Inter (Part-I) 2019

Physics	Group-II	PAPER: I
Time: 2.40 Hours	(SUBJECTIVE TYPE)	Marks: 68

SECTION-I

2. Write short answers to any EIGHT (8) questions: (16)

(i) Define light year. Calculate its value. (Speed of light $C = 3 \times 10^8\ ms^{-1}$)

Ans A light is the distance that light travels in one year.

Speed of light = $C = 3 \times 10^8\ ms^{-1}$

Time = 1 year

$= 1 \times 365 \times 24 \times 60 \times 60$

$= 31536000 = 3.1536 \times 10^7\ s$

Required: Distance traveled by light = d = ?

$$C = \frac{d}{t}$$

$$d = ct$$

$$d = 3 \times 10^8 \times 3.1536 \times 10^7$$

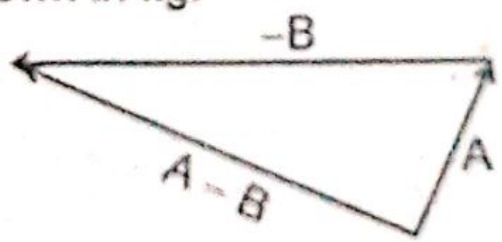
$$= 9.5 \times 10^{15}\ m$$

(ii) Give the definition of unit of solid angle.

Ans The steradian is the solid angle (three-dimensional angle) subtended at the centre of a sphere by an area of its surface equal to the square of radius of the sphere.

(iii) How a vector is subtracted from another vector? Explain using diagram.

Ans The subtraction of vector is equivalent to the addition of the same vector with its direction reversed. Thus, subtract vector B from A, reverse the direction of an add it to A, as shown in fig.



$A - B = A + (-B)$ where $(-B)$ is negative vector of B.

(iv) Find unit vector in the direction of the vector $\vec{A} = 12\hat{i} - 5\hat{j}$.

Ans

$$A = 12i - 5j$$

$$\hat{A} = \frac{A}{|A|}$$

$$= \frac{12\hat{i} - 5\hat{j}}{\sqrt{(12)^2 + (-5)^2}} = \frac{12\hat{i} - 5\hat{j}}{\sqrt{144 + 25}} = \frac{12\hat{i} - 5\hat{j}}{\sqrt{169}}$$

$$\hat{A} = \frac{12\hat{i} + 13\hat{j}}{13}$$

(v) Name three different conditions that could make $\vec{A}_1 \times \vec{A}_2 = 0$.

Ans The product $\vec{A}_1 \times \vec{A}_2 = 0$, when

1. Vectors are parallel.
2. Vectors are anti-parallel.

(vi) Calculate the work done in kilo joules in lifting a mass of 10 kg (at steady velocity) through a vertical height of 10 m.

Ans Mass = m = 10 kg

Acceleration due to gravity = g = 9.8 m/s^2

Vertical Height = h = 10 m

$$W = P.E = mgh$$

$$= 10 \times 9.8 \times 10 = 980 \text{ J}$$

$$= 0.98 \text{ kJ}$$

(vii) Prove that 1 kWh = 3.6 MJ.

Ans One kilowatt hour is the work done in one hour by an agency whose power is one kilowatt. Therefore,

$$1 \text{ kWh} = 1000 \text{ W} \times 3600 \text{ s.}$$

$$1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

(viii) How does a chimney work?

Ans The rising hot gas creates a pressure difference called draft which draws combustion air into the appliance and expels the exhaust gas outside. Two factors affect the amount of draft produced by chimney.

(ix) Explain, how the swing is produced in a fast moving cricket ball?

Ans When cricket ball is bowled by a fast bowler, then velocity of air on one side of ball increases due to less friction. According to Bernoulli's equation, when velocity is high, then pressure is low and the ball moves in a curved shaped path towards the shined side which is called swing.

(x) What happens to the period of a simple pendulum if its length is doubled? What happens if the suspended mass is doubled?

Ans We know that time period T simple pendulum is;

$$T = 2\pi\sqrt{\frac{l}{g}} \qquad (1)$$

Where l = length of pendulum,

g = Acceleration due to gravity.

If length is double, $l' = 2l$, then the time period is

$$T' = 2\pi\sqrt{\frac{l'}{g}} \Rightarrow$$

$$T = 2\pi\sqrt{\frac{2l}{g}} \qquad T' = \sqrt{2}\left(2\pi\sqrt{\frac{l}{g}}\right)$$

$$T' = \sqrt{2}\,T$$

Therefore, the time period increases to $\sqrt{2}$ or 1.41 times from eq. (1). It is clear that time period does not depend upon the suspended mass m. So, time period will not change by increasing (doubling) mass.

(xi) Does frequency depend on amplitude for harmonic oscillator?

Ans No, the frequency "f" of harmonic oscillator does not depend upon the amplitude x_0. For example:

We know that for mass, spring system, the time period of oscillation is

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where m = mass attached to spring

k = spring constant

So, $f = \frac{1}{T} = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$

This relation shows that frequency does not depend upon amplitude x_0.

(xii) Define angular frequency. Give its formula and unit.

Ans It relates circular motion with S.H.M.

Definition:

It is equal to angular velocity of a body rotating in a circle whose projection is performing SHM on the nearby wall.

Symbol = ω

Formula $\omega = 2\pi f$

The unit of angular frequency is radian per second.

3. Write short answers to any EIGHT (8) questions: (16)

(i) A rubber ball and lead ball of same size, are moving with same velocity. Which ball have greater momentum and why?

Ans Since both the balls are of same size, they have same volume. However, lead is denser then rubber, so, since $D = \frac{m}{V}$, therefore, lead has more mass than rubber.

By Newton's first law, law of intertia, it is the tendency of an object to remain it rest, or in motion. Since mass of the lead ball will be maximum and both balls have same velocity. Hence, product of mass and velocity for lead ball is maximum. So, momentum of the lead ball be maximum.

(ii) A bullet is fired from a rifle. Derive the relation for velocity of rifle.

Ans Let "m" the mass of bullet fired from a rifle of mass "M" with a velocity "V". Before firing, the gun and bullet are at rest. Therefore, the momentum of the both is zero. This is total momentum before firing = 0 (1)

After firing, suppose the velocity of the bullet becomes v and velocity of the rifle becomes v′.

Total momentum after firing = mv + mv′ (2)

According to the law of conservation of momentum,

Total momentum before firing = Total momentum after firing

$$O = mv + Mv'$$

$$Mv' = -mv \quad (3)$$

$$v' = \frac{-mv}{M} \quad (4)$$

Eq. 3 shows that the momentum of the rifle is thus equal and opposite to the momentum of the bullet. Since, mass of the rifle is much greater than the bullet, it results that the rifle moves back or recoils with only a fraction of the velocity of the bullet.

(iii) Define range of projectile. In which situations its value is maximum and minimum?

Ans Definition:

The horizontal distance covered by the projectile from the place of its projection to the place where it hits the ground is called the range of projectile. It is represented by R.

$$R = \frac{v_1^2 \sin 2\theta}{g}$$

Maximum Range:

R_{max}, the factor sin 2θ should have maximum value which is 1.

Maximum value of sin 2θ = 1

$$2\theta = \sin^{-1}(1) = 90$$

$$\theta = \frac{90}{2} = 45^\circ$$

This is the angle of projection for maximum range $\left(R_{max} = \frac{v_1^2}{g}\right)$.

Minimum Range:

For an angle less than 45°, the height reached by the projectile and the range both will be less than that at 45°.

When the angle of projection is larger than 45°, the height attained will be more but the range is again less.

(iv) Define impulse of the force and how can it relate with momentum.

Ans When a very large force F acts on a body for a very short interval of time t, then the product of force and time is called impulse of the force.

Relation of impulses with linear momentum:

As we know

$$\text{Impulse} = F \propto t$$

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

$$\text{Impulse} = \frac{\Delta\bar{P}}{t} \times t$$

$\Delta\bar{P}$ where $\Delta\bar{P} = \bar{v}_f - m\bar{v}_i$

$$I = m\bar{v}_f - m\bar{v}_i$$

The mathematical form of impulse shows that it is related to linear momentum, not the angular momentum.

Unit of impulse is Ns.

Dimension = $[MLT^{-1}]$

(v) Define radian and degree and what is relation between them.

Ans **Degree:**

If the circumference of a circle is divided into 360° equal parts, then angle made by each part at the centre of circle is equal to one degree.

Radian:

It is the angle made at the centre of a circle by a circular arc whose length is equal to the radius of circle.

Relation between Radians and Degrees:

For complete circle $\theta = 360°$ (1)

And length of arc = circumference of a circle = $2\pi r$

We know that $\theta = \frac{S}{r} \Rightarrow \theta = \frac{2\pi r}{r}$

$\theta = 2\pi$ radian (2)

Comparing (1) and (2),

2π radian = 360°

π radian = 180°

$$1 \text{ radian} = \frac{360}{2\left(\frac{22}{7}\right)} = 57.3 \text{ degree}$$

(vi) Define critical velocity and find its value.

Ans This is the minimum velocity necessary to put a satellite into the orbit and is called critical velocity.

Calculation:

When a satellite is moving in a circle, it has acceleration. In a circular orbit around the earth, the centripetal acceleration is supplied by gravity and we have:

$g = \frac{V^2}{R}$; V = orbital velocity

R = Radius of earth = 6400 km

$V^2 = gR$; $V = \sqrt{gR}$

$V = \sqrt{9.8\ ms^{-2} \times 6.4 \times 10^6\ m}$

$= 7.9\ km\ s^{-1}$

$7.9\ km\ s^{-1}$ is the critical velocity.

(vii) What is difference between Newton's and Einstein's views of gravitation?

Ans According to Newton, the gravitation is the natural property of matter that every particle of matter attracts every other particle with a force which is directly proportional to the product of their masses and is inversely proportional to the square of the distance between them.

According to the Einstein's theory, space time is curved near massive bodies. In order to observe it, we might think of space as a thin rubber sheet. If a heavy weight is hung from it, it curves or dents, the weight refers to a huge curve. The heavier weight, the greater the curve or dent.

(viii) Define geo-synchronous satellite and what is the height of such satellite above the earth?

Ans An interesting and useful example of satellite motion is the geo-synchronous or geo-stationary satellite. This type of satellite is the one whose orbital motion is synchronized with the rotation of the earth. Synchronous satellite remains always over the same point on the equator as the earth spins on its axis. Such satellite is very useful for worldwide communication, weather, observations, navigation and other military uses.

The height above the earth lobe 36000 km.

(ix) What are the conditions for interference of two sound waves?

Ans The phenomenon in which two sound waves of same frequency travelling in the same direction in a medium, superpose to given another sound wave called the resultant wave due to which loudness of sound increases or decreases; is known as interference of sound waves.

There are two types of interference of sound waves:

1. Constructive 2. Destructive interference

(x) What is effect of temperature on speed of sound?

Ans As we know that speed of sound varies directly as the square root of absolute temperature:

$$v \propto \sqrt{T}$$

Reason for increase in speed of sound:

When a gas is heated as constant pressure, its volume is increased and its density decreased.

$$V = \sqrt{\frac{rP}{\rho}}$$

So, speed of sound increased with rise in temperature.

And $V_t = V_o + 0.61\,t$

This equation shows that one degree Celsius rise in temperature produces approximately 0.61 ms^{-1} increase in the speed of sound.

(xi) What is effect on frequency of sound waves, when source and observer are moving towards each other?

Ans

- Two waves having same frequency and travelling in the same direction. (Interference)
- Two waves of slightly different frequencies and travelling in the same diffraction. (Beats)
- Two waves of equal frequency travelling in opposite direction. (Stationary waves)

(xii) How are beats useful in tuning musical instruments?

Ans Beats are used to tune a string instrument, such as piano, or violin, by beating a note against a note of known frequency. The string can then be adjusted to the desired frequency by tightening-or loosening it unit, no beats are heard.

4. Write short answers to any SIX (6) questions: (12)

(i) 5000 lines per centimeter has been ruled on a diffraction grating. Find its grating element.

Ans

$N = 5000 \text{ line / m}$

$N = 50000 \text{ line / m}$

$d = ?$

$$d = \frac{1}{N} = \frac{1}{500000} = 2 \times 10^{-6} \text{ m}$$

(ii) What is optically active crystals?

Ans When a plane polarized light is passed through specific crystals and liquid, they rotate the plane of polarization. Typical examples are quartz and sodium chlorate crystal. These substances are also known as optical active substances.

(iii) State Huygen's principle.

Ans Huygen's Principle consists of two parts:

1. Every point of a wave front may be considered as a source of secondary wavelets which spread out in

forward direction with a speed equal to the speed of propagation of the wave.

2. The new position of the wave front after a certain interval of time can be found by constructing a surface that touches all the secondary wavelets.

(iv) How the power is lost in optical fibre through dispersion? Explain.

Ans When the source of light signal is not perfectly monochromatic, then the narrow and of wavelengths will disperse in different directions. When the light sight signals enter the glass fibre, the light spreads into different wavelengths λ_1, λ_2, and λ_3 as shown in fig.

As λ_1 meets the core and cladding at the critical angle and λ_2 and λ_3 are slightly greater angles. The light paths have thus different lengths. So, the light of different wavelengths reaches the other end of the fibre at different times. In the presence of power losses due to dispersion and spreading of the light signal, the information received at the other end of a fiber will be faulty and distorted.

(v) What is Repeater? Why it is necessary in the optical fibre communication system?

Ans Despite the ultra-purity (99.99% glass) of the optical fiber. the light signals eventually become dim and must be regenerated by devices called repeaters. Repeaters are typically placed about 30 km apart, but in the newer systems, they may be separated by as much as 100 km.

(vi) What is the effect on efficiency of carnot engine, if the temperature of the sink only be decreased?

Ans The efficiency of carnot engine depends on the temperature T_1 and T_2 of hot and cold reservoirs. It is independent of the nature of the working substance. The larger the temperature difference of two reservoirs, the greater is the % efficiency. But it can never be 100% unless cold reservoir is at absolute zero temperature ($T_2 = 0$)

$\Rightarrow \% \eta = (1 - \frac{0}{T_1}) \times 100 = 100\%$. Such cold reservoirs are not available and hence the maximum percentage efficiency is always less then 100%.

(vii) What is metabolism? How first law of thermodynamics explain it?

Ans Energy transforming processes that occur within an organism are termed as metabolism. We can apply the first law of thermodynamics, $\Delta U = Q - w$ to an organism of the human body. Work done W will result in decrease in internal energy of the body. Consequently, the body temperature or in other words internal energy is maintained or kept constant by the food, we eat which supply heat equal to work done.

(viii) State second law of thermodynamics in term of entropy.

Ans The 2nd law of thermodynamics in terms of entropy can also be defined as "When a system undergoes a natural process, it will always proceed in a direction that causes the entropy of system and environment to increase.

(ix) An engine absorbs heat of 10 joule and reject 5 joule heat. What is the heat being used by the engine?

Ans

$q_1 = 10\ J$

$q_2 = 5\ J$

$w = q_1 - q^2$

$= 10 - 5 = 5\ J$

Hence, 5 J heat is being used by the engine.

SECTION-II

NOTE: Attempt any Three (3) questions.

Q.5.(a) What is carnot engine? Discuss carnot cycle. Also derive the relation for its percentage efficiency. **(1,4)**

Ans **Carnot Engine and Carnot's Theorem:**

Sadi Carnot, in 1840, described an ideal engine using only isothermal and adiabatic processes. He showed that a heat engine operating in an ideal reversible cycle between two heat reservoirs at different temperatures, would be the most efficient engine. A Carnot cycle using an ideal gas as the working substance is shown on PV diagram. It consists of following four steps:

1. The gas is allowed to expand isothermally at temperature T_1, absorbing heat Q_1 from the hot reservoir. The process is represented by curve AB.
2. The gas is then allowed to expand adiabatically until its temperature drops to T_2. The process is represented by curve BC.
3. The gas at this stage is compressed isothermally at temperature T_2 rejecting heat Q_2 to the cold reservoir. The process is represented by curve CD.
4. Finally, the gas is compressed adiabatically to restore its initial state at temperature T_1. The process is represented by curve DA.

Thermal and mechanical equilibrium is maintained all the time so that each process is perfectly reversible. As the working substance returns to the initial state, there is not change in its internal energy *i.e.*, $\Delta U = 0$.

The total work done during one cycle equals to the area enclosed by the path ABCDA of the PV diagram. It can also be estimated from net heat Q absorbed in one cycle.

$$Q = Q_1 - Q_2$$

From 1^{st} law of thermodynamics,

$$Q = \Delta U + W$$

$$W = Q_1 - Q_2$$

The efficiency η of the heat engine is defined as:

$$\eta = \frac{\text{Output (Work)}}{\text{Input (Energy)}}$$

Thus, $$\eta = \frac{Q_1 - Q_2}{Q_1} = 1 - \frac{Q_2}{Q_1} \qquad (1)$$

The energy transfer in an isothermal expansion or compression turns out to be proportional to Kelvin temperature. So Q_1 and Q_2 are proportional to Kelvin temperatures T_1 and T_2, respectively and hence,

$$\eta = \frac{T_1 - T_2}{T_1} = 1 - \frac{T_2}{T_1} \qquad (2)$$

The efficiency is usually taken in percentage, in that case,

$$\text{Percentage efficiency} = \left(1 - \frac{T_2}{T_1}\right) 100$$

Thus, the efficiency of Carnot engine depends on the temperature of hot and cold reservoirs. It is independent of the nature of working substance. The larger the temperature difference of two reservoirs, the greater is the efficiency. But it can never be one or 100% unless cold reservoir is at absolute zero temperature ($T_2 = 0$ K).

Such reservoirs are not available and hence the maximum efficiency is always less than one. Nevertheless, the Carnot cycle establishes an upper limit on the efficiency of all heat engines. No practical heat engine can be perfectly reversible and also energy dissipation is inevitable. This fact is stated in Carnot's theorem.

(b) The speed 'v' of sound waves through a medium may be assumed to depend on (i) the density 'ρ' of the medium, and (ii) its modulus of elasticity E which is the ratio of stress to strain. Deduce by the method of dimensions, the formula for the speed of sound. (3)

Ans As speed of sound v depends upon E, so

$v \propto E^m$ where m is a constant

Similarly, $v \propto \rho^n$ where n is a constant

Combining above two factors,

$$v \propto E^m \rho^n$$

$$v = \text{constant } E^m \rho^n \quad (1)$$

Now as $E = \frac{\text{stress}}{\text{strain}}$

Where $\text{Stress} = \text{Pressure} = \frac{F}{A}$

And $\text{Strain} = \frac{\text{Change in volume}}{\text{Original volume}}$

Strain has no dimension because it is ratio of same physical quantity (volume)

$$\therefore \quad [E] = \frac{[\text{Stress}]}{[\text{Strain}]} = [\text{Pressure}]$$

$$= \frac{[F]}{[A]} = \frac{[MLT^{-2}]}{[L^2]}$$

$$= [MLT^{-2}][L^{-2}]$$

$$= [ML^{1-2}T^{-2}]$$

$$\therefore \quad [E] = [ML^{-1}T^{-2}]$$

Also $[\rho] = \frac{[m]}{[V]} = \frac{[M]}{[L^3]} = [ML^{-3}]$

Putting the values in eq. (1),

$$[LT^{-1}] = \text{constant } [ML^{-1}T^{-2}]^m [ML^{-3}]^n$$

$$[LT^{-1}] = \text{constant } [M^mL^{-m}T^{-2m}]\,[M^nL^{-3n}]$$

$$[LT^{-1}] = \text{constant } [M^{m+n}L^{-m-3n}T^{-2m}]$$

Comparing the powers of L, M, T

$$1 = -m - 3n$$

$$0 = m + n \quad \Rightarrow \quad m = -n \qquad (2)$$

$$-1 = -2m \quad \Rightarrow \quad m = \frac{1}{2}$$

Putting the value of m in eq. (2), we get $n = \frac{-1}{2}$

Substituting the values of m and n in eq. (1), we get

$$v = \text{constant } E^{1/2}\,\rho^{-1/2} = \text{constant } \frac{E^{1/2}}{\rho^{1/2}}$$

$$\boxed{v = \text{constant}\sqrt{\frac{E}{\rho}}}$$

Q.6.(a) Define vector product of two vectors. And write any four characteristics of vector product. (5)

Ans There are two types of vector multiplications. The product of these two types are known as scalar product and vector product. As the name implies, scalar product of two vector quantities is a scalar quantity, while vector product of two vector quantities is a vector quantity.

Vector or Cross Product:

The vector product of two vectors A and B, is a vector which is defined as

$$A \times B = AB \sin\theta\, \hat{n} \qquad (1)$$

where $\hat{n}$ is a unit vector perpendicular to the plane containing A and B as shown in Fig. (a).

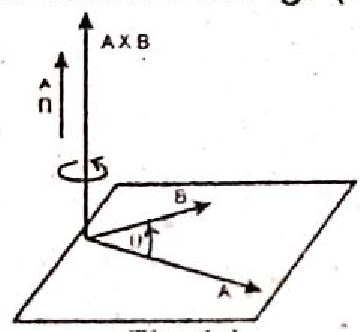


Fig. (a)

Its direction can be determined by right hand rule. For that purpose, place together the tails of vectors A and B to define the plane of vectors A and B. The direction of the product vector is perpendicular to this plane. Rotate the first vector A into B through the smaller of the two possible angles and curl the fingers of the right hand in the direction of rotation, keeping the thumb erect. The direction of the product vector will be along the erect thumb, as shown in the Fig. (b).

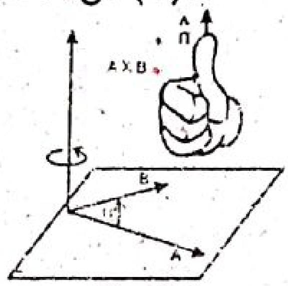


Fig. (b)

Because of this direction rule, B × A is a vector opposite in sign to A × B. Hence,

$$A \times B = -B \times A \qquad (2)$$

Characteristics of Cross Product:

1. Since, A × B is not the same as B × A, the cross product is non-commutative.
2. The cross product of two perpendicular vectors has maximum magnitude $A \times B = AB \sin 90^\circ = \hat{n} = AB\,\hat{n}$. In case of unit vectors, since they form a right handed system and are mutually perpendicular. See Fig. (c) below:

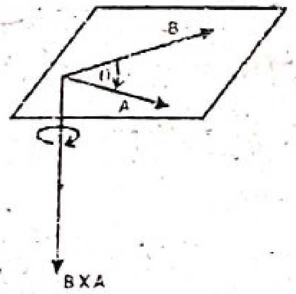


Fig. (c)

$$\hat{i} \times \hat{j} = \hat{k},\ \hat{j} \times \hat{k} = \hat{i},\ \hat{k} \times \hat{i} = \hat{j}$$

3. The cross product of two parallel vectors is null vector, because for such vectors $\theta = 0^\circ$ or 180°. Hence,

$$A \times B = AB \sin 0^\circ \hat{n} = AB \sin 180^\circ \hat{n} = 0$$

As a consequence, $A \times A = 0$

Also $\hat{i} \times \hat{i} = \hat{j} \times \hat{j} = \hat{k} \times \hat{k} = 0$ (3)

4. Cross product of two vectors A and B in terms of their rectangular components is:

$$A \times B = (A_x \hat{i} + A_y \hat{j} + A_z \hat{k}) \times (B_x \hat{i} + B_y \hat{j} + B_z \hat{k})$$

$$A \times B = (A_yB_z - A_zB_y)\hat{i} + (A_zB_x - A_xB_z)\hat{j} + (A_xB_y - A_yB_x)\hat{k} \quad (4)$$

The result obtained can be expressed for memory in determinant form as below:

$$A \times B = \begin{vmatrix} i & j & k \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix}$$

(b) A boy places a fire cracker of negligible mass in an empty can of 40 g mass. He plugs the end with a wooden block of mass 200 g. After igniting the fire cracker, he throws the can straight up. It explodes at the top of its path. If the block shoots out with a speed of 3 m/s, how fast will it can be going? (5)

Ans Given:

Mass of wooden block = m_1 = 200 g = 0.2 kg

Initial velocity of wooden block = v_1 = 0 (at rest)

Mass of can = m_2 = 40 g = 0.04 kg

Initial velocity of can = v_2 = 0 (at rest at the top of path)

Final velocity of wooden block = v_1' = 3 m/s

Required:

Final velocity of can = v_2' = ?

Solution:

According to the law of conservation of momentum

Initial momentum before explosion = Final momentum after explosion

$$m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'$$

$$m_1(0) + m_2(0) = m_1v_1' + m_2v_2'$$

$$0 = 0.2 \times 3 + 0.04\, v_2'$$

$$0.04\, v_2' = -0.6 \quad \text{or} \quad v_2' = -\frac{0.6}{0.04}$$

$$\boxed{v_2' = -15 \text{ m/s}}$$

Negative sign shows that the can will shoot off in opposite direction.

Q.7.(a) What is absolute gravitational potential energy? Derive an expression for it in gravitational field. (5)

Ans For Answer see Paper 2018 (Group-II), Q.6.(a).

(b) A stationary wave is established in a string which is 120 cm long and fixed at both ends. The string vibrates in four segments at a frequency of 120 Hz. Determine its wavelength and the fundamental frequency. (3)

Ans (i)

Data:

Length of string = l = 120 cm

$$= \frac{120}{100} = 1.2 \text{ m}$$

Number of loops = n = 4

Frequency of vibration in four segments = f_4 = 120 Hz

To Find:

(i) Fundamental frequency = f_1 = ?

(ii) Wavelength = λ = ?

FORMULA:

(i) $\frac{\lambda}{2} \times 4 = l$ or $\lambda = l/2$

(ii) $f_n = nf_1$

CALCULATIONS:

We know that the distance between two consecutive nodes is $\lambda/2$. Since, the string vibrates in four segments, therefore, the length of the string is given by:

$$l = 4 \times \frac{\lambda}{2}$$

or $$\lambda = \frac{2l}{4} = \frac{l}{2}$$

Putting the value of 'l', we get

$$\lambda = \frac{1.2}{2} = 0.6 \text{ m}$$

Hence, $\boxed{\lambda = 0.6 \text{ m}}$ Ans.

(ii) Fundamental frequency:

When a string vibrates in n loops, the formula for the frequency of stationary waves is given by:

$$f_n = nf_1$$

where f_1 is the fundamental frequency and n is number of loops.

In the problem, number of loops is 4 *i.e.*, n = 4.

Therefore,

$$f_4 = 4f_1$$

Putting the value of f_4 = 120 Hz, we get

$$120 = 4 f_1$$

$$f_1 = \frac{120}{4} = 30 \text{ Hz}$$

Hence, $\boxed{f_1 = 30 \text{ Hz}}$ **Ans.**

Q.8.(a) What is the difference between real and apparent weight? Discuss the apparent weight in different cases for an object suspended by a spring balance in a lift. (5)

Ans Generally, the weight of an object is measured by a spring balance. The force exerted by the object on the scale is equal to the pull due to gravity on the object, *i.e.*, the weight of the object. This is not always true, as will be explained a little later, so we call the reading of the scale as apparent weight.

To illustrate this point, let us consider the apparent weight of an object of mass m, suspended by a string and spring balance, in a lift. When the lift is at rest, Newton's second law tells us that the acceleration of the object is zero, the resultant force on it is also zero. If w is the gravitational force acting on it and T is the tension in the string, then we have

$$T - w = ma$$

As $a = 0$

Hence, $T = w$ (1)

This situation will remain so long as a = 0. The scale thus shows the real weight of the object. The weight of the object seems to a person in the lift to vary, depending on its motion.

When the lift is moving upwards with an acceleration a, then

$$T - w = ma$$

or $T = w + ma$ (2)

the object will then weight more than its real weight by an amount ma.

Now suppose, the lift and hence, the object is moving downwards with an acceleration a, then we have

$$w - T = ma$$

which shows that

$$T = w - ma \quad (3)$$

The tension in the string, which is the scale reading, is less than w by an amount ma. To a person in the accelerating lift, the object appears to weigh less than w. Its apparent weight is then (w – ma).

Let us now consider that the lift is falling freely under gravity. Then a = g, and hence,

$$T = w - mg$$

As the weight w of the body is equal to mg, so

$$T = mg - mg = 0$$

The apparent weight of the object will be shown by the scale to be zero.

It is understood from these considerations that apparent weight of the object is not equal to its true weight in an accelerating system. It is equal and opposite to the force required to stop it from falling in that frame of reference.

(b) A block weighing 4 kg extends a spring by 0.16 m from its unstretched position. The block is removed and a 0.50 kg body is hung from the same spring. If the spring is now stretched and then released, what is the period of vibration? (3)

Ans Applied stretching force F = kx or $k = \frac{F}{x}$

$F = mg$

$= 4 \text{ kg} \times 9.8 \text{ ms}^{-2}$

$= 39.2 \text{ kg ms}^{-2}$

$= 39.2 \text{ N}$

$x = 0.16 \text{ m},$

$$k = \frac{4 \text{ kg} \times 9.8 \text{ ms}^{-2}}{0.16 \text{ m}}$$

$= 245 \text{ kg s}^{-2}$

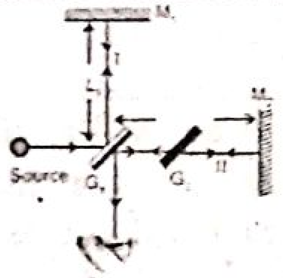
Now time period,

$$T = 2\pi\sqrt{\frac{m}{k}}$$

or $$T = 2\pi\sqrt{\frac{0.5 \text{ kg}}{245 \text{ kg s}^{-2}}} = 0.28 \text{ s}$$

Q.9.(a) Explain the construction and working of Michelson's interferometer. (5)

Ans Michelson's interferometer is an instrument that can be used to measure distance with extremely high precision. Albert A. Michelson devised this instrument in 1881 using the idea of interference of light rays.



Monochromatic light from an extended source falls on a half-silvered glass plate G_1 that partially reflects it and partially transmits it. The reflected portion labeled as I in the figure travels a distance L_1 to mirror M_1, which reflects the beam back towards G_1. The half-silvered plate G_1 partially transmits this portion that finally arrives at the observer's eye. The transmitted portion of the original beam labeled as II, travels a distance L_2 to mirror M_2 which reflects the beam back towards G_1. The beam II partially reflected by G_1 also arrives the observer's eye finally. The plate G_2, cut from the same piece of glass as G_1, is introduced in the path of beam II as a compensator plate. G_2, therefore, equalizes the path length of the beams I and II in glass. The two beams having their different paths are coherent. They produce interference effects when they arrive at observer's eyes. The observer then sees a series of parallel interference fringes.

In a practical interferometer, the mirror M_1 can be moved along the direction perpendicular to its surface by means of a precision screw. As the length L_1 is changed, the pattern of interference fringes is observed to shift. If M_1 is displaced through a distance equal to $\lambda/2$, a path difference of double of this displacement is produced, *i.e.*, equal to λ. Thus, a fringe is seen shifted forward across the line of reference of cross wire in the eyepiece of the telescope used to view the fringes.

A fringe is shifted, each time the mirror is displaced through $\lambda/2$. Hence, by counting the number m of the fringes which are shifted by the displacement L of the mirror, we can write the equation,

$$L = m\frac{\lambda}{2}$$

(b) A glass light pipe in air will totally reflect a light ray if its angle of incidence is at least 39°. What is the maximum angle for total internal reflection if pipe is in water? (Refractive index of water = 1.33) (3)

Ans **Given:**

Incident angle at total internal reflection for glass pipe in air = $\theta_1 = \theta_c = 39^\circ$

For total interval reflection, refraction angle $\theta_2 = 90^\circ$

Required:

Minimum angle of incidence for total internal reflection if pipe is in water $\theta_1' = \theta_c' = ?$

Solution:

For glass, n_1 = refractive index of glass

n_2 = refractive index of air = 1

n_2' = refractive index of water = 1.33

For glass pipe in air, using Snell's law

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

$$n_1 \sin 39^\circ = 1 \times \sin 90^\circ$$

$$n_1 = \frac{1 \times 1}{\sin 39^\circ} \Rightarrow \frac{1}{0.629}$$

$$n_1 = 1.589 \approx 1.59$$

Using Snell's law for glass pipe in water,

$$n_1 \sin\theta'_1 = n'_2 \sin\theta_2$$

$$1.59 \sin\theta'_c = 1.33 \sin 90^\circ$$

$$\sin\theta'_c = \frac{1.33 \times 1}{1.59} = 0.83645$$

$$\theta'_c = 56.77^\circ$$

$$\boxed{\theta'_c \approx 57^\circ}$$