KEY MODEL PAPER
PHYSICS HSSC-I
SECTION - A

Q.1

1. (D) Strain
2. (A) Free Fall
3. (C) Total momentum of the system
4. (B) Constant
5. (B) kg m/s
6. (B) 61 cm/s
7. (C) $\frac{\omega}{2\pi}$
8. (B) v=$\sqrt{\frac{GM}{R}}$
9. (B) 9.8 N
10. (D) 1:√2
11. (C) Spherical objects falling at slow speed
12. (D) Wave Fronts
13. (A) Q = W
14. (A) Adiabatic process
15. (D) At the lowest point
16. (C) $I = \frac{1}{12}ML^2$
17. (A) $f_2 - f_1$

SECTION – B

Q.2

i. Applications of Moment due to a Force:
- A person pushing a swing will make the swing rotate about its pivot.
- A worker applies a force to a spanner to rotate a nut.
- A person removes a bottle's cork by pushing down the bottle opener's lever.
- A force is applied to a door knob and the door swings open about its hinge.
- A driver can turn a steering wheel by applying a force on its rim.

ii. $v = \sqrt{\frac{T\ x\ L}{M}}$

[L.H.S.] = [v] = [LT^{-1}]

[R.H.S] = $\left[\left(\frac{T\ x\ L}{M}\right)^{1/2}\right]$

= $\left[\frac{MLT^{-1}L}{M}\right]^{1/2}$

= $[M^0L^2T^{-1}]^{1/2}$

[R.H.S] = $[LT^{-1}]$

Since dimensions of [L.H.S.] = [R.H.S.]

So, given equation is dimensionally correct.

iii. Crane loads operate on the principle of lever. The shorter the end of the beam is applied by a force and the longer end (called Boom) can rotate and move the load radially inward or outward, to position the object at the correct location.

Since Boom is having large length even a small load lifted at its end will produce large torque and there is a danger for the crane to topple over.

To overcome such a situation, cranes have a counter weight at the other side that moves in an opposite direction from the

object that is lifted. The counter weight exerts a torque on the crane in equal and opposite direction to the torque from the load. Mathematically,

$$\vec{\tau}_{boom} = \vec{\tau}_{counter\ weight}$$

iv. Let θ be the required angle between $\vec{F_1}$ and $\vec{F_2}$. Let $\vec{F_1}$ is taken along +x-direction and $\vec{F_2}$ makes an angle θ with $\vec{F_1}$. To find their resultant, first we find their rectangular components as:

$$F_{1x} = F_1 \cos 0 = F_1$$
$$F_{1y} = F_1 \sin 0 = 0$$
$$F_{2x} = F_2 \cos\theta$$
$$F_{2y} = F_2 \sin\theta$$

x-component of their resultant is

$R_x = F_1 \text{ Cos } 0^o + F_2 \text{ Cos } \theta$

$R_x = F_1 + F_2 \text{ Cos } \theta$

y-component of their resultant is

$R_y = F_1 \text{ Sin } 0^o + F_2 \text{ Sin } \theta$

$R_y = F_2 \text{ Sin } \theta$

Now resultant $R^2 = R^2_x + R^2_y$

As $|\vec{R}| = |\vec{F_1}| = |\vec{F_2}| = |F|$

Hence

$R^2 = (F_1 + F_2 \text{ Cos } \theta)^2 + (F_2 \text{ Sin } \theta)^2$

$F^2 = (F + F \text{ Cos } \theta)^2 + (F \text{ Sin } \theta)^2$

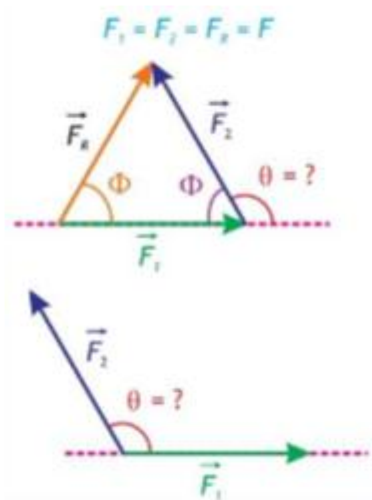
Or

$0 = 2 F^2 \text{ Cos } \theta + F^2 (\text{Cos}^2 \theta + \text{Sin}^2 \theta)$

$0 = 2 F^2 \text{ Cos } \theta + F^2$

$\text{Cos } \theta = -0.5$

$\theta = \text{Cos}^{-1}(-0.5) = 120^o$



v. Consider a body of mass m moving with velocity $\vec{v_i}$. A force is applied on the body for time t and its velocity changes to $\vec{v_f}$. Acceleration produced by the force is

$$\vec{a} = \frac{\vec{v_f} - \vec{v_i}}{t} \quad \text{———} \quad (1)$$

According to Newton's second law of motion

$$\vec{F} = m\,\vec{a} \quad \text{———} \quad (2)$$

$$\vec{F} = m\frac{\vec{v_f} - \vec{v_i}}{t}$$

$$\vec{F} = \frac{m\vec{v_f} - m\vec{v_i}}{t} \quad \text{———} \quad (3)$$

$$\Rightarrow \vec{F} = \frac{\vec{P_f} - \vec{P_i}}{t}$$

$$\vec{F} = \frac{\Delta\vec{P}}{t}$$

Hence the time rate of change of momentum of body is equal to the applied force.

vi. When a driver applies brake suddenly then the upper part of the passenger's body get jerk or move in the forward direction. It is due to inertia, body wants to continue its motion in the forward direction. The upper part of the passenger's body continues its motion in the forward direction while the lower part of the body stops with the vehicle.

Inertia is the natural resistance to acceleration that all objects have. The greater the mass the greater this resistance.

vii. Expression for the orbital radius of geo-stationary satellite:

As the orbital speed necessary for circular orbit is given by

$$v_o = \sqrt{\frac{G\,M_e}{r_o}} \quad \text{———} \quad (1)$$

But this speed must be equal to average speed of satellite in one day. So,

$$v_o = \frac{S}{t}$$

Or $v_o = \frac{2\pi r_o}{T}$ ———————————— (2)

Where 'T' is period of revolution of satellite that is equal to one day. So the satellite also complete one rotation in exactly one day.equating equations (1) and (2), we get

$$\frac{2\pi r_o}{T} = \sqrt{\frac{G\,M_e}{r_o}}$$

Squaring both sides, we get

$$\frac{4\pi^2 r_o^2}{T^2} = \frac{GM_e}{r_o}$$

$$r_o^3 = \frac{GM_eT^2}{4\pi^2}$$

Taking cube root of both sides,

Or $r_o = \left[\frac{GM_eT^2}{4\pi^2}\right]^{\frac{1}{3}}$

This equation gives the orbital radius of geostationary satellite.

Substituting the values, G= 6.67×10^{-11} Nm^2/kg^2, M = 6×10^{24} kg

T= 1 day=24 hours = 24 x 60 x 60 s = 86400 s

So, $r = \left[\frac{6.67\times10^{-11}\times6\times10^{24}\times(86400)^2}{4\times(3.14)^2}\right]^{\frac{1}{3}}$

= 0.423×10^8 m

= 4.23×10^7 m

r = 4.23×10^4 km

Which is the orbital radius measured from center of the earth for geo-stationary satellite.

viii. Given Data:

v = 30 ms^{-1}

d= 1.5 m

$\Rightarrow$ r= $\frac{d}{2}$=$\frac{1.5}{2}$ $= 0.75\ m$

To Find:

We know that v= $r\omega$

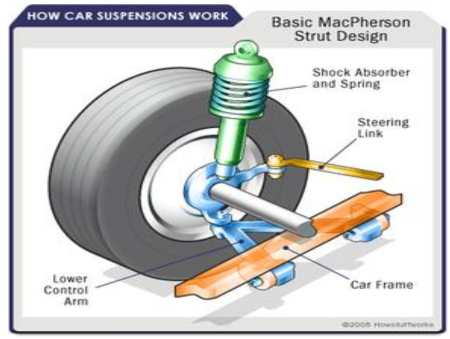
$\Rightarrow \omega = \frac{v}{r} = \frac{30}{0.75} = 40\ rad\ s^{-1}$

$\Rightarrow \omega = 40\ rad\ s^{-1} = 40\ \times \frac{1}{2\pi} rev\ s^{-1} = 6.37\ rev\ \ s^{-1}$

ix. Hard-boiled egg will spin faster than raw egg when same torque is applied on both.
Explanation: The raw egg contains liquid in it and when you rotate it the centrifugal force will act on the liquid and push it towards outer shell. Therefore moment of inertia of raw egg is greater and angular velocity is smaller. Hard-boiled egg acts as a rigid body, while rotating. The moment of inertia of hard-boiled egg is smaller and its angular velocity is greater. Hence hard-boiled egg will spin faster than raw egg when same torque is applied in both the cases.

x. Large tyre has large moment of inertia so its angular velocity is small that's why heavier tyre rotates slower than its lighter tyre. **Reason:** The moment of inertia is I= mr^2. Where m= Mass of the body and r= Distance from the axis of rotation. The mass and size (r) of the heavier wheel is large value, due to which it has large rotational inertia. So when a tractor moves with uniform velocity, its heavier wheel rotates slower than its lighter wheel. Lighter wheel has smaller moment of inertia and their speed of rotation is greater.

xi. **shock absorber**, also called **Snubber**, device for controlling unwanted motion of a spring-mounted vehicle. On an automobile, for example, the springs act as a cushion between the axles and the body and reduce the shocks on the body produced by a rough road surface. Some combinations of road surface and car speed may result in excessive up-and-down motion of the car body. Shock absorbers slow down and reduce the magnitude of these vibratory motions. Modern shock absorbers are hydraulic devices that oppose both the compression and the stretch of the springs. The direct-acting, or strut, type is attached to the vehicle frame and the axle by two eyes. One eye is attached to a piston that slides in an oil-filled cylinder attached to the other eye. Any relative motion between the frame and the axle causes the piston to act against the oil in the cylinder. This oil has to leak through small openings or pass through a spring-loaded valve. In this way, a force is created that opposes the contraction and stretching of the springs, and the vibration of the body is dampened.



xii. Scalar Product of vector: $\vec{A}.\vec{B} = AB \cos\theta$

a) The scalar product of two vectors is positive if the angle between them is between 0^o and 90^o, including 0^o.

b) The scalar product is negative when $90^o < \theta \leq 180^o$.

xiii. Given Data:

m = 3000 kg, $v_i = 0\ ms^{-1}$, $v_f = 80\ ms^{-1}$, t = 4.0 s

$$\Delta v = 80\ ms^{-1}$$

$$a = \frac{\Delta v}{t} = \frac{80\ m/s}{4.0\ s} = 20 ms^{-2}$$

F= m a = 3000kg x 20 ms^{-2} = 6 x 10^4 N

P = **F** x **v** = (6x10^4 N) (80 ms^{-1}) = 48x 10^5 W.

xiv. When the speed of sound and listener are moving away from each other, then apparent wave length λ' is

$$\lambda' = \frac{v+a}{f}$$

The speed of sound relative to the listener is $v' = (v - b)$

The apparent frequency f' is

$$f' = \frac{v'}{\lambda'}$$

Substituting the value of v' and λ' we get

$$f' = \frac{(v-b)}{\frac{v+a}{f}}$$

$$f' = \left(\frac{v-b}{v+a}\right) f$$

$$\left[\frac{v-b}{v+a}\right] < 1$$

$$f' < f$$

When source and listner moving away from each other then pitch of sound decreases.

xv. The Polaroid sunglasses reduce the intensity of light passing through them, due to which the glare of light is decreased. They protect the eyes from harmful rays of sunlight. That is why they are better than ordinary sunglasses.

xvi. Given Data: m= 2, θ= 25o, $\lambda = 650\ nm$.

To find: d=?

Solution:

d Sin θ= m λ

d=$\frac{m\,\lambda}{\sin\theta} = \frac{2\times650\times10^{-9}\ m}{\sin 25} = 3.076\ \times 10^{-6}\ m$

d = 3.076 μm.

xvii. The following conditions must be fulfilled in order to observe the interference phenomenon:

- The interference beams must be monochromatic.
- The interference beams of light must be coherent.
- The sources must be narrow and close to each other.
- The intensity of the two sources be comparable.

The waves coming from the two separate head lamps differ in phase. Their phase difference not satisfies the conditions of interference.
Also these sources are not monochromatic. Due to these reasons, it is not possible to see the interference where the light beams from the head lamps of a car overlap.

xviii. Cricketers shine the ball because this increase the chances that the bowler will get the ball to swing in air. The shine is applied to one side of the ball, which allows that side to remain smooth and shiny. If one side of the ball is rougher than the other, the ball will swing towards the shiny side, simply because it slice through the air easier as opposed to the resistance to air flow and friction created on the other side, which causes a net sideward force to act on the ball.

xix. It is impossible for a thermodynamic system to achieve a 100% thermal efficiency according to the Second law of thermodynamics. This is impossible because there are inefficiencies such as friction and heat loss that convert the energy into alternative forms. The output of the system is always less than the input.

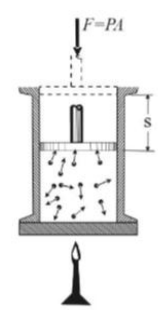
xx. Given Data: $v = 340\ ms^{-1}$, $f_2 = 1200$ Hz
To find: length of pipe, L
Formula: for the first over tone, $f_2 = 2\ (v/2L)$
Put values,
$1200 = 2\left(\frac{340}{2L}\right) \Rightarrow 1200 = \frac{340}{L}$

$$\Rightarrow L = \frac{340}{1200}$$
$$\Rightarrow L = 0.283\ m = 28.3\ cm$$

SECTION – C (Marks 26)

Q.3 a) Molar Heat Capacity at Constant Pressure C_P: **(1+1+4)**

The amount of heat energy required to raise the temperature of one mole of the gas through 1K at constant pressure is called molar specific heat or molar heat capacity at constant pressure.



$$\Delta Q_P = C_P n\ \Delta T$$

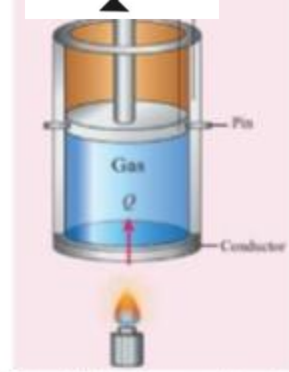
Where C_P molar heat capacity at constant pressure and its SI unit is J mol^{-1} K^{-1}.

Molar Heat Capacity at Constant Volume C_V:

The amount of heat energy required to raise the temperature of one mole of the gas through 1K at constant volume is called molar specific heat or molar heat capacity at constant volume.

$$\Delta Q_V = nC_V n\ \Delta T$$

Where C_V molar heat capacity at constant volume and its SI unit is J mol^{-1} K^{-1}.



Specific heat capacity at constant volume

Derivation of $C_P - C_V = R$:

At constant volume:

If n moles of an ideal gas are heated at constant volume so that its temperature rises by ΔT then the heat transferred ΔQ_V is given by
$\Delta Q_V = nC_V n\ \Delta T$ --------------------- (1)
Applying first law of thermodynamics,

$$\Delta Q_V = \Delta U + \Delta W$$

Putting value of ΔQ_V from equation (1)

$$nC_V\ \Delta T = \Delta U + \Delta W$$

Since volume remains constant (i.e. ΔV =0), so work done the system is zero.
ThΔus thΔe above equation becomes

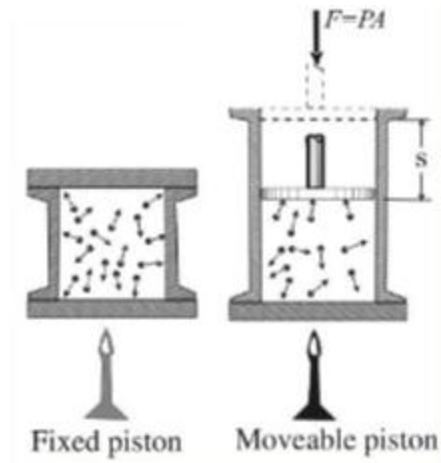
$nC_V\Delta T = \Delta U + 0$ $[\because \Delta W = P\Delta V = P(0) = 0]$
Hence $nC_V\Delta T = \Delta U$ ---------------(2)
$\Delta U = n\, C_V\Delta T$---------------(3)

At constant pressure:

If n moles of an ideal gas are heated at constant pressure so that its temperature rises by ΔT then the heat transferred ΔQ_P is given by
$\Delta Q_P = nC_Pn\,\Delta T$ --------------------- (4)
Since, the gas expands to keep the pressure constant, so the work done by the gas is
$\Delta W = P\Delta V$ ---------------(5)
PV= nRT
And PΔV=nRΔT
Putting the value of PΔV=nRΔT in the equation (5)
$\Delta W = nR\Delta T$---------------(6)
According tp the first law of thermodynamics:
$\Delta Q_P = \Delta U + \Delta W$ ---------------(7)
Putting the values of equations (2), (3) and (6) in equation (7)

$$nC_P\Delta T = nC_V\Delta T + nR\Delta T$$
$$nC_P\Delta T = n\Delta T(C_V + R)$$
$$C_P = C_V + R$$
OR
$$C_P - C_V = R$$

It is clear that $C_P > C_V$ by the amount equal to the universal constant R.



b) Given Data: **(2+2)**

Heat energy supplied to the system, $\Delta Q = 25200\, J$

Work done by the system, $\Delta W = 6000\, J$

Change in internal energy= ΔU= ?

Solution:

According to 1st law of thermodynamics

$$\Delta Q = \Delta U + \Delta W$$
$$\Delta U = \Delta Q - \Delta W$$
$$\Delta U = 25200 - 6000 = 19200 \text{ J}$$

c) In young's double slit experiment, the double slits are used to observe interference phenomenon for visible light.
X-rays are electromagnetic waves having very short wavelength ($\approx 10^{-10}\, m$) as compared to visible light. Therefore the x-rays do not show diffraction effect by using ordinary diffracting objects like slits, diffraction gratings etc. Because their width is very larger than the wavelength of x-rays.
That is why in Young's double slit experiment the diffraction is not possible. X- rays are diffracted by crystals.

Q.4 a) <u>Simple Harmonic Motion:</u> **(2+3+1)**

The type of oscillatory motion, in which acceleration of the body at any instant is directly proportional to displacement from the mean position and directed towards the mean position, is called simple harmonic motion (SHM).

$$\vec{a} \propto -\vec{x}$$

<u>Simple Pendulum:</u>

A simple pendulum consists of a small heavy mass attached with light and inextensible string suspended with a frictionless support.

Motion of simple Pendulum:

Consider an object of mass m attached with the end of a light weight string.

Length of the pendulum:

The length of the simple pendulum l is the distance between the point of suspension and the center of bob.

Working:

When the simple pendulum is displaced from its mean position through a small angle θ and released then it start to oscillate about mean position O.

Components of weight:

Resolve the weight w of simple pendulum into two rectangular components w cos θ and w sin θ ,

Tension in string = w cos θ

⇒ Tension= mg cos θ

Restoring Force:

The only force responsible for motion of the simple pendulum is w sin which bring the bob back torwards its mean position and acts as the restoring force for the bob.

Restoring force= F = -w sin θ

F= - mg sin θ --------------------- (1)

Negative sign shows that restoring force is directed towards mean position and direction of restoring force is opposite to displacement,

Also we know that

F=ma ------------------- (2)

Comparing above equation (1) and (2) we get

ma = -mg sin θ

a= -g sin θ

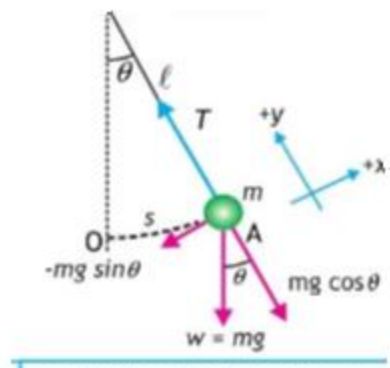
For small value of angle θ, sin $\theta \approx \theta$

So, a=-g θ ----------------(3)

From figure $\theta = \frac{arc\ OA}{l}$ $\left[\because S = r\theta \Rightarrow \theta = \frac{S}{r}\right]$

$\theta = \frac{x}{l}$ [$\because \theta$ is small so are OA ≈ x]

Putting $\theta = \frac{x}{l}$ in equation (3)



oscillating simple pendulum

$$a = -g\left(\frac{x}{l}\right)$$

$$a = -\left(\frac{g}{l}\right)x$$

This expression for the acceleration of simple pendulum,

$a = -constant\ (x) \left[\because \frac{g}{l} = constant\right]$

Or $\vec{a} \propto -\vec{x}$

This proves that the motion of simple pendulum is SHM.

Time Period:

Definition: Time required to complete one vibration is called time period. As the time period for SHM can be expressed as,

$$T = \frac{2\pi}{\omega}$$

Putting value of from equation (6) we get

$$T = \frac{2\pi}{\sqrt{g/l}}$$

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

This equation shows that the time period of a simple pendulum depends upon length of the pendulum and acceleration due to gravity.

b) Given Data: Time period = T= 1s **(2+1)**
Gravitational acceleration= g= 9.8 m s^{-2}
To Find: Length = l= ?
Frequency =f = ?

Solution: $T = 2\pi\sqrt{\frac{l}{g}}$

Squaring both sides

$$T^2 = \frac{4\pi^2 l}{g}$$
$$l = \frac{gT^2}{4\pi^2}$$
$$l = \frac{9.8 \times (1)^2}{4(3.14)^2}$$
$$l=0.25 \text{ m}$$
$$f = \frac{1}{T} = \frac{1}{1} = 1\,Hz$$

c) Factors on which te speed of sound depends: **(4)**
Sound waves are compressional mechanical waves propagating in gas or air with a speed of

$$v = \sqrt{\frac{\gamma P}{\rho}} \text{ ----------------- (1)}$$

The following factors affect the speed of sound in gas.

1. Density: The speed of sound in a gas varies inversely as the square root of the density of the gas $v \propto \frac{1}{\sqrt{\rho}}$

2. Moister: The presence of moisture in the air reduces the resultant density of air:
Therefore the speed of sound increases with humidity. Hence the velocity of sound in damp air is greater than the value in dry air.

3. Pressure: For gases the change in speed of sound with temperature is very large. The increase in speed of sound with temperature in gas is about 0.61 ms-1 for each o C rise in temperature. Since the speed of sound in a gas is

$$v = \sqrt{\frac{\gamma RT}{m}} \text{ -------------------(2)}$$

Therefore, $v \propto \sqrt{T}$
This shows that the speed of sound is directly proportional to the square root of the absolute temperature of the gas.

4. Wind: If the air carrying sound waves, is itself moving i.e., there is wind.

- The speed of sound in the direction of wind relative to the ground is $(v + v_w)$ i.e., increases.
- While the speed of sound against the wind is $(v - v_W)$ and directions, where v_W is the speed of wind and v is the speed of sound.

5. Pressure: From equations (1) and (2) it is clear that speed of sound in air is independent of its pressure.

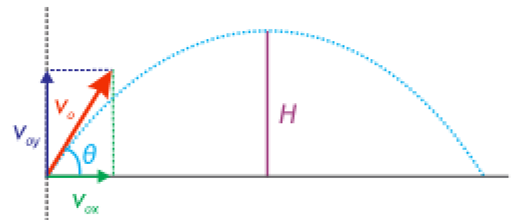
Q.5 **(2+2+2)**

MAXIMUM HEIGHT: Maximum Vertical distance reached by projectile from projection level is called maximum height of projectile. Consider a projectile which is thrown with certain velocity v making an angle θ with the horizontal as shown in figure. To find o the maximum height we will use third equation of motion along y- axis

$$2a_yS_y = v_{fy}^2 - v_{iy}^2$$

Here $v_{fy} = v_y = 0,$ $\quad v_{iy} = v_o \sin\theta$

$$a_y = -g, \quad S_y = H$$



Maximum height H

Putting values

$$-2g\,H = (0)^2 - (v_o \sin\theta)^2$$

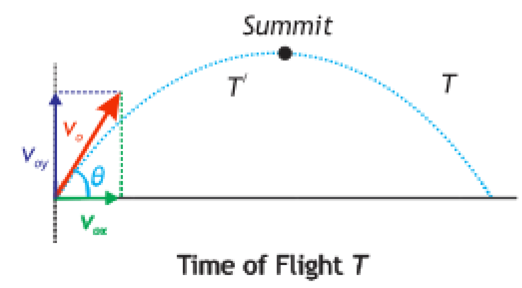
Therefore, $$\boldsymbol{H = \frac{v_o^2 \sin^2\theta}{2g}}$$

TIME OF FLIGHT:

Time taken by projectile to go from point of projection to the point of impact is called time of flight of projectile.

Consider a projectile which is thrown with certain velocity v making an o angle θ with the horizontal as shown in figure. To find the time of flight we will use second equation of motion along y-axis.

$S_y = v_{iy}\, t + \frac{1}{2}\, a_y\, t^2$



Here $S_y = 0$, $v_{iy} = v_o \sin\theta$

$a_y = -g$ $t = T$

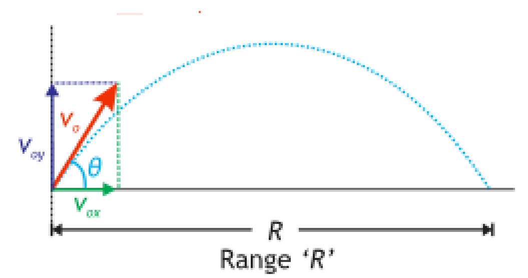
Hence $0 = v_o \sin\theta\, T - \frac{1}{2} g T^2$

or $$\boldsymbol{T = \frac{2v_o \sin\theta}{g}}$$

Time to reach summit: Time to reach summit (highest point), will be half of / / the total time of flight. Let T be time of summit height i.e. T =T/2

RANGE: The horizontal distance from point of projection to point of impact is called range of projectile. Consider a projectile which is thrown with certain velocity v making an angle θ with the horizontal as shown in figure. To find the o maximum range we will use second equation of motion along x- axis.

$S_x = v_{ix}\, t + \frac{1}{2}\, a_x\, t^2$



Here $v_{ix} = v_o \cos\theta$

$S_x = R$, $a_x = 0$ $t = T = \dfrac{2v_o \sin\theta}{g}$

Putting values

$$R = v_o \cos\theta \left(\frac{2v_o \sin\theta}{g}\right) + (0)\left(\frac{2v_o \sin\theta}{g}\right)^2 \quad \text{or} \quad R = v_o \cos\theta \left(\frac{2v_o \sin\theta}{g}\right)$$

Or $R = \frac{v_o^2}{g}(2 \sin\theta \cos\theta)$ since $2\sin\theta\cos\theta = \sin 2\theta$

Therefore $$\boldsymbol{R = \frac{v_o^2}{g} \sin 2\theta}$$

b) Given Data: **(1+2+1)**

r_1 = 1 cm
r_2 = ?
v_1 = 1 m/s

$v_2 = 20$ m/s

Solution:

According to equation of continuity

$$A_1 \times v_1 = A_2 \times v_2$$

$$\pi r_1^2 \; x \; v_1 = \pi r_2^2 \; x \; v_2$$

$$r_1^2 \; x \; v_1 = r_2^2 \; x \; v_2$$

$$r_2 = r_1 \sqrt{\frac{v_1}{v_2}}$$

$$r_2 = 1\sqrt{\frac{1}{20}} = 0.2236 \text{ cm}$$

Diameter of a nozzle is

$$D = 2 \times r_2 = 2 \times 0.2236 = 0.4472 \text{ cm}$$

c) **(3)**

The smoke rises faster in a chimney on a windy day due to difference in pressure inside the chimney and outside the chimney. **Reason:** The Bernoulli's principle plays a vital role in this process. According to Bernoulli's principle. *"Where the speed of fluid is high, the pressure will be low and where speed of fluid is low the pressure will be high'*. As the wind blows with high speed across the top of a Chimney, the pressure is low there then the pressure inside the chimney. Thus the air and smoke are pushed upwards from high pressure towards the low pressure and rises faster in upwards.