1. Gravitational force

2. (a) $A=\pi r^2$

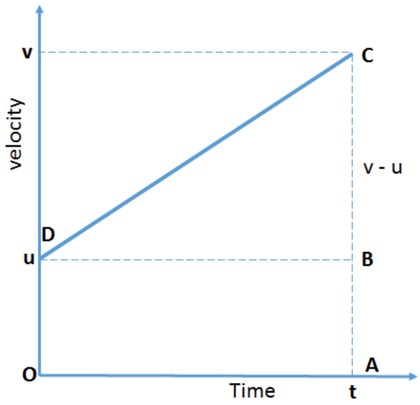
Therefore % error in area = 2 (% error in r) =2 x 0.6% = 1.2 %

(b) Principle of homogeneity of dimensional equations.

(c) No. of significant figures = 3

3. (a) Uniformly accelerated motion

(b)



We know that the area under v-t graph gives the displacement.

Therefore,

Displacement, S= Area of rectangle OABD + area of triangle BCD

$= ut + \frac{1}{2} t (v-u)$

$= ut + \frac{1}{2} t (at)$

$= ut + \frac{1}{2} at^2$

(c) Either less than one or equal to one

4. (a) Vertical component of initial velocity

$u_y = u\sin\theta$

Horizontal component of initial velocity

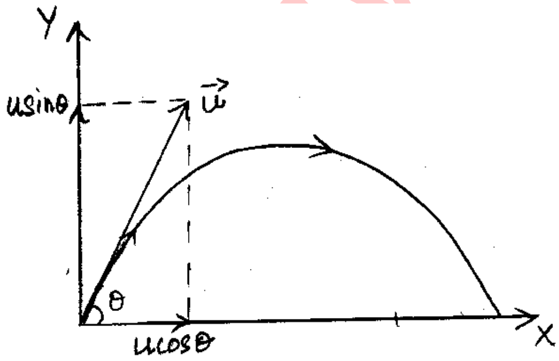
$u_x = u\cos\theta$

After a time 't'

$v_y = u_y - gt = u\sin\theta - gt$

$v_x = u_x = u\cos\theta$

(b)



(i) **Maximum height (H)**

To derive expression for maximum height reached, let us consider the **vertical motion** of the projectile.

Displacement, $S_y = H$

Initial velocity, $u_y = u \sin \theta$

Final velocity, $v_y = 0$

Acceleration, $a_y = -g$

$$\mathbf{v_y^2 = u_y^2 + 2a_yS_y}$$

$$0^2 = (u \sin\theta)^2 + 2 \times -g \times H$$

$$\Rightarrow 0 = u^2 \sin^2\theta - 2g H$$

$$\Rightarrow 2g H = u^2 \sin^2\theta$$

$$\boxed{H = \frac{u^2\sin^2\theta}{2g}}$$

(ii) Time of flight (t_f)

To derive the expression for time of flight we must consider the **vertical motion** of the projectile.

Vertical Displacement $S_y = 0$,

time $t \to t_f$

Initial velocity $u_y = u \sin\theta$

Acceleration $a_y = -g$

$$S_y = u_y t + \frac{1}{2} a_y t^2$$

$$0 = u \sin\theta \times t_f + \frac{1}{2} \times -g \times t_f^{\,2}$$

$$0 = u \sin\theta \, t_f - \frac{1}{2} g \, t_f^{\,2}$$

$$\Rightarrow \frac{1}{2} g \, t_f^{\cancel{2}} = u \sin\theta \, \cancel{t_f}$$

$$\frac{1}{2} g \, t_f = u \sin\theta \Rightarrow \boxed{t_f = \frac{2u \sin\theta}{g}}$$

(c) Follows a parabolic path

5. (a) Newton's 1st Law of motion

Newton's first law states that "everybody continues in its state of rest or of uniform motion in a straight line unless compelled by some external unbalanced force to change that state".

(b) The law states that "If no external force acts on a system of several particles, the total linear momentum of the system remains constant."

6. (a) Potential energy

U =mgh

(b) m=60 + 20 = 80kg, h=50m, g=9.8 m/s^2

U =mgh

=80 x 9.8 x 50= 39200J

7. (a) 90^0

(b) $\omega_0 = 0$, $\omega_t = 10$ rad/s, t=2s,

$I = 0.4 kgm^2$, $\tau = ?$

$\omega_t = \omega_0 + \alpha t$

⇨ $10 = 0 + \alpha \times 2$

⇨ $\alpha = 5$ rad/s^2

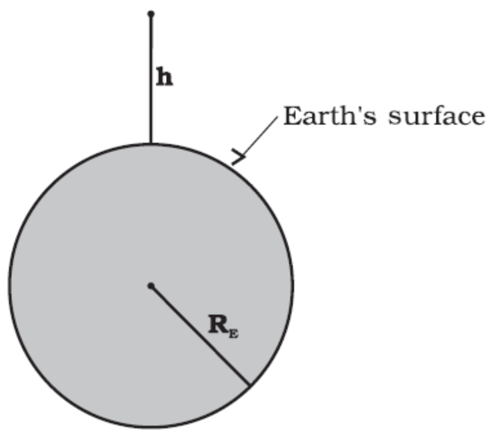
Therefore, $\tau = I\,\alpha = 0.4 \times 5 = 2Nm$

(c)

$$\vec{\tau} = \vec{r} \times \vec{F}$$

As the distance from the axis of rotation (r) increases, the torque also increases. When we are high on the ladder the, r is greater and so a small force in the perpendicular direction can cause a large torque. So there is a greater chance of falling.

8. (a)



The value of 'g' on the surface of earth is

$$g = \frac{GM}{R^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Suppose the body is taken to a height '**h**' above the surface of earth, the value of acceleration due to gravity is

$$g_{(h)} = \frac{GM}{(R+h)^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

$$\frac{(2)}{(1)} \rightarrow \frac{g_{(h)}}{g} = \frac{\cancel{GM}}{(R+h)^2} \times \frac{R^2}{\cancel{GM}}$$

$$\frac{g_{(h)}}{g} = \frac{R^2}{(R+h)^2}$$

$$= \frac{R^2}{\left[R\left(1+\frac{h}{R}\right)\right]^2}$$

$$= \frac{\cancel{R}^2}{\cancel{R}^2\left(1+\frac{h}{R}\right)^2}$$

$$\frac{g_{(h)}}{g} = \left(1+\frac{h}{R}\right)^{-2}$$

If $h << R$, then $\frac{h}{R}$ is very small compared to 1. Expanding the RHS of the above equation by Binomial theorem and neglecting the higher powers of $\frac{h}{R}$, we get,

$$\frac{g_{(h)}}{g} = \left(1-\frac{2h}{R}\right)$$

$$\Rightarrow \boxed{g_{(h)} = g\left(1-\frac{2h}{R}\right)}$$

The above equation shows that the value of acceleration due to gravity decreases with height.

(b) A satellite revolves round a planet because of centripetal force. The satellite is in uniform circular motion, and so the only force acting on the satellite is the centripetal force (gravitational force). The work done by centripetal force on the satellite, W= FScos90 =0.

So no energy is needed for the revolution of the satellite. And so no fuel is needed.

(c) Mass of the body

OR

(a) Escape velocity

(b) The total work done to move a body of mass '**m**' from the surface of earth (r = R) to infinity (r = ∞) is given by,

$$W = \frac{GMm}{R}$$

Let v be velocity of the body, then K.E of the body when projected is

$$K = \frac{1}{2}mv^2$$

The body can escape from the gravitational pull of earth only if the KE is greater than or equal to the work done in overcoming the gravity.

$$\frac{1}{2}\cancel{m}v^2 \geq \frac{GM\cancel{m}}{R}$$

$$\frac{1}{2}\cancel{m}v_e^2 = \frac{GM\cancel{m}}{R}$$

$$v_e^2 = \frac{2GM}{R}$$

$$\boxed{v_e = \sqrt{\frac{2GM}{R}}}$$

But $g = \frac{GM}{R^2}$ or $GM = gR^2$

$$v_e = \sqrt{\frac{2g\cancel{R}^2}{\cancel{R}}}$$

$$\boxed{v_e = \sqrt{2gR}}$$

(c) Since the moon has no atmosphere, there will be no loss of mechanical energy during the fall and rise due to viscous force. And when the ball hits the ground, no mechanical sound energy. So the ball can rise higher on the moon.

9. (a) Material A is more ductile.

(b) This is due to a phenomenon known as fatigue. Due to continuous usage for a long time, the elasticity of materials decreases. So they show wrong reading.

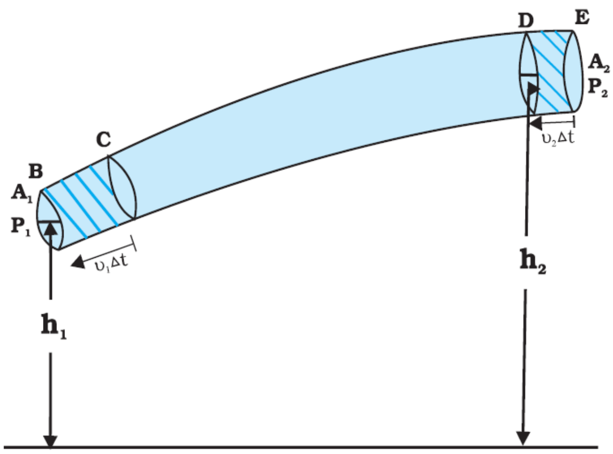
10. (a)

Statement: -

Bernoulli's theorem states that

"**For a steady flow of an incompressible fluid through a pipe, the sum of pressure energy per unit volume, KE per unit volume and PE per unit volume is a constant.**"

Proof:-



Consider a fluid moving in a pipe of variable area of cross section. Let the pipe be at different heights as shown in figure. Suppose an incompressible fluid is flowing through the pipe in a steady flow. Its velocity must change because of variable cross sectional area, and according to equation of continuity. A force is required to produce this acceleration, which is caused by the fluid surrounding it; the pressure must be different at different regions. Bernoulli's theorem is a general relation which connects the pressure difference between two points in a pipe to both changes in KE and change in PE.

Consider the flow at the two regions BC and DE. In a very small interval of time Δ t, the fluid at B moves to C at the same time fluid at D moves to E.

The **work done on the fluid** at the left end BC is $W_1 = F_1 . S_1$

$$= (P_1 A_1).(v_1 \Delta t) = P_1 \Delta V$$

Since the same volume ΔV passes through both the regions (from the equation of continuity) the **work done by the fluid** at the other end (DE) is

$$W_2 = F_2 . S_2$$

$$= (P_2 A_2).(v_2 \Delta t)$$

$$= P_2 \Delta V$$

So the **net work done on the fluid**,

$$\Delta W = W_1 - W_2 = P_1 \Delta V - P_2 \Delta V$$

$= (P_1 - P_2)\Delta V$ ----- (1)

According to **work – energy theorem** a part of this work is used to change the potential energy and the other part is used to change the kinetic energy.

$\Delta W = \Delta KE + \Delta PE$ ----------------- (2)

Change in KE,

$$\Delta K = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2$$
$$= \frac{1}{2}m(v_2^2 - v_1^2)$$
$$= \frac{1}{2}\Delta V\rho(v_2^2 - v_1^2)......(3)$$

Change in PE,

$$\Delta PE = mgh_2 - mgh_1$$
$$= mg(h_2 - h_1)$$
$$= \Delta V\rho g(h_2 - h_1)......(4)$$

Substituting eqns (1), (3), (4) in eqns(2) we get

$$(P_1 - P_2)\Delta V = \frac{1}{2}\Delta V\rho(v_2^2 - v_1^2) + \Delta V\rho g(h_2 - h_1)$$

Dividing by ΔV,

$$P_1 - P_2 = \frac{1}{2}\rho v_2^2 - \frac{1}{2}\rho v_1^2 + \rho g h_2 - \rho g h_1$$

$$\Rightarrow \boxed{P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2}$$

$$\Rightarrow \boxed{P + \frac{1}{2}\rho v^2 + \rho g h = \text{Constant}} .... (5)$$

This is **Bernoulli's equation**.

$P \rightarrow$ Pressure energy per unit volume

$\frac{1}{2}\rho v^2 \rightarrow$ KE per unit volume

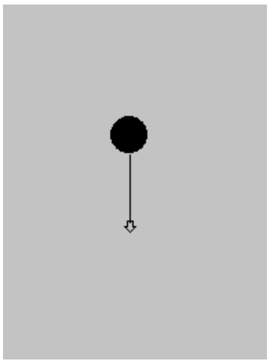
$\rho g h \rightarrow$ PE per unit volume

(b) When the aeroplane is at high altitudes the pressure inside it can be less than the pressure at the ground level. So due to excess pressure inside the pen, it may leak ink. So it is better to remove ink from the fountain pen, while travelling in an aeroplane.

OR

(a)

Consider a spherical body falling through a viscous medium.



There are three forces acting on the body:

(i) Weight of the body(F_g) , acting in the downward direction.

(ii) Buoyant force (F_b), acting in the upward direction.

(iii) Viscous force(F_v) acting in the upward direction.

If initially $F_g > F_b + F_v$, the body will accelerate in the downward direction. The velocity of the body goes on increasing and so viscous force also increases.

And finally a stage can be reached at which the total upward force (**F_v+F_b**) becomes equal to the downward force (**F_g**). Then the total force acting on the body become zero. Thereafter the body will move with constant velocity called **terminal velocity**.

When the body attains the terminal velocity.

$F_v+F_b=F_g$ -------------------- (1)

$$F_v = 6\pi\eta r v_t$$
$$F_g = m_g$$
$$= V\rho g$$
$$= \frac{4}{3}\pi r^3 \rho g$$
$$F_b = \text{weight of fluid displaced}$$
$$= \text{mass of fluid displaced} \times g$$
$$= \text{Volume} \times \sigma \times g$$
$$= \frac{4}{3}\pi r^3 \sigma g$$

$$\therefore \text{ eqn (1)} \rightarrow$$

$$6\pi\eta r v_t + \frac{4}{3}\pi r^3 \sigma g = \frac{4}{3}\pi r^3 \rho g$$

$$6\pi\eta r v_t = \frac{4}{3}\pi r^3 g(\rho - \sigma)$$

$$v_t = \frac{4\pi r^3(\rho - \sigma)\, g}{3 \times 6\pi\eta r}$$

$$\boxed{v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)\, g}{\eta}}$$

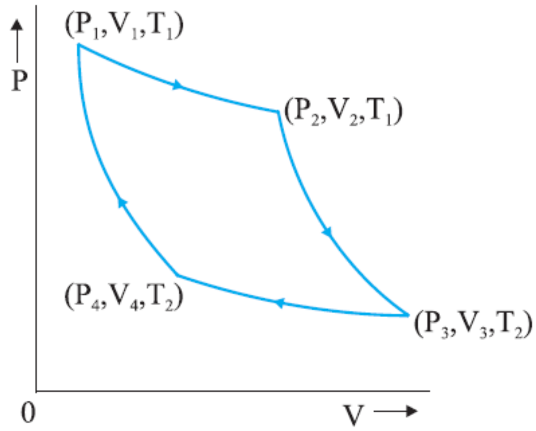
11. (a) Heat energy into mechanical energy

(b) (i) Isothermal expansion

(ii) Adiabatic expansion

(iii) Isothermal compression

(iv) Adiabatic compression



(c) L= 4.24cm, T_1 = 27^0C, T_2 = 227^0C

ΔL= ? α =1.7 x $10^{-5}/^0$C

$\Delta L/L = \alpha\ \Delta T$

⇨ $\Delta L = \alpha\ \Delta T\ L$

= 1.7 x $10^{-5}/^0$C x 200 x 4.24 cm

= 1441.6 x 10^{-5} cm

= 1.44 x 10^{-2} cm

(d) The main postulates of kinetic theory are:

(i) A given amount of gas is a collection of large number of molecules that are in constant random motion. During their motion, they collide with each other and also collide with the walls of the container. These collisions are elastic. So the kinetic energy and linear momentum are conserved.

(ii) The actual volume of gas molecules can be neglected as compared to the volume of the container.

(iii) The intermolecular force of attraction between gas molecules is very weak.

(iv) The average kinetic energy of a gas molecule is proportional to the absolute temperature.

12. (a)

An oscillating particle is said to execute SHM if the restoring force on the particle at any instant of time is directly proportional to its displacement from the mean position and is always directed towards the mean position.

(b) g_m =1.7 m/s^2, T_m= ? T= 3.5 s

$$T = 2\pi\sqrt{\frac{L}{g}}$$

$$\Rightarrow 3.5 = 2\pi\sqrt{\frac{L}{g}}$$

$$\Rightarrow 12.25 = 4\pi^2\frac{L}{g}$$

$$\Rightarrow L = \frac{12.25\times 9.8}{4\times 3.14^2}$$

$$= 3.04m$$

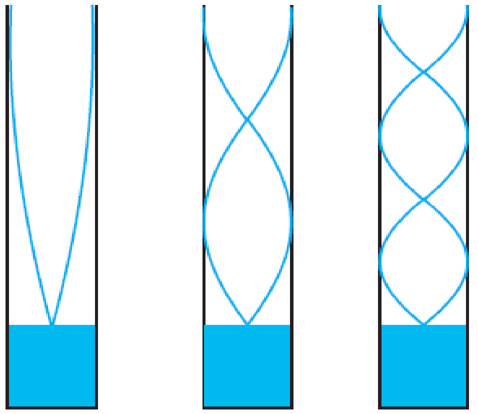
$$T_m = 2\pi\sqrt{\frac{L}{g_m}}$$

$$= 2\times 3.14\sqrt{\frac{3.04}{1.7}}$$

$$= \underline{\underline{8.4\sec}}$$

13. a)

Standing waves in a closed pipe



First mode of vibration

Here, Length of the pipe L= $\frac{\lambda_1}{4}$

$$\Rightarrow \lambda_1 = 4L$$

Frequency of vibration,

$\upsilon_1 = \frac{v}{\lambda_1} = \frac{v}{4L}$, this frequency is called **fundamental frequency** or **first harmonic**.

Second mode of vibration

L=3λ₂/4 $\Rightarrow \lambda_2 = \frac{4}{3}L$

$$\upsilon_2 = \frac{v}{\lambda_2} = \frac{v}{\frac{4}{3}L} = 3\frac{v}{4L} = 3\upsilon_1$$

This frequency is called **third harmonic** or **first overtone**.

Third Mode of vibration

$$\text{Here, } L = \frac{5\lambda_3}{4}$$

$$\Rightarrow \lambda_3 = \frac{4}{5} L$$

$$\upsilon_3 = \frac{v}{\lambda_3} = 5\left(\frac{v}{4L}\right) = 5\upsilon_1$$

This frequency $\upsilon_3 = 5\upsilon_1$ is called **5th harmonic** or **second overtone**. Thus for a closed pipe only **odd harmonics** are present.

ie,

$\upsilon_3 : \upsilon_3 : \upsilon_3 : ---- = 1:3:5: ----$

(b) In open pipes, all harmonics are present. But in closed pipes only odd harmonics are present. This is why open pipes are preferred over closed ones.