Gravitation - Questions

Short Answer Questions

1. A change in the speed of a moving object can be obtained by applying a ________________.
2. A change in the direction of a moving object can be obtained by applying a ________________.
3. Gravity acts on objects pertaining the property of ________________.
4. Are horizontal and vertical velocity dependent on each other?
5. Is "falling" scientifically correct?
6. Define centripetal Force?
7. How does an object under circular motion will react if the centripetal force is suddenly removed?
8. What is barycentre?
9. Write down two clauses of the newton's law of gravitation with their mathematical couterparts.
10. Who is credited with discovering the value for the universal gravitational constant?
11. List down Kepler's law of planetary motion.
12. Why is the earth round?
13. At what point on the earth's surface would you feel the highest amount of pull?
14. At what point on the earth's surface would you feel the least amount of pull?
15. Why is the earth not a perfect sphere?
16. If a stone of 1 kg is dropped from a distance of 10 m, what is its velocity when it hits the ground? (Take g as 10 $m\ s^{-2}$.
17. Mass is a
    (a) Scalar
    (b) Vector
    (c) Tensor
    (d) None of the above
18. To what point is your weight acting?

19. If a stone of 100 *kg* is dropped from a distance of 10 *m* on the sun, what is its speed when it hits the ground? (Given $g_s un$ = 28.02 × $g_e arth$).
20. How much time will a stone of 10 *kg* take to touch the ground of the moon, if dropped from a height of 10 *m*?
21. The other name of the units $N\ m^{-2}$ is also known as .
22. Why do sports-persons wear studs (shoes with pointy protrusions)?
23. It would be a nightmare to sleep on a bed with single nail, but can be comfortable (relaiveley) when there are thousands of nails kept at the same level to make a nice bed of nails?
24. Is there a force above our heads due to the atmosphere?
25. We have about 6.66 *kg* of air *per* $inch^2$ above our heads due to the atmosphere. What is the pressure? (1 $inch^2$ = $0.00064516 m^2$)
26. Why are tires inflated?
27. What special property fluids posses with respect to pressure which differs from solids?
28. What is buoyant force?
29. Buoyant force can be balanced by applying an ________________.
30. Define density.
31. Calculate the density of an object of mass 2 *kg* and a volume of 20 m^3.
32. Ice floats on water even though it is essentially made up of water, why?
33. Density of an object is directly proportional to the ________________.

Long Answer Questions

For simplicity, take $g = 10\ m\ s^{-2}$

1. At some point of the year, Jupiter is about 5.8×10^{11} m away from earth. Calculate the gravitational force between the two.
   $M_J = 1.9 \times 10^{27}\ kg$; $M_E = 6 \times 10^{24}\ kg$; $G = 6.67x10^{-11}\ N\ m^2\ kg^{-2}$
2. Calculate the gravitational force between the sun and the earth and hence calculate the acceleration experienced by the earth.
   $M_S = 2 \times 10^{30}\ kg$; $M_E = 6 \times 10^{24}\ kg$; $r = 1.5 \times 10^{11}\ m$; $G = 6.67 \times 10^{-11}\ N\ m^2\ kg^{-2}$
3. Using Kepler's laws of gravitation, deduce the inverse square law incorporated in the universal law of gravitation given by Newton.

4. We all have heard that the earth revolves around the sun or the moon revolves around the earth. Is it really the case? Do they really revolve around the Sun or the earth? If No, explain. Think along the lines that if we have two planets of the same mass pulling each other, how would they respond?

5. State Kepler's three laws for the motion of celestial objects and explain the variation of the speed of the earth at different seasons. Is it fast in summer and slow in winter or vice versa.
Hint: The earth is farthest from the sun in July and closest in January.

6. A rocket is propelled at the start with a constant acceleration of 30 $m\ s^{-2}$. At an altitude of 5000 m, the first part of the rocket is shed. Calculate

   (a) The time at which the part is shed.

   (b) The time taken by the part to hit the ground.

   (c) The final speed at which the part hits the ground.

7. In the above problem, we have neglected air drag. Usually the force experienced by an object due to air drag is directly proportional to its square of the velocity. Take the proportionality constant to be 0.1, mass of the part to be 500 kg and find the speed at which the part hits the ground. Also find the time and distance it takes to attain this speed from the maximum distance i.e., at the top.

8. Assume that the path of a stone, under gravity, thrown at an angle is a parabola. Using just this assumption, argue that the orbit of the planets is elliptical.

9. Assume that the earth is a hollow sphere with all the mass concentrated at the circumference. Prove that an object placed inside the shell does not experience any gravitational force.

10. Determine the different physical factors by which g varies on a planet.

11. Assume that we do not know the mass of the moon. You are given the task to calculate the mass of the moon using the some data of the moon. If a light beam can circle the moon it will circle 27.48 times around the moon in 1 *second*. It is also given that a 10 kg stone when dropped from a 10 m height on moon takes about 3.5 *seconds* to reach the ground. Using these data find the mass of the moon. $c = 3x10^8\ m/s$

12. If we doubled the mass of the moon, Calculate the amount, in meters, by which the orbit will shrink.

13. Imagine you are standing on a weighing scale and it is showing 50 kg. You push the scale to jump and the reading starts to increase. You jump till a height of 2 *meters* and fall back on the scale and the reading of the scale again increases drastically before

settling back at 50 kg. If it took 0.5 *seconds* to come to a stop from the time your feet touched the floor of the scale, answer the following questions:

(a) Will the maximum reading at the start of the jump be equal to the maximum reading at the end of the jump.

(b) Find the maximum reading of the scale.

14. Explain the different states in which you would fell weightlessness.

15. You are in deep space along with your crew inside a space craft of of 25 *meters*. You are given a task to create artificial gravity so that your weight is equal to the weight as measured on the earth. How would you achieve this task and what should be the speed of rotation.

16. What is the difference between force, weight and thrust?

17. A person weighs 70 kg. In summer he wears a shoe with the sole area as 7 cm^2 and in winter, due to snow, he wears a shoe with a sole area of 15 cm^2. Find the different applied pressure on the ground by the person.

18. The dimensions of a block of wood is $60 \times 60 \times 60$ cm. A person is applying force of 30 N at an angle of 30 *degrees* with respect to the floor. Find the pressure experienced by the floor.

19. The leaning tower of Pisa leans about 4 *degrees* about the vertical axis. It weighs 14500 *metric tons* and the area of the base diameter is 15.5 *meters*. Find the pressure applied by the tower.

20. Mercury is contained inside a spherical container of radius 5 *meters*. Density of mercury is 13.6 $g\ mL^{-1}$. Find the pressure applied by mercury on the walls of the container.

21. A bucket weighs 500 *grams* and is used to ferry water from a well. Calculate the net change in the force required to pull a full bucket of water if the capacity of the bucket is 2 *liters*. Also calculate the amount of force required to pull the bucket when submerged as well as when it is outside the water. (1 L = 1 *kg of water*)

22. A block of gold is immersed in water, which is kept in a cylindrical container of diameter 10 cm. When the block of gold is completely submerged the water level is increased by 2 cm. Find the:

(a) Force experienced by the block of gold.

(b) Mass of the gold.

23. A plastic cylinder of radius 5 cm and 10 cm height floats on water. The weight of the container is 100 *grams*. How much force you have to apply in order to completely submerge the container.

24. A hot air balloon can hold about 150 m^3 of air (density = 0.Kg m^3 at 25 °C). The weight of the balloon is 15 KN. The pressure of the air inside the balloon changes with temperature and is given by the formula $pressure(T) = pressure(25) \times temperature$. Find the temperature at which the balloon will start to lift. Assume the balloon to be spherical.

25. Relative density of a particular substance is 0.5. If a cylindrical block of mass 100 kg and height of 5 m is made out of this substance and is put in water vertically. Find

    (a) If the block floats or sinks

    (b) Height of the block submerged

    (c) How much mass can be kept on top until the block touches the brim

Short Answers

1. Force
2. Force
3. Mass or Energy
4. No
5. No
6. A force that keeps an object in a circular motion by pulling it towards the centre is known as centripetal force.
7. If the centripetal force is suddenly removed, the object will start to move but in a straight line in the direction of motion which will be tangential to the circle of revolution.
8. Barycentre is the central point around which two or more bodies revolve.
9. The universal law of gravitation says that the force of gravitation between two objects of mass M and m respectively, separated by a distance r is:

   (a) Directly proportional to the product of their masses, and

   $$F \propto Mm$$

   (b) Inversely proportional to the square of the distance between them.

   $$F \propto \frac{1}{r^2}$$

10. Sir Henry Cavendish
11. Kepler's laws of planetary motion:

    (a) Planets move in ellipses with the Sun at one focus.

    (b) The radius vector describes equal areas in equal times.

    (c) The squares of the periodic times are to each other as the cubes of the mean distances.

12. Because the gravitational force pulls everything towards the center
13. At north and south poles, where the surface is closer to the centre of the earth
14. At the equator
15. Because it is spinning and hence, tends to throw the surface along the equator which flattens the poles

16. As the mass of object has no effect on an object under freefall, the final velocity can be calculated as follows:
Initial velocity, $u = 0\ m\ s^{-1}$,
Distance, $s = 10\ m$,
As acceleration due to gravity is acting along to the direction of motion.
Hence, $g = 10\ m\ s^{-2}$.

We know that,

$$v^2 = u^2 + 2\,a\,s$$
$$v^2 = (0)^2 + 2 \times (10\ m\ s^{-2}) \times 10$$
$$v^2 = 20 \times 10$$
$$v = \sqrt{200}\ m$$
$$v = 14.14\ m\ s^{-1}$$

17. (a) Scalar

18. Towards the centre of the earth

19. As the mass of object has no effect on an object under freefall, the final velocity can be calculated as follows:
Initial velocity, $u = 0\ m\ s^{-1}$,
Distance, $s = 10\ m$,
As acceleration due to gravity is acting along to the direction of motion.
Hence, $g = 28.02 \times 9.8 = 274.6\ m\ s^{-2}$.

We know that,

$$v^2 = u^2 + 2\,a\,s$$
$$v^2 = (0)^2 + 2 \times (274.6\ m\ s^{-2}) \times 10$$
$$v = \sqrt{5492}\ m$$
$$v = 74.1\ m\ s^{-1}$$

20. As the mass of object has no effect on an object under freefall, the time taken can be calculated as follows:
Initial velocity, $u = 0\ m\ s^{-1}$,
Distance, $s = 10\ m$,
As acceleration due to gravity is acting along to the direction of motion.
Hence, $g = 1.625\ m\ s^{-2}$.

We know that,

$$\text{Distance travelled, } s = ut + \frac{1}{2}at^2$$
$$10 = 0 + \frac{1}{2} \times 1.625 \times t^2$$
$$\implies t^2 = 12.3$$
$$\implies t = \sqrt{12.3} = 3.5\ s$$

21. Pascals
22. Studs concentrates the thrust of the body’s weight and makes the shoes sole go inside the surface, hence increasing the grip of the person.
23. Pressure is less on each nail as the force is distributed.
24. Yes
25.

$$\begin{aligned} Thrust &= 6.66 \times 9.8 = 65.27\ N\ inch^{-2} \\ Area &= 0.00064516m^2 \\ Pressure &= \frac{Thrust}{Area} \\ &= \frac{65.37}{0.00064516} \\ &= 1,01,168.70\ N\ m^{-2} \\ &= 1.01 \times 10^5\ N\ m^{-2} \end{aligned}$$

26. To reduce the wire and tear of the wheel and the rim as the force is distributed.
27. Fluids exert thrust and pressure undiminished in all directions whereas solids exert thrust and pressure in only one direction which is towards the centre of the earth.
28. When an object is immersed in a fluid, it experiences an upward force which is always acting opposite to gravity. This force is known as buoyant force.
29. Downthrust
30. Density is defined as an objects mass per unit volume.

31. Density is defined as an objects mass per unit volume. Hence,

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{2}{20} = 0.2\ kg\ m^{-3}$$

32. When Ice is formed, it expands which creates tiny air pockets which decreases its density

33. Mass

Long Answers

1. The gravitational force berween any two bodies is given by,

$$F = G\,\frac{Mm}{r^2}$$

$$\text{Mass of Jupiter, } M = 1.9 \times 10^{27}\ kg$$
$$\text{Mass of Earth, } m = 6 \times 10^{24}\ kg$$
$$\text{Distance, } r = 5.8 \times 10^{11}\ m$$
$$F = (6.67 \times 10^{-11}\ N\ m^2\ kg^{-2}) \times \frac{1.9 \times 10^{27}\ kg \times 6 \times 10^{24}\ kg}{(5.8 \times 10^{11}\ m)^2}$$
$$= 2.26 \times 10^{18}\ N$$

2. The gravitational force berween any two bodies is given by,

$$F = G\,\frac{Mm}{r^2}$$

$$\text{Mass of Jupiter, } M = 2 \times 10^{30}\ kg$$
$$\text{Mass of Earth, } m = 6 \times 10^{24}\ kg$$
$$\text{Distance, } r = 1.5 \times 10^{11}\ m$$
$$F = (6.67 \times 10^{-11}\ N\ m^2\ kg^{-2}) \times \frac{2 \times 10^{30}\ kg \times 6 \times 10^{24}\ kg}{(1.5 \times 10^{11}\ m)^2}$$
$$= 35.57 \times 10^{21}\ N$$

The acceleration experienced by earth can be calculated as,

$$F = ma$$
$$35.57 \times 10^{21}\ N = (6 \times 10^{24}\ kg) \times a$$
$$\implies a = \frac{35.57 \times 10^{21}\ N}{6 \times 10^{24}\ kg}$$
$$= 5.93 \times 10^{-3}\ m\ s^2$$

3. Kepler's first law states that "The orbit of a planet is an ellipse with the Sun at one of the foci". We can assume that the orbit is circular as circle is a special type of ellipse with both its foci coinciding at the center. In this very special case, the planet of mass M is going around the Sun at velocity $v$and the radius is r. The centripetal force experienced by the planet is $F_c = \frac{mv^2}{r}$ which makes $F_c \propto \frac{v^2}{r}$. As the motion of the planet is periodic, let us assume the period to be T, that means the planet takes 'T' amount of time to complete one revolution around the sun. Then the velocity of the planet is given by $velocity = \frac{Distance}{Time}$. In T amount of time, the distance covered by the planet is $2\pi r$. Therefore, $v = \frac{2\pi r}{T}$. Substituting this in F_c gives, $F_c \propto \frac{r}{T^2}$, which can also be written as $F_c \propto \frac{r^3}{T^2} \times \frac{1}{r^2}$; By Kepler's III law, $\frac{r^3}{T^2} = constant$, which implies, $F_c \propto \frac{1}{r^2}$. This is how Newton arrived at the famous inverse square relationship for the universal law of gravitation.

4. No, the earth and the other planets do not revolve around the Sun. In fact, the moon also does not revolve around the earth. Even though the pull by the small planets or the moon is very small, it does have an effect and the effect is that they revolve around a common center called the barycenter. The whole solar system revolves around a common point, including the sun. For the earth and the moon the barycenter is inside the earth, about 1700 Km inside the earth's surface, as for the solar system, the barycenter changes it location which depends upon the instantaneous location of all the planets. And as for the planets with equal mass, they would revolve around the center of the line joining their center of masses. This is most commonly seen in stars, and these type of star system is called as binary stars.

5. The 3 Kepler's laws for the motion of celestial objects is as follows:

   (a) The orbit of a planet is an ellipse with the Sun at one of the foci.

   (b) The line joining the planet and the Sun sweep equal areas in equal intervals of time.

   (c) The cube of the mean distance of a planet from the Sun is proportional to the square of its orbital period T. Or,

$$\frac{r^3}{T^2} = constant$$

.

The variation of speed of any planet along its orbit depends upon the distance from the massive object around which it is rotating. From Kepler's II law, the area swept by the line joining the planet and the Sun is equal, this implies that the speed needs to be larger when it is closer to the sun and slower if the planet is farther from the sun. Therefore, the speed of earth is highest in January and slowest in July. This also tells that the distance from the sun is not responsible for the occurrence of seasons on earth.

6. Acceleration of the rocket, $a_r = 30\ m\ s^{-2}$
Acceleration due to gravity, $g = 10\ m\ s^{-2}$
Effective acceleration, $a = (30 - 10) = 20\ m\ s^{-2}$
Distance, $s = 5000\ m$
Initial velocity, $u = 0\ m\ s^{-1}$

(a) Time at which first part was shed,

$$\begin{aligned} \textit{Distance travelled},\ s &= \frac{1}{2}at^2 \\ 5000 &= 0.5 \times 20 \times t^2 \\ t &= 22.36\ \textit{seconds} \end{aligned}$$

(b) Time taken by the part to hit the ground has to be calculated in two parts. In the first part, we calculate the time it takes to reach the top after the part was shed because the part will not start falling the moment it is shed. The part will travel upwards till its velocity becomes zero and then start falling back to the ground, which is the second part. For the first part, we need the initial velocity once the part is shed,

$$\begin{aligned} v &= u + at \\ v &= 0 + at \\ v &= 20 \times 22.36 \\ v &= 447.2\ m\ s^{-1} \end{aligned}$$

Take the current distance as ground zero and the time to be zero seconds as well. At the maximum distance the final velocity will be zero. As the part is already shed, it will experience only the acceleration due to gravity downwards.
Acceleration due to gravity, $g = -10\ m\ s^{-2}$
Time taken to reach the maximum height,

$$\begin{aligned} v &= u + at \\ 0 &= 447.2\ m\ s^{-1} - 10 \times t_{up} \\ \implies t_{up} &= 44.72\ s \end{aligned}$$

Distance covered in 44.72 seconds, to reach the maximum height,

$$\begin{aligned} v^2 &= u^2 + 2as \\ 0^2 &= 447.2^2 - 2 \times 10 \times s_{up} \\ \implies s_{up} &= 9999.4\ m \end{aligned}$$

The part was shed at 5000 m and it has travelled an additional 9999.4 m so that its velocity becomes zero. Total distance to be covered to reach the surface,

$$s_t = 5000 + 9999.4 = 14999.4m$$

Time taken to cover this distance,

$$\begin{aligned} s_t &= ut + \frac{1}{2}at^2 \\ 14999.4 &= 0 + \frac{1}{2} \times 10 \times t_{down}^2 \\ \implies t_{down} &= \sqrt{2,999.88} = 54.77\ s \end{aligned}$$

Total time to hit the ground is,

$$\begin{aligned} t &= t_{up} + t_{down} \\ t &= 44.72 + 54.77 \\ t &= 99.5\ s \end{aligned}$$

(c) Final velocity when the part hits the ground,

$$\begin{aligned} v &= u + at \\ v &= 0 + 10 \times 99.5 \\ v &= 547.7\ m\ s^{-1} \end{aligned}$$

7. If the air drag force is directly propotional to square of the velocity, then

$$F_{drag} \propto v^2$$

As the constant of proportionality is 0.1, we can write the drag force as,

$$F_{drag} = 0.1\, v^2$$

The maximum velocity, v_{max} will be attained by the object when the drag force is balanced by the weight of the object,

$$F_{drag} = mg$$
$$0.1 \times v_{max}^2 = 500 \times 10$$
$$v_{max} = 223.6\ m\ s^{-1}$$

Time take to reach this velocity,

$$v = u + at$$
$$223.6 = 0 + 10 \times t$$
$$\implies t = 22.36\ s$$

Distance travelled to reach this velocity,

$$s = ut + \frac{1}{2}at^2$$
$$s = 0 + \frac{1}{2} \times 10 \times (22.36)^2$$
$$s = 2499.85\ m$$

8. A stone follows a parabolic path when thrown upwards at an angle. The more force we apply i.e., more acceleration and hence more initial velocity the parabola starts to stretch and the stone covers a larger distance. At a particular initial velocity, the stone moves just the right amount of horizontal and vertical distance as the earth's surface curves. This enables the orbit to be circular or elliptical.

9. Consider an arbitrary point inside the hollow sphere. Let this point be r_1 and r_1 meters away from each of the walls respectively. Imagine a torch light is being shone from this point towards the walls. Note that the angle, *theta*(θ), at both the ends is very small (this can be made sure using a very good quality torch light). The illuminated region one of the parts that applies a gravitational force at this point. Also the illuminated region contains the mass that affects this force. More the area implies more the mass, therefore the mass depends on the area. The area is proportional to the radius (πr^2), and r is given by the arc length $r_1\theta$ and $r_2\theta$. Therefore we can write,

$$\frac{m_1}{m_2} = \frac{r_1^2 \times \theta^2}{r_2^2 \times \theta^2} = \frac{r_1^2}{r_2^2}$$

The total force experience at this point by an object of mass, M, is,

$$F_{total} = \frac{Gm_1}{r_1^2} - \frac{Gm_2}{r_2^2}$$
$$F_{total} = GMm_1 \times \left(\frac{1}{r_1^2} - \frac{m_2}{m_1 \times r_2^2}\right)$$

But,

$$\frac{m_2}{m_1} = \frac{r_2^2}{r_1^2}$$

$$F_{total} = GMm_1 \times \left(\frac{1}{r_1^2} - \frac{r_2^2}{r_1^2 \times r_2^2}\right)$$
$$F_{total} = 0$$

If we carry this same argument for all the different angles at which the light can be shown, by symmetry of the sphere, the total force at this arbitrary point and henceforth, all the points inside the hollow sphere is zero.

10. The different physical factors by which g varies on a planet:

    (a) The mass density of the planet: The distribution of the mass determines the center of mass of the planet and hence the distance to the surface changes with this.

    (b) The speed of rotation of the planet: The speed of rotation determines how much centripetal force is experienced at the equator and the planet bulges at the equator. This changes the distance of every point on the planet to the center of mass.

    (c) The shape of the planet: The shape of the planet determines the actual distance between the center of mass and the surface.

11. The force of gravitation is given by,

$$F = G\frac{Mm}{r^2}$$

The radius of the moon can be given by,

$$Speed = \frac{Distance}{Time}$$
$$Distance = speed\ of\ light \times total\ time$$
$$27.48 \times 2\pi r_{moon} = speed\ of\ light \times total\ time$$
$$r_{moon} = 1737499.37\ meters$$

Acceleration due to gravity on moon, a_{moon},

$$
\begin{aligned}
s &= ut + 0.5at^2 \\
10 &= 0 + 0.5 \times a_{moon} \times 3.5^2 \\
a_{moon} &= 1.63\ m/s^2
\end{aligned}
$$

We know that,

$$
\begin{aligned}
F &= G\,\frac{Mm}{r^2} \\
ma_{moon} &= G\,\frac{Mm}{r^2} \\
1.63 &= 6.67 \times 10^{-11}\,\frac{M}{(1737499.37)^2} \\
\implies M &= 7.37 \times 10^{22}\ kg
\end{aligned}
$$

12. Changing the mass affects the force of gravity between the objects but does not change the size of the orbit. The force of gravitation between the earth and the moon will double but the reaction ($F = ma$) to this force by the moon will also double. Hence, the effect of mass cancels out and we have the same orbit as before. This is the same reason as to why objects in freefall does not react to their masses, they will all fall at the same speed regardless of their mass.

13. (a) Yes, as the energy is always conserved, the reading will be equal.

    (b) Initial velocity while jumping is same as final velocity whicle landing. This is given by,

$$
\begin{aligned}
v^2 &= u^2 + 2as \\
v^2 &= 0 + 2 \times 10 \times 2 \\
\implies v &= \sqrt{40} = 6.32\ m\ s^{-1}
\end{aligned}
$$

The aceeleration experienced y the person while landing can be calculated as,

$$
\begin{aligned}
v &= u + at \\
0 &= 6.32 + a \times 0.5 \\
\implies a &= -12.64\ m\ s^{-2}
\end{aligned}
$$

Net downward acceleration, $a_{net} = g + a = 22.64\ m\ s^{-2}$

$$
\begin{aligned}
F &= ma = 50 \times 22.64 \\
F &= 632\ N
\end{aligned}
$$

As the weighing scale divides the force by the acceleration due to gravity, which is 10, the reading will be, 63.2 kg.

14. Different states in which you would fell weightlessness:

    (a) At the center of the earth: We would feel no gravity as the mass is symmetrically divided along all directions and the pull from all the sides are equal. All forces, hence, cancel out and we feel no gravity at that point.
    (b) During freefall: During freefall, the gravity is pulling the objects in proportion to their respective masses and the objects react to that force with proportion to their respective masses. Hence, everything falls at the same rate and no gravity is felt by any of the objects.
    (c) At infinite distance: At infinite distance the r^2 term in the denominator is too large and the force due to gravity is zero.

15. To find the acceleration due to the centripetal force, the acceleration due to gravity should be equal to the acceleration due to rotation of the spaceship.

$$mg = \frac{mv^2}{r}$$
$$10 = \frac{v^2}{25}$$
$$v = 15.8\ m/s^2$$

16. **Force** is a push or a pull. It is way of expending energy.
    Weight is the force experienced by an object under gravity. This always acts towards the center of the earth.
    Thrust is the Force experienced by an object perpendicular to its surface.

17. Pressure is thrust per unit area.

$$Thrust,\ F = mg$$
$$F = 70 \times 10 = 700\ N$$

$$P_{summer} = \frac{700}{7 \times 10^{-4}}$$
$$P_{summer} = 100 \times 10^4\ Pa\ or\ N/m^2$$
$$P_{winter} = \frac{700}{15 \times 10^{-4}}$$
$$P_{winter} = 46.67 \times 10^4\ Pa\ or\ N/m^2$$

18. As pressure is always perpendicular tot he surface. The component of force acting perpendicular is,

$$F = mg\sin(\theta)$$
$$F = mg\sin(30^o)$$
$$F = 15\ N$$
$$P = \frac{Perpendicular\ Force}{Area}$$
$$P = \frac{15}{3600 \times 10^{-4}}$$
$$P = 41.67\ Pa\ or\ N/m^2$$

19. As pressure is always perpendicular tot he surface. The component of weight acting perpendicular to the ground is,

$$F = mg\cos(\theta)$$
$$F = 14500 \times 10 \times \cos(4^o)$$
$$F = 144.6 \times 10^6\ N$$
$$P = \frac{144.6 \times 10^6}{\pi \times (15/2)^2}$$
$$P = 8,18,533.37\ Pa\ or\ N/m^2$$

20. Volume of the container, $V_c = \frac{4}{3}\pi r^3 = 523.53\ m^3$
Area of the container, $A_C = 4\pi r^2 = 314.16\ m^2$
Mass of mercury inside the container, $M_c = 13.6 \times 523.56 \times 1000 = 7.12 \times 10^6\ kg$
Force on walls, $F = 7.12 \times 10^6 \times 10 = 71.2 \times 10^6\ N$
Pressure applied on walls, $P_c = \frac{71.2\times10^6}{314.16} = 226.63 \times 10^3\ Pa\ or\ N/m^2$

21. When the bucket is full, the total weight of the bucket is, $M_{bucket} = 0.5\ kg + 2\ kg = 2.5\ kg$
Force experienced when outside of the well, $F_{out} = 2.5 \times 10 = 25\ N$
Volume of water displaced when the bucket is submerged, $V_{sub} = 2\ L = 2\ Kg$ of water displaced by mass.
Force of buoyancy, $F_{buoy} = 2 \times 10 = 20\ N$
Net difference in force, $F_{net} = 25 - 20 = 5\ N$
Therefore, when the bucket is submerged, the person has to apply 5 N of force whereas when it is out of the water, the person has to apply 25 N of force. So, the net change is 20 N.

22. (a) Force of buoyancy, F_{buoy} = *mass of water displaced* $\times$ 10
Mass of water displaced, $M_{displaced}$ = *Volume of water displaced* $\times$ *density of water*
Volume of water displaced, $V_{displaced}$ = *Area of the cylinder* $\times$ *change in height*
$V_{displaced} = \pi \times r^2 \times h = 157.08 \times 10^{-5}\ m^3$
$M_{displaced} = 157.08 \times 10^{-5} \times 1000 = 157.08 \times 10^{-2}\ kg$
$F_{buoy} = 157.08 \times 10^{-2} \times 10 = 15.708\ N$

(b) Mass of gold,

$$\begin{aligned} M_g &= \text{Volume of water displaced} \times \text{density of gold} \\ &= 157.08 \times 10^{-5} \times 19300 \\ &== 30.31\ kg \end{aligned}$$

23. Force of buoyancy when the cylinder is completely submerged,
F_{buoy} = *Volume of water displaced* $\times$ *density of water* $\times$ *g*
Volume of water displaced, $V_{displaced}$ = *area of the base* $\times$ *height*
$V_{displaced} = \pi \times r^2 \times h = 785.4 \times 10^{-5}\ m^3$
$F_{buoy} = 785.4 \times 10^{-5} \times 1000 \times 10 = 78.54\ N$
Force due to the weight of the cylinder, $F_{weight} = 0.1 \times 10 = 1\ N$
Force to be applied to submerge the cylinder, $F_{submerge} = F_{buoy} - F_{weight} = 77.54\ N$
Or just keep a weight of 7.754 kgs on top of the cylinder to completely submerge it.

24. Force of the hot air balloon due to the weight of the gas and its own physical weight,
$F_{weight} = (Mass\ of\ the\ air) \times g + 15\ KN$
Mass of the air, M_{air} = *volume of air* $\times$ *density of air*
$M_{air} = 150 \times 0.1 = 15\ kg$
Force of buoyancy, F_{buoy} = *mass of air displaced* $\times$ *g*
$F_{buoy} = 15 \times 10 = 150\ N$
$F_{weight} = 15000\ N$
The balloon will start to lift when the net force becomes zero and the force of buoyancy becomes greater than the weight of the balloon. To find the temperature at which the balloon rises, we need to find the Force as the temperature rises. To find the force at a particluar temperature, the given formula can be multiplied by surface are of the balloon,

$$pressure(25) = \frac{Mass\ of\ air \times 10}{surface\ area\ of\ the\ balloon}$$

Multiplying both sides with surface area of the balloon,

$$Force(T) = Force(25) \times Temperature$$
$$= (\text{Mass of air} \times \text{acceleration due to gravity}) \times Temperature$$
$$= (150 \times 10)\times$$

This force is the upward force, which should balance the net downward force,

$$F_n = Force(T)$$
$$15000 = 150 \times T$$
$$\implies T = 100°C$$

25. (a) As the relative density is less than 1, it means that the density of the block is less than that of water which will make it float.

(b) Force of buoyancy when immersed in water,
F_{water} = *weight of water displaced* = *volume of water displaced* $\times$ *density of water* $\times$ g
Force of buoyancy when immersed in the fluid of similar density,
F_{same} = *weight of the fluid displaced* = *volume of fluid displaced* $\times$ *density of the fluid* $\times$ g
When densities are same, the substance will completely submerge.
Note that force of buoyancy is always the same for an object, no matter in which fluid it is placed.
$F_{water} = F_{same}$
volume of water displaced $\times$ *density of water* $\times$ 10 = *volume of fluid displaced* $\times$ *density of the fluid* $\times$ 10

$$\frac{density\ of\ the\ fluid}{density\ of\ water} = \frac{volume\ of\ water\ displaced}{volume\ of\ fluid\ displaced}$$

Density of fluid is same as the substance.

$$relative\ density = \frac{area\ of\ the\ base \times height\ submerged}{area\ of\ the\ base \times textittotalheight}$$
$$relative\ density = \frac{height\ submerged}{total\ height}$$

$0.5 = height\ submerged/5$
$height\ submerged = 2.5\ m$

(c) When the block of cylinder is floating, the force of buoyancy is equal to the weight of the block = $100 \times 10\ N$

At 1000N the submerged height is 2.5m.
For 5m to be submerged, the total force required is $5 \times \frac{1000}{2.5}$ = 2000 N
$\frac{1000}{10}$ = 100 kg mass should be placed on the cylindrical block to completely submerge it.