183) |
| | | Figure 1 | P.182 |

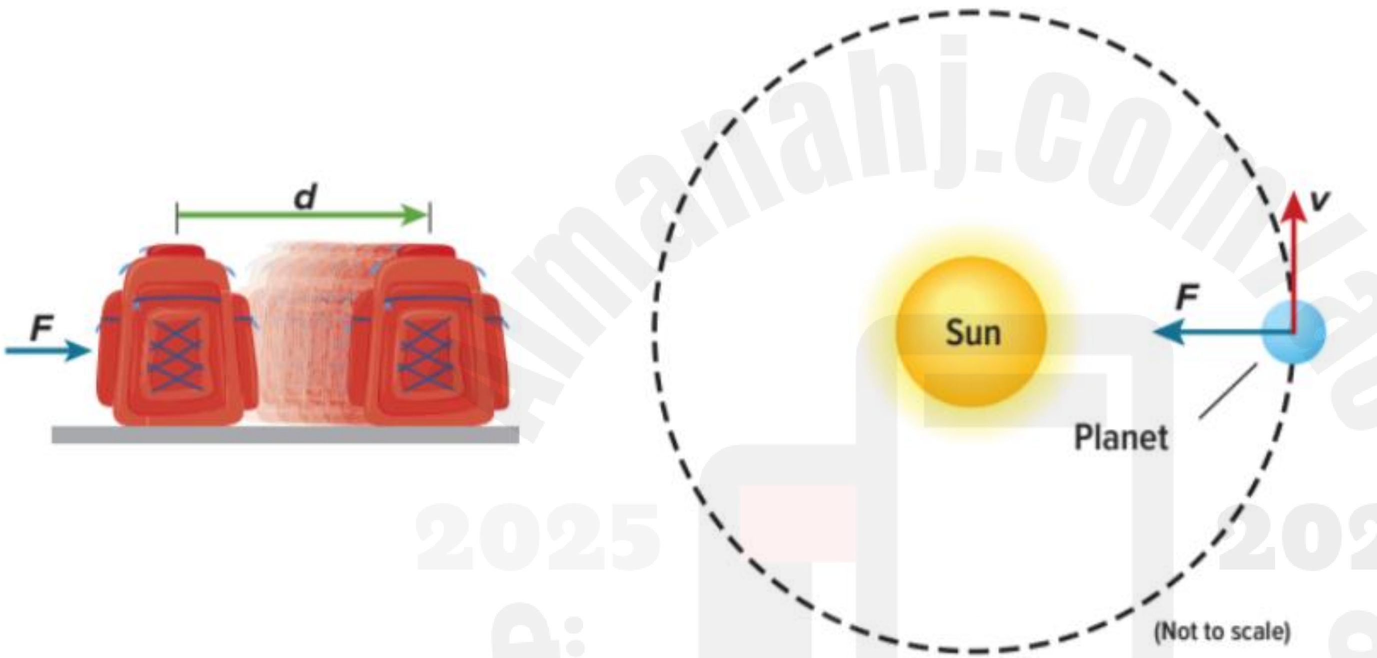



**Figure 1** Work is done when a force is applied through a displacement.

**Identify** *another example of when a force does work on an object.*

| | | | |
|---|---|---|---|
| 7 | 1. Determine the mechanical work done on a body by a constant force divided by a displacement as the dot product of the force vector and the displacement vector, and explain that the work done by a variable force is represented by the area under the force-displacement graph.<br>2. Illustrate when work is positive, negative or zero with suitable examples. | student Book | P.185 |
| | | Q.(1 – 9) & 8 | P.(186 – 187) |

## PRACTICE Problems

1. Refer to Example Problem 1 to solve the following problem.
   a. If the hockey player exerted twice as much force (9.00 N) on the puck over the same distance, how would the amount of work the stick did on the puck be affected?
   b. If the player exerted a 9.00-N force, but the stick was in contact with the puck for only half the distance (0.075 m), how much work does the stick do on the puck?
2. Together, two students exert a force of 825 N in pushing a car a distance of 35 m.
   a. How much work do the students do on the car?
   b. If their force is doubled, how much work must they do on the car to push it the same distance?

| | | | |
|---|---|---|---|
| 7 | 1. Determine the mechanical work done on a body by a constant force divided by a displacement as the dot product of the force vector and the displacement vector, and explain that the work done by a variable force is represented by the area under the force-displacement graph.<br>2. Illustrate when work is positive, negative or zero with suitable examples. | student Book | P.185 |
| | | Q.(1 – 9) | P.(186 – 187) |

**3.** A rock climber wears a 7.5-kg backpack while scaling a cliff. After 30.0 min, the climber is 8.2 m above the starting point.

**a.** How much work does the climber do on the backpack?

**b.** If the climber weighs 645 N, how much work does she do lifting herself and the backpack?

**4. CHALLENGE** Marisol pushes a 3.0-kg box 7.0 m across the floor with a force of 12 N. She then lifts the box to a shelf 1 m above the ground. How much work does Marisol do on the box?

| | | | |
|---|---|---|---|
| 7 | 1. Determine the mechanical work done on a body by a constant force divided by a displacement as the dot product of the force vector and the displacement vector, and explain that the work done by a variable force is represented by the area under the force-displacement graph.<br>2. Illustrate when work is positive, negative or zero with suitable examples. | student Book | P.185 |
| | | Q.(1 – 9) & 8 | P.(186 – 187) |

**5.** If the sailor in Example Problem 2 pulls with the same force through the same displacement but at an angle of 50.0°, how much work is done on the boat by the rope?

**6.** Two people lift a heavy box a distance of 15 m. They use ropes, each of which makes an angle of 15° with the vertical. Each person exerts a force of 225 N. Calculate the work done by the ropes.

**7.** An airplane passenger carries a 215-N suitcase up the stairs, a displacement of 4.20 m vertically and 4.60 m horizontally.

**a.** How much work does the passenger do on the suitcase?

**b.** The same passenger carries the same suitcase back down the same set of stairs. How much work does the passenger do on the suitcase to carry it down the stairs?

| 8 | Apply the relationship between power, the work done by a force, and the time interval in which that work is done (P=W/t). | Student Book | P.(190 – 192) |
|---|---|---|---|
| | | Q.(14 – 18); Q.(25 – 26) | P.191; P.192 |

## PRACTICE Problems

**14.** A cable attached to a motor lifts a 575-N box up a distance of 20.0 m. The box moves with a constant velocity and the job is done in 10.0 s. What power is developed by the motor in W and kW?

**15.** You push a wheelbarrow a distance of 60.0 m at a constant speed for 25.0 s by exerting a 145-N force horizontally.

**a.** What power do you develop?

**b.** If you move the wheelbarrow twice as fast, how much power is developed?

**16.** What power does a pump develop to lift 35 L of water per minute from a depth of 110 m? (One liter of water has a mass of 1.00 kg.)

| | | | |
|---|---|---|---|
| 8 | Apply the relationship between power, the work done by a force, and the time interval in which that work is done (P=W/t). | Student Book | P.(190 – 192) |
| | | Q.(14 – 18); Q.(25 – 26) | P.191; P.192 |

**17.** An electric motor develops 65 kW of power as it lifts a loaded elevator 17.5 m in 35 s. How much force does the motor exert?

**18. CHALLENGE** A winch designed to be mounted on a truck, as shown in **Figure 10,** is advertised as being able to exert a $6.8\times10^{3}$-N force and to develop a power of 0.30 kW. How long would it take the truck and the winch to pull an object 15 m?


Figure 10

| | | | |
|---|---|---|---|
| 8 | Apply the relationship between power, the work done by a force, and the time interval in which that work is done (P=W/t). | Student Book | P.(190 – 192) |
| | | Q.(14 – 18); Q.(25 – 26) | P.191; P.192 |

25. **Work and Power** Does the work required to lift a book to a shelf depend on how fast you raise it? Does the power required to lift it depend on how fast you raise it? Explain.

26. **Power** An elevator lifts a total mass of $1.1\times10^3$ kg a distance of 40.0 m in 12.5 s. How much power does the elevator deliver?

| 9 | 1. Define energy as the ability of a system to do work or produce a change in itself or in the surrounding world, measured in Joules.<br>2. Determine the international unit by which all types and forms of energy are measured. | Student Book | P.188 |
|---|---|---|---|
| | | Content | P.188 |

## Energy

Look again at the equation $W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$. What property of a system does $\frac{1}{2}mv^2$ describe? A massive, fast-moving vehicle can do damage to objects around it, and a baseball hit at high speed can rise high into the air. That is, a system with this property can produce a change in itself or the world around it. This ability of a system to produce a change in itself or the world around it is called **energy** and is represented by the symbol $E$.

The right side of the equation, $\frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$, indicates a change in a specific kind of energy. That is, work causes a change in energy. This is the **work-energy theorem,** which states that when work is done on a system, the result is a change in the system's energy. The work-energy theorem can be represented by the following equation.

### Work-Energy Theorem

Work done on a system is equal to the change in the system's energy.

$$W = \Delta E$$

Since work is measured in joules, energy must also be measured in joules. In fact, the unit gets its name from the nineteenth-century physicist James Prescott Joule, who established the relationship between work done and the change in energy. Recall that 1 joule equals 1 N·m and that 1 N equals 1 kg·m/s$^2$. Therefore, 1 joule equals 1 kg·m$^2$/s$^2$. These are the same units that $\frac{1}{2}mv^2$ has.

Through the process of doing work, energy can move between the external world and the system. The direction of energy transfer can be either way. If the external world does work on a system, then $W$ is positive and the energy of the system increases. If a system does work on the external world, then $W$ is negative and the energy of the system decreases. In summary, work is the transfer of energy that occurs when a force is applied through a displacement.

**Changing kinetic energy** So far, we have discussed the energy associated with a system's motion. For example, the bobsledders in **Figure 6** do work on their sled to get it moving at the beginning of a race. The energy associated with motion is called **kinetic energy** ($KE$).

In the case of the bobsled, work resulted in a change in the object's kinetic energy. There are, however, many other forms of energy.

Work can cause a change in these other forms, as well. Some of these forms, such as potential energy and thermal energy, will be explored later in this module and in subsequent modules.

**Figure 6** The bobsledders do work on the bobsled when they push it. The result is a change in the bobsled's kinetic energy.

| 10 | 1. Calculate the work done by the gravitational force when an object is lifted or lowered from a reference level.<br>2. Discuss energy transformations in situations where an object moves vertically upward or downward. | Student Book<br>Figure 15 & 16; Q.(30 – 34) | P.(196 – 198)<br>P.(196 – 197); P.199 |
|---|---|---|---|

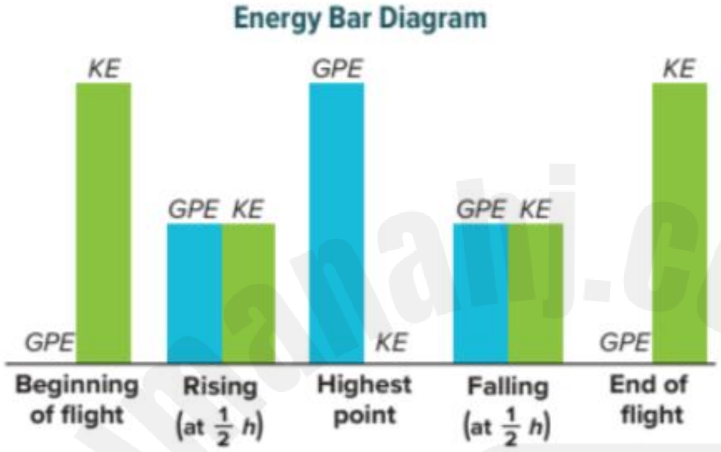



**Figure 15** As the ball rises, its kinetic energy transforms into potential energy in the ball-Earth system. As it falls, the potential energy is transformed into kinetic energy. In this process, Earth also gains and loses very small amounts of kinetic energy. The energy bar diagrams show how the ball's energy changes.

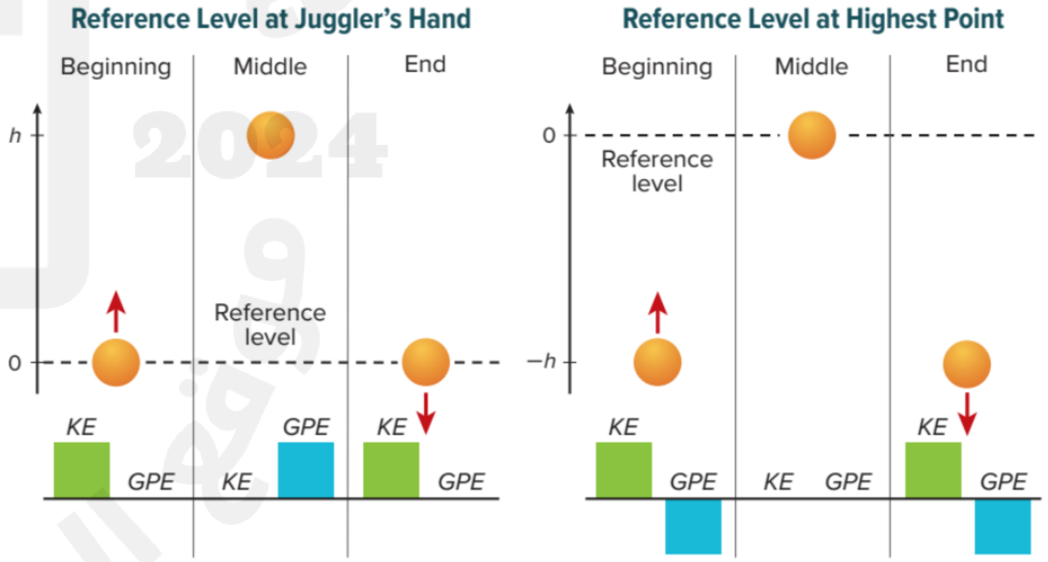



**Figure 16** Where you put the reference level affects the system's *GPE*. Where you put the reference level does not affect how the system's *GPE* changes over time, however.

| 10 | 1. Calculate the work done by the gravitational force when an object is lifted or lowered from a reference level.<br>2. Discuss energy transformations in situations where an object moves vertically upward or downward. | Student Book | P.(196 – 198) |
|---|---|---|---|
| | | Figure 15 & 16; Q.(30 – 34) | P.(196 – 197); P.199 |

## PRACTICE Problems

**30.** In Example Problem 4, what is the potential energy of the ball-Earth system when the bowling ball is on the floor? Use the rack as your reference level.

**31.** If you slowly lower a 20.0-kg bag of sand 1.20 m from the trunk of a car to the driveway, how much work do you do?

**32.** A boy lifts a 2.2-kg book from his desk, which is 0.80 m high, to a bookshelf that is 2.10 m high. What is the potential energy of the book-Earth system relative to the desk when the book is on the shelf?

**33.** You are walking around an old building and notice that it is falling apart. If a 1.8-kg brick falls to the ground from the building's chimney, which is 6.7 m high, what is the change in the potential energy of the brick-Earth system?

**34. CHALLENGE** A worker picks up a 10.1-kg box from the floor and sets it on a table that is 1.1 m high. He slides the box 5.0 m along the table and then lowers it back to the floor. What were the changes in the box-Earth system's energy, and how did the system's total energy change? (Ignore friction.)

| | | | |
|---|---|---|---|
| 11 | 1. Define kinetic energy and apply the relationship between a particle's kinetic energy, mass, and speed ($KE=1/2mv^2$).<br>2. Solve problems related to work and kinetic energy. | Student Book | P.194 |
| | | Get it? Explain; Q.49 | P.194; P.211 |

## Get It?

**Explain** Using the equation for translational kinetic energy, show why a car moving at 20 m/s has four times the translational kinetic energy of the same car moving at 10 m/s.

49. **Kinetic Energy** Suppose a glob of chewing gum and a small, rubber ball collide head-on in midair and then rebound apart. Would you expect kinetic energy to be conserved? If not, what happens to the energy?

| | | | |
|---|---|---|---|
| 12 | 1. Relate the rotational kinetic energy to the object's moment of inertia and its angular velocity: 〖KE〗_rot=1/2 Iω^2.<br>2. Calculate the translational and rotational kinetic energies for objects. | Student Book | P.195 |
| | | Q.37 | P.201 |

37. **Rotational Kinetic Energy** On a playground, some children push a merry-go-round so that it turns twice as fast as it did before they pushed it. What are the relative changes in angular momentum and rotational kinetic energy of the merry-go-round?

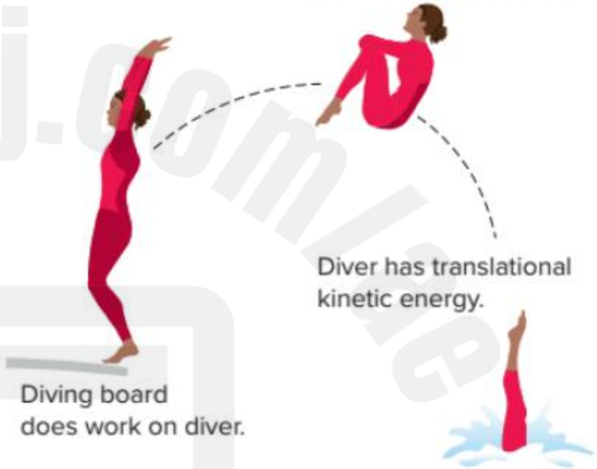



**Figure 14** The diving board does work on the diver. This work increases the diver's kinetic energy.

**Rotational kinetic energy** If you spin a toy top in one spot, you might say that it does not have kinetic energy because the top does not change its position. However, to make the top rotate, you had to do work on it. The top has **rotational kinetic energy,** which is energy due to rotational motion. Rotational kinetic energy can be calculated using $KE_{rot} = \frac{1}{2} I\omega^2$, where $I$ is the object's moment of inertia and $\omega$ is the object's angular velocity.

In **Figure 14,** the diving board does work on a diver, transferring translational and rotational kinetic energy to the diver. Her center of mass moves as she leaps, so she has translational kinetic energy. She rotates about her center of mass, so she has rotational kinetic energy. When she slices into the water, she has mostly translational kinetic energy.

| | | | |
|---|---|---|---|
| 13 | Apply the equation (P=ρgh) to calculate the pressure exerted by a column of fluid on a body where ρ is the density of the fluid, g is the gravitational acceleration, and h is the height of the column of fluid. | Student Book | P.238 |
| | | Figure 11 | P.238 |

## Pressure of Fluid on a Body

The pressure a column of fluid exerts on a body is equal to the density of the fluid times the height of the column times the free-fall acceleration.

$$P = \rho h g$$

The pressure of a fluid on a body depends on the density of the fluid, its depth, and $g$. As shown in **Figure 11,** submersibles have explored the deepest ocean trenches and encountered pressures in excess of 1000 times standard air pressure.

**BIOLOGY Connection** Scientists use submersibles to learn more about deep ocean ecosystems. In 1977 the first hydrothermal vents were discovered as the crewed submersible ALVIN cruised over the Pacific Ocean floor. Hydrothermal vents form when superheated water flows up from cracks in the seafloor.

**Figure 11** Submersibles are built to withstand the crushing pressure exerted by the water column.

| 14 | Apply Pascal's principle to hydraulic systems to solve problems. | Student Book | P.(237 - 238) |
|---|---|---|---|
| | | Figure 10; Q.(24 – 26); Q.(33, 36) | P.237; P.238; P.244 |

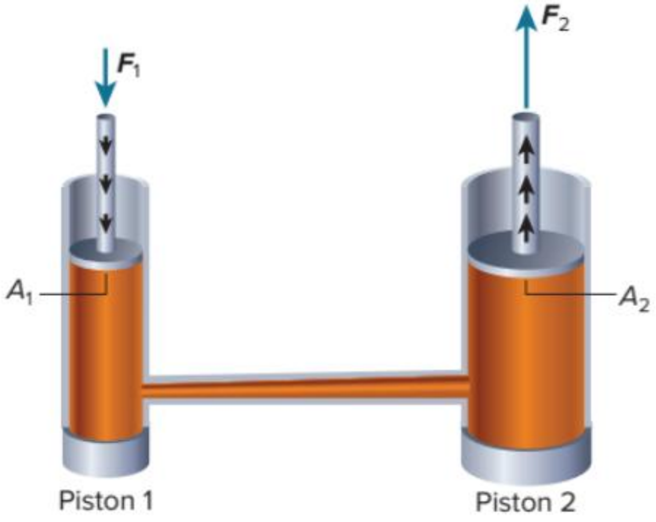



**Figure 10** As $F_1$ exerts pressure on the smaller piston (piston 1), the pressure is transmitted throughout the fluid. As a result, a multiplied force ($F_2$) is exerted on the larger piston (piston 2).

**Infer** *How would $F_2$ change if $F_1$ increased? Explain why.*

**24.** Dentists' chairs are examples of hydraulic-lift systems. If a chair weighs 1600 N and rests on a piston with a cross-sectional area of 1440 $cm^2$, what force must be applied to the smaller piston, with a cross-sectional area of 72 $cm^2$, to lift the chair?

**25.** A mechanic exerts a force of 55 N on a 0.015 $m^2$ hydraulic piston to lift a small automobile. The piston the automobile sits on has an area of 2.4 $m^2$. What is the weight of the automobile?

**26.** **CHALLENGE** By multiplying a force, a hydraulic system serves the same purpose as a lever or a seesaw. If a 400-N child standing on one piston is balanced by a 1100-N adult standing on another piston, what is the ratio of the areas of their pistons?

33. **Transmission of Pressure** A toy rocket launcher is designed so that a child stomps on a rubber cylinder, which increases the air pressure in a launching tube and pushes a foam rocket into the sky. If the child stomps with a force of 150 N on a $2.5\times10^{-3}$-$m^2$ area piston, what is the additional force transmitted to the $4.0\times10^{-4}$-$m^2$ launch tube?

36. **Pressure and Force** An automobile weighing $2.3\times10^4$ N is lifted by a hydraulic cylinder with an area of 0.15 $m^2$.
    a. What is the pressure in the hydraulic cylinder?
    b. The pressure in the lifting cylinder is produced by pushing on a 0.0082-$m^2$ cylinder. What force must be exerted on this small cylinder to lift the automobile?

| | | | |
|---|---|---|---|
| 15 | 1. Verify, through experimental demonstration, Bernoulli equation [dependence of pressure at some point inside a dynamic fluid on the speed of the fluid at that point and the height of the point], and develop mathematical models for special cases of fluid flow.<br>2. Explain the change of speed of flow of a fluid passing through a pipe with a variable cross – section. | Student Book | P.(242 - 243) |
| | | Figure 15; [redacted] Q.38 | P.243; [redacted]; P.244 |

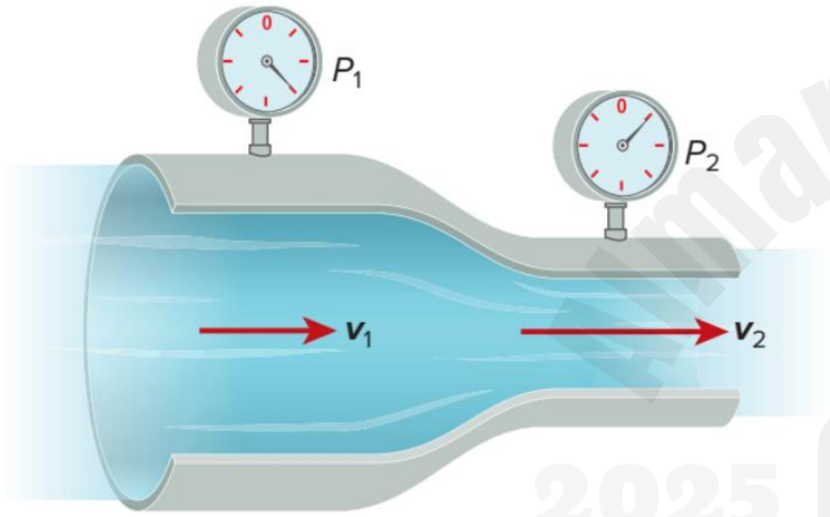



**Figure 15** The fluid flowing through this pipe also demonstrates Bernoulli's principle. As the velocity of the fluid increases ($v_2$ is greater than $v_1$), the pressure it exerts decreases ($P_2$ is less than $P_1$).

38. **Critical Thinking** A tornado passing over a house sometimes makes the house explode from the inside out. How might Bernoulli's principle explain this phenomenon? What could be done to reduce the danger of a door or window exploding outward?