Gravitation & Fluids (IXth) –Detailed Exercise Solutions

Objective Questions:

Level-I

1. (c) The value of gravitational acceleration at moon's surface is 1/6 th of the gravitational acceleration on the earth's surface i.e., $g_m = \frac{1}{6} g_e$ hence, $W_m = Mg_m = \frac{1}{6} Mg_e = \frac{1}{6} W_e$.
2. (a) The S.I. unit mass is kilogram, abbreviated as 'kg'.
3. (b) Thrust per unit area is called pressure; its S.I. unit is Pascal (Pa).
4. (a) At point in a fluid the pressure is same in all directions i.e., a fluid exerts pressure in all direction.
5. (d) The loss in weight and apparent weight of an object depends on the buoyant force acting on it and which is proportional to the immersed volume of the body in fluid. Hence, the loss in the weight will be maximum, when the body will completely immersed in fluid.
6. (a)The Magnitude of buoyant force acting on an object is proportional to the immersed volume of the body in fluid and the density of fluid.
7. (a) The weight of the body is acting on it in downward direction, while the buoyant force is acting on it in upward direction. So, if the magnitude of buoyant force is less than the magnitude of weight of the body then, in this condition a net downward force is acting on the body due to which the body get sink into the liquid.
8. (b) A ship made of iron and steel floats on water because the average density of the ship is less than the density of water, and due to which the buoyant force acting on ship is more than its weight.
9. (c) The density of water is nearly about 1000 kg/m^3 or 1 g/cc.
10. (d) Relative density is defined as the ratio of density of any fluid to the density of a reference (or standard) fluid. As it is a ratio of two physical quantity of same unit hence, it is a unit less quantity.
11. (a) From the equation of motion, $s = ut + \frac{1}{2}at^2$

    Here, u=0, t=4s, a=g=9.8 m/s^2 then, $s = (0)4 + \frac{1}{2}(9.8)4^2 = 78.4\, m$. hence, the height of the building is 78.4 m.
12. (b) From the equation of motion, $v^2 = u^2 + 2as$

    Here, u=0, s=400m, a=g=9.8 m/s^2 then, $v^2 = 0^2 + 2(9.8)(400) \Rightarrow v = 88.54\, m/s$
13. (a) When an object is thrown up, force of gravity is acted on in vertically downward direction i.e., opposite to its motion in this case. The magnitude of force of gravity remains constant, as the mass of the body does not change.
14. (b) From the equation of motion, $v^2 = u^2 + 2as$

    Here, v=0, s=100m, a=(-g)= -9.8 m/s^2 then, $0^2 = u^2 + 2(-9.8)(100) \Rightarrow u = 44.27\, m/s$
15. (d) The weight of an object is the force through which the earth attracted the object towards it.

16. (d) We know that the gravitational force is given by, $F = \frac{Gm_1m_2}{d^2} \Rightarrow G = \frac{Fd^2}{m_1m_2}$

Hence, the S.I. unit of G is, $G \rightarrow \frac{Nm^2}{kg^2}$

17. (d) The mass of a body is defined as the amount or quantity of matter contained within it, which remains constant everywhere. Hence, the mass of the object remains 12 kg on the surface of the moon or on the surface of any other planet.
18. (a) Pascal is unit of pressure which is equivalent to N/m^2.
19. (b) The density of silver is about 10.5 g/cc, of lead it is about 11.3 g/cc. The densities of tungsten and gold are almost same which are, 19.25 g/cc for tungsten and 19.30 g/cc for gold.
20. (b) Gas is a compressible fluid hence; its density depends on the temperature and pressure. At normal pressure and temperature the densities of the given gases are as follow. The density of air is about 1.20 kg/m^3, for argon it is about 1.66 kg/m^3, for ozone it is about 2.14 kg/m^3, and the density of chlorine is about 2.99 kg/m^3. Hence, among these four gases chlorine is the densest.

Level-II

1. (d) The escape velocity does not depends on the angle of projection, its only depend on the mass and radius of the earth. Hence, the escape velocity for the given case remains v.
2. (b) The acceleration due to gravity is given by, $g = \frac{GM}{R^2}$. If the mass and radius are decreased by 1% then, the new value of g will be,

   $g' = \frac{GM'}{(R')^2} = \frac{G(0.99M)}{(0.99R)^2} = 1.01\left(\frac{GM}{R^2}\right) = 1.01g$

   Hence, the percentage change in the value of g is,

   $\left(\frac{g'-g}{g}\right) \times 100\% = \left(\frac{1.01g-g}{g}\right) \times 100\% = 1\%$ i.e., the value of g increased by 1%.
3. (c) The centripetal force for the circular motion of satellite around the planet is provided it by the gravitational attraction force on the satellite due to the planet. If the value of acceleration due to gravity of the planet on the surface of satellite is 'g' then,

   $mg = \frac{mv^2}{r}$, where m is the mass of the satellite, hence, $g = \frac{v^2}{r}$
4. (d) The centripetal force for the circular motion of satellite around the planet is provided it by the gravitational attraction force on the satellite due to the planet. If the value of acceleration due to gravity of the planet on the surface of satellite is 'g' then,

   $mg = \frac{mv^2}{r}$, where m is the mass of the satellite, hence, $K.E. = \frac{1}{2}mv^2 = \frac{mgr}{2}$

   i.e., $K.E. \propto r$. Now from the Kepler's law we know that, $T^2 \propto r^3 \Rightarrow r \propto T^{\frac{2}{3}}$

   Hence, $K.E. \propto r \propto T^{\frac{2}{3}}$
5. (c) According to Kepler's law we know that, $T^2 \propto r^3$

   Hence, $\frac{T_2^2}{T_1^2} = \frac{r_2^3}{r_1^3} \Rightarrow \frac{T_2}{T_1} = \left(\frac{r_2}{r_1}\right)^{3/2}$

$$\frac{T_2}{T_1} = \left(\frac{1.01R}{R}\right)^{3/2} = (1.01)^{3/2} = \left(1 + \frac{1}{100}\right)^{3/2}$$

According to binomial theorem, $\left(1 + \frac{x}{a}\right)^n \approx \left(1 + \frac{nx}{a}\right), if\ x \ll a$

Here, 1<<100 hence, according to binomial, $\left(1 + \frac{1}{100}\right)^{3/2} \approx \left[1 + \frac{3}{2}\left(\frac{1}{100}\right)\right]$

Hence, $\frac{T_2}{T_1} \approx \left[1 + \frac{3}{2}\left(\frac{1}{100}\right)\right] \Rightarrow \frac{T_2}{T_1} - 1 = \frac{3}{2}\left(\frac{1}{100}\right)$

$$\left(\frac{T_2 - T_1}{T_1}\right) \times 100 = \frac{3}{2} = 1.5$$

Hence, the period of second satellite is longer than first satellite by approx 1.5%.

6. (b) The angular momentum of the sun-comet system remains constant as there is no external torque is acting. Hence, mvr = mVR, where V is the speed of the comet when it is farthest from the sun. So, $V = \frac{vr}{R}$
7. (b) According to Kepler's law we know that, $T^2 \propto r^3 \Rightarrow T \propto r^{3/2}$

   Hence, frequency, $f = \frac{1}{T} \propto \frac{1}{r^{3/2}}$.

   As, $\frac{GMm}{r^2} = \frac{mv^2}{r}$

   $$K.E. = \frac{1}{2}mv^2 = \frac{GMm}{2r} \Rightarrow K.E. \propto \frac{1}{r}$$

   As, $\frac{GMm}{r^2} = \frac{mv^2}{r} \Rightarrow v = \sqrt{\frac{GM}{r}}$

   Hence, linear momentum, $p = mv \propto \frac{1}{\sqrt{r}}$

   And angular momentum, $l = mvr \propto \sqrt{r}$

   Hence, option (b) is incorrect.

8. (c) Given that W=63 N at the earth surface. At the earth surface $g = \frac{GM}{R^2}$, at a height equal to half the radius of the earth above the earth surface, $g' = \frac{GM}{\left(R+\frac{R}{2}\right)^2} = \frac{4}{9}\frac{GM}{R^2} = \frac{4g}{9}$

   Hence, $W' = mg' = m\left(\frac{4g}{9}\right) = \frac{4}{9}mg = \frac{4}{9}W = \frac{4}{9} \times 63 = 28N$
9. (c) When the elevator was not accelerated initially, the block was in equilibrium under the influence of buoyant force and gravity i.e., B = mg, where B is the buoyant force initially. After the elevator starts accelerating, the block will also accelerate with the elevator with same acceleration a in downward direction.

   The net downward force on the block in this condition, $F_{net} = mg - B'$, where $B'$is the buoyant force on the block in accelerating condition.

   Now, according to Newton's second law of motion, $F_{net} = ma = mg - B'$

   Hence, $B' = mg - ma = B - ma$

$$B' < B$$

Hence, the up thrust will be less than the weight of the liquid displaced.

10. (c) As the block sinks down it means the net force on the block (mg-B) acting on it downwards. According to Newton's second law of motion, $F_{net} = ma$

$$ma = mg - B = mg - \rho_{water}Vg$$

$$a = g - \frac{\rho_{water}Vg}{m} = g - \frac{\rho_{water}Vg}{\rho_{stone}V} = g - \frac{g}{\frac{\rho_{stone}}{\rho_{water}}}$$

$$a = g\left(1 - \frac{1}{k}\right)$$

Subjective Questions-I

1. The acceleration due to gravity is given by, $g = \frac{GM}{R^2}$. At the surface of the earth its value is about 9.807 m/s^2.
2. G is universal gravitational constant and its value is $6.674 \times 10^{-11}\ Nm^2kg^{-2}$
3. Weight of an object is the gravitational attraction force on it by earth. It is a force hence its S.I. unit is Newton (N).
4. The relation between weight of an object and its mass is W = mg, where g is the acceleration due to gravity.
5. The weight of a man is depends on its position, at the surface of earth it is W = mg =1×9.8 =9.8 N.
6. Weight of an object is the gravitational attraction force on it by earth hence, it is a vector quantity.
7. The relation between acceleration due to gravity and universal gravitational constant is given by, $g = \frac{GM}{R^2}$, where M is the mass of the planet and R is its radius.
8. At equator due to the rotation of the earth acceleration due to gravity reduces by an amount, $\omega^2 R$, where ω is the angular velocity of rotation of the earth and R is the radius of the earth. The value of g is greater at poles as compare to the equator hence, the weight of a body will be more at poles than at equator.
9. The acceleration due to gravity at earth's surface is about 9.8 m/s^2, which is independent of mass of the body. Hence, the acceleration of the man of mass 3kg will be9.8 m/s^2 as he is on earth's surface.

Subjective Questions-II

2. $F = \frac{GMm}{R^2}$, where $G = 6.674 \times 10^{-11}\ Nm^2kg^{-2}$
3. The force of gravitation between two objects is given by, $F = \frac{GMm}{R^2}$, if the distance between them reduced to half then the force between them in new condition,

$$F' = \frac{GMm}{(R/2)^2} = 4\frac{GMm}{R^2} = 4F$$

Hence, the force becomes 4 times of the initial value.

4. The force between earth and an object of mass 1kg on its surface can be calculated as,

$$F = \frac{GMm}{R^2} = \frac{6.674 \times 10^{-11} \times (6 \times 10^{24}) \times 1}{(6.4 \times 10^6)^2} \approx 9.807\ N$$

10. The value of gravitational acceleration at moon's surface is 1/6 th of the gravitational acceleration on the earth's surface i.e., $g_m = \frac{1}{6} g_e$

    Hence, $W_m = Mg_m = \frac{1}{6} Mg_e = \frac{1}{6} W_e = \frac{1}{6} \times 10 = 1.67\ N$

11. The value of gravitational acceleration at moon's surface is 1/6 th of the gravitational acceleration on the earth's surface i.e., $g_m = \frac{1}{6} g_e$

    Hence, $W_m = Mg_m = \frac{1}{6} Mg_e = \frac{1}{6} \times 70 \times 9.8 = 114.33\ N$

As the mass of a body is defined as the amount or quantity of matter contained within it, which remains constant everywhere. Hence, the mass of the man remains 70 kg on the surface of the moon and on the surface of the earth.

13. The value of gravitational acceleration at moon's surface is 1/6 th of the gravitational acceleration on the earth's surface i.e., $g_m = \frac{1}{6} g_e$ hence, $W_m = Mg_m = \frac{1}{6} Mg_e = \frac{1}{6} W_e$.
14. From the equation of motion, $s = ut + \frac{1}{2} at^2$

    Here, u=0, t=2.5s, a=g=9.8 m/s^2 then, $s = (0)2.5 + \frac{1}{2}(9.8)(2.5)^2 = 30.625\,m$. hence, the height of the building is 30.625 m.
15. (a) From the equation of motion, $v^2 = u^2 + 2as$

    Here, v=0, s=5m, a=(-g)= -10 m/s^2 then, $0^2 = u^2 + 2(-10)(5) \Rightarrow u = 10\ m/s$

    (b) From another equation of motion $v = u + at$

$$0 = 10 + (-10)t \Rightarrow t = 1\ sec$$

16. (a) In this case the area of the base of the block is $A = 0.5m \times 0.25m = 0.125m^2$

    Hence, pressure due to its weight, $P = \frac{F}{A} = \frac{mg}{A} = \frac{4\times10}{0.125} = 320\frac{N}{m^2} = 320\ Pa$

    (b) In this case the area of the base of the block is $A = 0.25m \times 0.1m = 0.025m^2$

    Hence, pressure due to its weight, $P = \frac{F}{A} = \frac{mg}{A} = \frac{4\times10}{0.025} = 1600\frac{N}{m^2} = 1600\ Pa$
17. (a) From the equation of motion, $v^2 = u^2 + 2as$

    Here, u=0, s=20m, a=g= 10 m/s^2 then, $v^2 = 0^2 + 2(10)(20) \Rightarrow v = 20\ m/s$

    (b) From another equation of motion $v = u + at$

$$20 = 0 + 10t \Rightarrow t = 2\ sec$$

23. Relative density of turpentine is given as, $R.D. = \frac{\rho_{terpentine}}{\rho_{water}} = \frac{840}{1000} = 0.84$
24. As the ball is completely immersed hence, the water level raise will be equal to the volume of the ball i.e., volume of the ball is 30 cm^3.

The density of the ball can be calculated as, $\rho = \frac{m}{V} = \frac{33g}{30\ cm^3} = 1.1\ g/cm^3$

25. The buoyant on a body immersed in liquid is equal to the weight of the liquid displaced by it. Hence, buoyant force on the boat = weight of the water displaced

$$\Rightarrow F_b = 600 \times 10 = 6000N = 6kN.$$

26. It is so because when the mug (filled with water) is immersed in the bucket which is also filled with water, mug displaces some volume of water in the bucket, as a result of which an up thrust (buoyant) force acts on the mug according to Archimedes principle. Due to this buoyant force the net downward force on the mug reduces and hence appears light in weight as compared to its weight in air.