Class 11 - Physics
Sample Paper - 01 (2024-25)

Maximum Marks: 70
Time Allowed: : 3 hours

General Instructions:

1. There are 33 questions in all. All questions are compulsory.
2. This question paper has five sections: Section A, Section B, Section C, Section D and Section E. All the sections are compulsory.
3. Section A contains sixteen questions, twelve MCQ and four Assertion Reasoning based of 1 mark each, Section B contains five questions of two marks each, Section C contains seven questions of three marks each, Section D contains two case study-based questions of four marks each and Section E contains three long answer questions of five marks each.
4. There is no overall choice. However, an internal choice has been provided in section B, C, D and E. You have to attempt only one of the choices in such questions.
5. Use of calculators is not allowed.

Section A

1. The number of significant digits in 2.64×10^{24} is

 a) 1
 b) 2
 c) 3
 d) 4

2. The pitch of a note depends upon its

 a) Intensity
 b) Frequency
 c) Amplitude
 d) Velocity

3. The front wheel on an ancient bicycle has radius 0.5 m. It moves with angular velocity given by the function $\omega(t) = 2 + 4t^2$, where t is in seconds. About how far does the bicycle move between t = 2 and t = 3 seconds?

 a) 27 m
 b) 14 m
 c) 36 m
 d) 21 m

4. Bernoulli's equation is an example of conservation of

 a) momentum
 b) angular momentum
 c) mass

d) energy

5. The ratio of escape velocity at earth (v_e) to the escape velocity at a planet (u_p) whose radius and mean density are twice as that of earth is:

   a) $1 : 2\sqrt{2}$
   b) 1 : 4
   c) $1 : \sqrt{2}$
   d) 1 : 2

6. Electromagnetic waves are different from sound waves in that:

   a) they need no medium and are longitudinal.
   b) they need medium and are transverse.
   c) they need no medium and are transverse.
   d) they need medium and are longitudinal.

7. A body sliding down on a smooth inclined plane slides down $\frac{1}{4}$ th distance in 2s. It will slide down the complete plane in:

   a) 3 s
   b) 5 s
   c) 2 s
   d) 4s

8. Change in temperature of the medium changes

   a) frequency of sound waves
   b) wavelength of sound waves
   c) amplitude of sound waves
   d) loudness of sound waves.

9. 8 mercury drops coalesce to form 1 mercury drop, the energy changes by a factor of

   a) 4
   b) 2
   c) 6
   d) 1

10. The period of a planet around sun is 27 times that of earth. The ratio of radius of planet's orbit to the radius of earth's orbit is:

    a) 27
    b) 4
    c) 9
    d) 64

11. A flywheel is attached to an engine to

    a) decrease its speed
    b) decrease its energy

c) increase its speed
d) help in overcoming the dead point

12. When a body is heated, then maximum rise will be in its

a) surface area
b) density
c) volume
d) length

13. **Assertion (A):** If momentum of a body increases by 50%, its kinetic energy will increase by 125%.
Reason (R): Kinetic energy is proportional to the square of velocity.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

14. **Assertion (A):** A refrigerator transfers heat from lower temperature to higher temperature.
Reason (R): Heat cannot be transferred from lower temperature to higher temperature.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

15. **Assertion:** Escape velocity of a satellite is greater than its orbital velocity.
Reason: Orbit of a satellite is within the gravitational field of planet whereas escaping is beyond the gravitational field of planet.

a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
c) Assertion is correct statement but reason is wrong statement.
d) Assertion is wrong statement but reason is correct statement.

16. **Assertion (A):** Whenever a particle moves in a circular path with uniform speed, an acceleration exists which is directed towards the centre.
Reason (R): The net acceleration of a particle in circular motion is always radially inward.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false but R is true.

Section B

17. A metre-long tube open at one end, with a movable piston at the other end, shows resonance with a fixed frequency source (a tuning fork of frequency 340 Hz) when the tube length is 25.5cm or 79.3cm. Estimate the speed of sound in air

at the temperature of the experiment. The edge effects may be neglected.

18. Differentiate between dimensional and non-dimensional variables.

19. State the rules for finding the number of significant figures in a measurement.

20. Explain why a cricketer moves his hands backward while holding a catch.

21. What would happen if the force of gravity were to disappear suddenly?

OR

What is Kepler's law of periods? Show it mathematically.

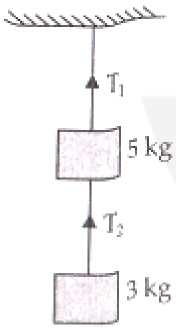
Section C

22. Water from a tap emerges vertically downward with an initial speed of 1.0 ms^{-1}. The cross-sectional area of the tap is 10^{-4} m^2. Assume that the pressure is constant throughout the stream of water, and that the flow is steady. What is the cross-sectional area of the stream 0.15 m below the tap?

23. Define the three modes of transfer of heat from one object to another. Also cite one example for each one of them.

24. Establish the relation $S_{nth} = u + \frac{a}{2}(2n-1)$ where the letters have their usual meanings.

25. Two masses of 5 kg and 3 kg are suspended with help of massless inextensible strings as shown in Figure. Calculate T_1 and T_2 when whole system is going upwards with acceleration = 2 ms^{-2} (use g = 9.8 ms^{-2})



26. What is a refrigerator? Draw a schematic representation of a refrigerator.

27. A small body tied to one end of the string is whirled in a vertical circle. Represent the forces on a diagram when the string makes an angle θ with initial position below the fixed point. Find an expression for the tension in the string. Also, find the tension and velocity at the lowest and highest points respectively.

28. On the basis of Bernoulli's principle, explain the lift of an aircraft wing.

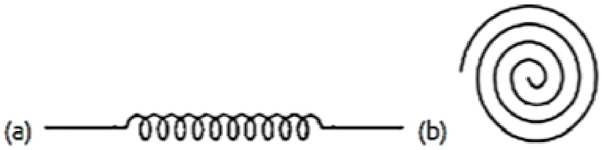
OR

If a number of little droplets of water, each of radius r, coalesce to form a single drop of radius R, show that the rise in temperature will be given by $\Delta\theta = \frac{3\sigma}{J}\left(\frac{1}{r} - \frac{1}{R}\right)$ where σ is the surface tension of water and J is the mechanical equivalent of heat.

Section D

29. **Read the text carefully and answer the questions:**

There are many types of spring. Important among these are helical and spiral springs as shown in the figure.



Usually, we assume that the springs are massless. Therefore, work done is stored in the spring in the form of the elastic potential energy of the spring. Thus, the potential energy of a spring is the energy associated with the state of compression or expansion of an elastic spring.

i. The potential energy of a spring increases in which of the following cases?

a) If work is done against conservative force
b) If work is done by non-conservative force
c) If work is done by conservative force
d) If work is done against non-conservative force

ii. The potential energy, i.e. U(x) can be assumed zero when

a) gravitational force is constant
b) x = 0
c) infinite distance from the gravitational source
d) All of these

iii. The ratio of spring constants of two springs is 2 : 3. What is the ratio of their potential energy, if they are stretched by the same force?

a) 3 : 2
b) 9 : 4
c) 2 : 3
d) 4 : 9

OR

The potential energy of a spring when stretched through a distance x is 10 J. What is the amount of work done on the same spring to stretch it through an additional distance x?

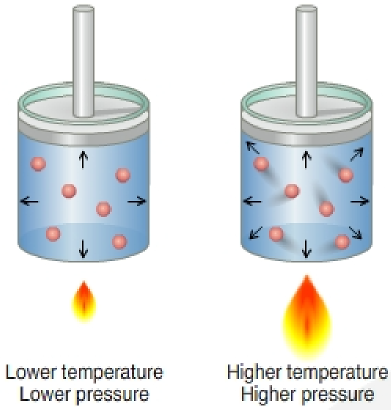
a) 40 J
b) 10 J
c) 30 J
d) 20 J

iv. The potential energy of a spring increases by 15 J when stretched by 3 cm. If it is stretched by 4 cm, the increase in potential energy is

a) 36 J
b) 30 J
c) 27 J
d) 33 J

30. **Read the text carefully and answer the questions:**

In a gas the particles are always in a state of random motion, all the particles move at different speed constantly colliding and changing their speed and direction, as speed increases it will result in an increase in its kinetic energy.



i. If the temperature of the gas increases from 300 K to 600 K then the average kinetic energy becomes:

a) same
b) becomes double
c) becomes half
d) become triple

ii. What is the average velocity of the molecules of an ideal gas?

a) Infinite
b) Same
c) Increase
d) Zero

iii. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will ________.

a) decrease
b) Rises
c) increase
d) remains same

iv. Find the ratio of average kinetic energy per molecule of Oxygen and Hydrogen:

a) 1:1
b) 4:1
c) 1:2
d) 1:4

OR

The velocities of the three molecules are 3v, 4v, and 5v. calculate their root mean square velocity?

a) 4.0 v
b) 4.02 v
c) 4.08 v

d) 4.04 v

Section E

31. A cylindrical piece of cork of base area A, density ρ and height L floats in a liquid of density ρ_{L}. The cork is depressed slightly and then released. Show that the cork oscillates up and down simple harmonically and find its time period of oscillations.

OR

Explain the total energy in simple harmonic motion and show the graphical representation of energy in SHM.

32. Given $\vec{a}$ + $\vec{b}$ + $\vec{c}$ + $\vec{d}$ = 0, which of the following statements are correct:

    i. $\vec{a}$, $\vec{b}$, $\vec{c}$, and $\vec{d}$ must each be a null vector.
    ii. The magnitude of ($\vec{a}$ + $\vec{c}$) equals the magnitude of ($\vec{b}$+ $\vec{d}$).
    iii. The magnitude of '$\vec{a}$' can never be greater than the sum of the magnitudes of $\vec{b}$, $\vec{c}$, and $\vec{d}$.
    iv. $\vec{b}$ + $\vec{c}$ must lie in the plane of $\vec{a}$ and $\vec{d}$ if $\vec{a}$ and $\vec{d}$ are not collinear, and in the line of $\vec{a}$ and $\vec{d}$, if they are collinear?

OR

State triangle law of vector addition. Give analytical treatment to find the magnitude and direction of a resultant vector by using this law.

33. Derive an expression for moment of inertia of a circular disc about an axis passing through its centre and perpendicular to its plane.

OR

    a. Find the moment of inertia of a sphere about a tangent to the sphere, given the moment of inertia of the sphere about any of its diameters to be $\frac{2MR^2}{5}$, where M is the mass of the sphere and R is the radius of the sphere.
    b. Given the moment of inertia of a disc of mass M and radius R about any of its diameters to be $\frac{MR^2}{4}$, find its moment of inertia about an axis normal to the disc and passing through a point on its edge.

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Solution

Section A

1. (c) 3

   Explanation:

   There are three rules on determining how many significant figures are in a number:

   - Non-zero digits are always significant.
   - Any zeros between two significant digits are significant.
   - A final zero or trailing zeros in the decimal portion ONLY are significant.

   So keeping these rules in mind, there are 3 significant digits.

2. (b) Frequency

   Explanation:

   The pitch of a note depends on its frequency.

3. (b) 14 m

   Explanation:

   $\omega t = \frac{d\theta}{dt} = 2 + 4t^2$
   $\int d\theta = \int_2^3 \left(2 + 4t^2\right) dt$
   $\theta = \left[2t + \frac{4}{3}t^3\right]_2^3 = (6 + 36) - \left(4 + \frac{32}{3}\right)$
   $= \frac{82}{3}\text{rad}$
   $s = \theta r = \frac{82}{3} \times 0.5 = 13.7 \simeq 14 \text{ m}$

4. (d) energy

   Explanation:

   Bernoulli's equation is based on the conservation of energy.

5. (a) 1 : $2\sqrt{2}$

   Explanation:

   $v_e = \sqrt{2gR} = R\sqrt{\frac{8}{3}\pi Gp}$
   $\therefore \quad \frac{\nu_s}{v_p} = \frac{R\sqrt{\rho}}{R_p\sqrt{P_p}}$
   = $\frac{R\sqrt{\rho}}{2R \times \sqrt{2p}} = \frac{1}{2\sqrt{2}}$
   = 1 : $2\sqrt{2}$

6. (c) they need no medium and are transverse.

   Explanation:

Electromagnetic waves are transverse waves. The EM **waves** are the waves that are created due to oscillating electric and magnetic fields perpendicular mutually and also to the direction of motion and EM waves(Electromagnetic waves) can travel in a vacuum, thus doesn't require any medium also.

7. (d) 4s
   Explanation:

   Let l be the length of the inclined plane. Then
   $\frac{I}{4} = \frac{1}{2}a(2)^2$ and l = $\frac{1}{2}at^2$
   $\therefore \frac{1}{\frac{1}{4}} = \frac{t^2}{4}$
   $\Rightarrow t^2$ = 16 or t = 4s

8. (b) wavelength of sound waves
   Explanation:

   We know that $v_t = v_0(1 + 61t)$ or $v_t \propto \sqrt{T}$. So, on increasing temperature, the speed also increases as frequency does not change during propagation of wave by formula v = vλ. So, velocity v and wavelength λ both increases.

9. (b) 2
   Explanation:

   8 $\times \frac{4}{3}\pi R^3 = \frac{4}{3}\pi R'^3$
   $\therefore R'$ = 2R
   $U_1 = 8 \times 4\pi R^2\sigma = 32\pi R^2\sigma$
   $U_2 = 4\pi R'^2\sigma = 4\pi (2R)^2 \sigma = 16\pi R^2$
   $\frac{U_2}{U_1} = \frac{1}{2}$
   Energy decreases by a factor of 2

10. (c) 9
    Explanation:

    9

11. (d) help in overcoming the dead point
    Explanation:

    Due to its large inertia of rotation, a flywheel helps the engine to overcome the dead points.

12. (c) volume
    Explanation:

    When a body is heated, the maximum change is in its volume.

13. (a) Both A and R are true and R is the correct explanation of A.
    Explanation:

    As, $P_2 = P_1$ + 50% of $P_1 = \frac{3}{2} P_1$
    $\therefore v_2 = \frac{3}{2} v_1$
    As, kinetic energy, $K \propto v^2$; $\therefore K_2 = \frac{9}{4} K_1$

Increase in K.E.
= $\frac{K_2-K_1}{K_1}\times$ 100 = 125%

14. (b) Both A and R are true but R is not the correct explanation of A.
Explanation:

Electric energy has to be supplied to a refrigerator to enable it to transfer heat energy from lower temperature to higher temperature. But in the absence of any external source of energy, heat cannot be transferred from lower temperature to higher temperature.

15. (a) Assertion and reason both are correct statements and reason is correct explanation for assertion.
Explanation:

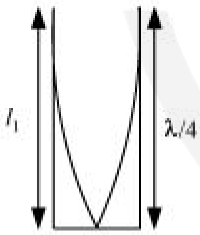
Assertion and reason both are correct statements and reason is correct explanation for assertion.

16. (c) A is true but R is false.
Explanation:

A is true but R is false.

Section B

17. We know that frequency of the tuning fork, v = 340 Hz
Since the given pipe is attached with a piston at one end, it will behave as a pipe with one end closed and the other end open, as shown in the given figure.



Such a system produces odd harmonics. The fundamental note in a closed pipe is given by the relation:
$\Rightarrow l_1=\frac{\lambda}{4}$
Where, Length of the pipe, l_1 = 25.5 cm = 0.255m
$\therefore \lambda=4 l_1=4\times$ 0.255 m = 1.02 m
The speed of sound is given by the relation:
$\Rightarrow v=v\lambda=340\times 1.02$ = 346.8 m/s
So, speed of sound is 346.8 m/s

18. The quantities which have dimensions but do not possess a constant value are called dimensional variables e.g., velocity, force etc. On the other hand, the quantities which have neither dimensions nor they have a constant value are called non-dimensional variables e.g., relative density, strain, etc.

19. Following rules are to be followed for finding the number of significant figures in a measurement:

i. All the non-zero digits are significant.
ii. All the zeros between two non-zero digits are significant, no matter where the decimal point is, if at all.

iii. If the number is less than 1, the zeros on the right side of decimal point but to the left of the first non-zero digit are not significant. For example, in 0.00456, the underlined zeros are not significant.
iv. The trailing zero(s) in a number without a decimal point are not significant. For example, 14500 have three significant figures as trailing zeros being not significant.
v. The trailing zero(s) in a number with a decimal point are significant. For example, 1.6500 have five significant figures.
vi. If a measurement is expressed in terms of powers of ten, then these powers are not significant.

20. From 2nd law of motion, we have
F = ma = $m\frac{\Delta v}{\Delta t}$
Where
'F' is the force experienced by the cricketer as he catches the ball.
'm' is the mass of the ball
'Δt' is the short time of the impact with the hand of a cricketer.
We can thus see from the equation that impact force is inversely proportional to the impact time, Thus, if the impact is for a shorter period of time then the force will be large.
It also shows that the force experienced by the cricketer decreases with the increase in the impact time.
Therefore, the cricketer moves his hand backwards while taking a catch to increase the impact time, and hence decrease the impact force on his hand and prevent it from getting hurt.

21. If the force of gravity suddenly disappears, then

i. All bodies will lose weight.
ii. We would be thrown away from the earth due to the centrifugal force.
iii. Eating, drinking and in fact all operations would become impossible.
iv. Motion of satellites around the planets and the motion of planets around the sun would cease.

OR

It states that the square of the period of revolution of a planet around the sun is proportional to a planet to the cube of the semi-major axis of the elliptical orbit. It means that if you know the period of a planet's orbit,then you can determine that planet's distance from the sun(a = the semimajor axis of the planet's orbit)
i.e. $T^2 \propto R^3$
$T^2 = KR^3$
where T is time period of evolution
R is the length of the semi-major axis
K is constant for all planets

Section C

22. Here $v_1 = 1.0\ ms^{-1}$, $a_1 = 10^{-4} m^2$, $h_1 - h_2 = 0.15 m$, v_2 = ?, a_2 = ?
According to Bernoulli's theorem,
$P + \frac{1}{2}\rho v_1^2 + \rho gh_1 = P + \frac{1}{2}\rho v_2^2 + \rho gh_2$ [$\because P_1 = P_2 = P$ (say)]
or $\frac{1}{2}v_1^2 + gh_1 = \frac{1}{2}v_2^2 + gh_2$
or $v_2^2 = v_1^2 + 2g(h_1 - h_2) = (1.0)^2 + 2 \times 10 \times 0.15 = 4$
or $v_2 = 2\ ms^{-1}$

By equation of continuity, $a_1v_1 = a_2v_2$

$\therefore a_2 = \frac{a_1v_1}{v_2} = \frac{10^{-4}\times1}{2} = 5 \times 10^{-5}\ m^2$

23. There are three possible modes of transfer of heat energy. These are conduction, convection, and radiation.

i. Conduction is the process in which heat energy is transmitted from hot surfaces to cold surfaces without the actual transfer of the particles themselves. Heat transfer In metallic solids generally takes place through conduction.
ii. Convection is the process in which heat is transmitted from one place to another due to the bodily motion of the heated particles of the system. In fluids (i.e., liquids and gases) heat transfer generally takes place by convection.
iii. Radiation is the process in which heat energy is transmitted directly without the presence of any medium from one place to another without heating the intervening medium (if any). Energy from the Sun is transmitted to earth by this method only. Thermal radiation does not need any material medium for their propagation and travel with a speed of 3 $\times 10^8\ ms^{-1}$ i.e., the same as the speed of light.

24. Distance traveled in n^{th} second is given by

$S_{nth} = S_n - S_{n-1}$ ...(i)

Distance traveled in n seconds

$S_n = un + \frac{1}{2}an^2$ ...(ii)

distance traveled in (n-1) seconds

$S_{n-1} = u(n-1) + \frac{1}{2}a(n-1)^2$ ...(iii)

Put equation (ii) and (iii) in equation (i)

$S_{nth} = un + \frac{1}{2}an^2 - u(n-1) - \frac{1}{2}a(n-1)^2$

$S_{nth} = un + \frac{1}{2}an^2 - un + u - \frac{1}{2}an^2 - \frac{1}{2}a + na$

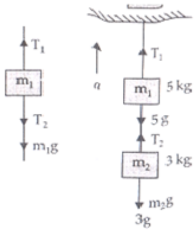
$\mathrm{S_{nth}} = \mathrm{u} - \frac{1}{2}a + \mathrm{na}$

$S_{nth} = \mathrm{u} + \frac{a}{2}(2n-1)$

Hence proved.

25. As the whole system is going up with acceleration = a = $2ms^{-2}$

As given that, m_1 = 5 kg, m_2 = 3 kg, g = 9.8 m/s^2



Tension in a string is equal and opposite in all parts of a string.

For the upper block of mass 5 kg, the forces on mass m_1

$T_1 - T_2 - m_1 g = m_1 a$

$T_1 - T_2 - 5g = 5a$

$T_1 - T_2 = 5 (g + a)$

For the lower block of mass 3 kg, the force on mass

$T_2 - m_2 g = m_2 a$

$T_2 = m_2 (g + a) = 3 (9.8 + 2) = 3 \times 11.8$

$T_2 = 35.4N$

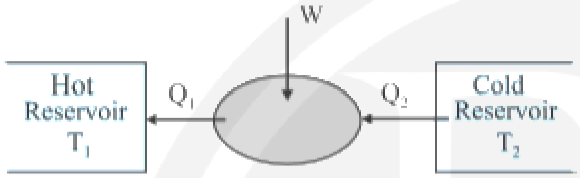
$T_1 = T_2 + 5(g+a)$

$\Rightarrow T_1 = 35.4 + 5(9.8+2) = 94.4$ N

26. A refrigerator or a heat pump is a heat engine working in reverse direction.
    In the refrigerator, we have 2 bodies, lower temperature (cold) body which is freezer and higher temperature (hot) body which is surroundings. It takes heat from the cold reservoir and then some work is done on the refrigerator and then the amount of heat is transferred to the hot reservoir. Let Q_2 be the heat takes from the cold reservoir, W is the work done on the system and then releases Q_1 amount of heat to the hot reservoir.

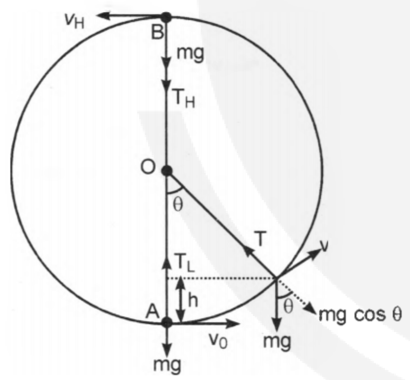
    Mathematically, $Q_2 + W = Q_1$

    The schematic representation of a refrigerator has been shown in the following Figure. Here the refrigerator extracts heat Q_2 from a cold reservoir at temperature T_2, work W is done on it and finally, it rejects Q_1 (= Q_2 + W) heat to surroundings (hot reservoir) maintained at a higher temperature T_1.



    The efficiency of the refrigerator can be calculated from the coefficient of performance of the refrigerator,
    $\alpha = \frac{Q_2}{Q_1 - Q_2}$

27. Consider a small body of mass m attached to one end of a string (of length l) and whirled in a vertical circle of radius 'r'. Let body starts motion from its initial position A, just below the fixed point O, with a speed v_o.



    The forces acting on the body, when the string makes an angle θ with the initial position are shown in the figure. Here, mg is the weight of body and T the tension in the string. If v be the instantaneous velocity at this point, then a centripetal force $F = \frac{mv^2}{l}$ is required radially inward. From figure, it is clear that in equilibrium the centripetal force is provided by resultant of two forces i.e.,

    $T - mg\cos\theta = \frac{mv^2}{l}$

    or $T = mg\cos\theta + \frac{mv^2}{l}$ ...(1)

    If the body has covered a vertical distance h, then from law of conservation of mechanical energy, we have

    $\frac{1}{2}mv_0^2 = \frac{1}{2}mv^2 + mgh$

    $\Rightarrow v^2 = v_0^2 - 2gh$ ...(ii)

    which is the required expression for the velocity of a particle at any point.

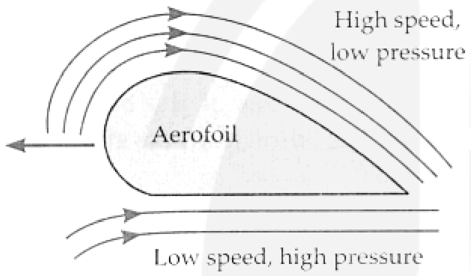
    At the lowest point θ = 0° and h = 0, hence we have

    $v_L = v = v_o$ ....[from (i) putting h = 0]

    Thus,

$T_L = mg\cos 0^\circ + \frac{m}{l}v_L^2 = mg + \frac{mv_0^2}{l}$
and at the highest point θ = 180° and h = $2l$. Hence,
$v_H^2 = v^2 = v_0^2 - 4gl$ [from (i) putting h = $2l$]
or $v_H = \sqrt{v_0^2 - 4gl}$
and $T_H = mg\cos 180^\circ + \frac{mv_H^2}{l} = mg(-1) + \frac{m}{l}\left(v_0^2 - 4gl\right) = \frac{mv_0^2}{l} - 5mg$
which is the required expression for the Tension.

28. Aerofoil: Lift of an aircraft wing. Aerofoil is the name given to a solid object shaped to provide an upward vertical force as it moves horizontally through air. This upward force (dynamic lift) makes aeroplanes fly.
As shown in Fig., the cross-section of the wing of an aeroplane looks like an aerofoil. The wing is so designed that its upper surface is more curved (and hence longer) than the lower surface and the front edge is broader than the rear edge. As the aircraft moves, the air moves faster over the upper surface of the wing than on the bottom. According to Bernoulli's principle, the air pressure above the upper surface decreases below the atmospheric pressure and that on the lower surface increases above the atmospheric pressure. The difference in pressure provides an upward lift, called dynamic lift, to the aircraft.



OR

Let n be the number of little droplets which coalesce to form a single drop. Then
The volume of n little droplets = Volume of a single drop
or n $\times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi R^3$ or $mr^3 = R^3$
Decrease in surface area = n $\times 4\pi r^2 - 4\pi R^2$
= 4π [nr^2 - R^2] = 4π [$\frac{nr^3}{r}$ - R^2]
= 4π [$\frac{R^3}{r}$ - R^2] = $4\pi R^3 \left[\frac{1}{r} - \frac{1}{R}\right]$ [$\because nr^3 = R^3$]
Energy evolved,
W = Surface tension $\times$ decrease in surface area
$= 4\pi\sigma R^3 \left[\frac{1}{r} - \frac{1}{R}\right]$
Heat produced,
Q = $\frac{W}{J} = \frac{4\pi\sigma R^3}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$
But Q = ms$\Delta\theta$
= Volume of single drop $\times$ density of water $\times$ specific heat of water $\times \Delta\theta$
= $\frac{4}{3}\pi R^3 \times 1 \times 1 \times \Delta\theta$
Hence
$\frac{4}{3}\pi R^3 \Delta\theta = \frac{4\pi\sigma R^3}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$
or $\Delta\theta = \frac{3\sigma}{J}\left[\frac{1}{r} - \frac{1}{R}\right]$

Section D

29. i. (a) If work is done against conservative force
Explanation:

If work is done against conservative force

ii. (d) All of these
Explanation:

All of these

iii. (a) 3 : 2
Explanation:

3 : 2

OR

(c) 30 J
Explanation:

30 J

iv. (c) 27 J
Explanation:

27 J

30. i. (b) becomes double
Explanation:

becomes double

ii. (d) Zero
Explanation:

Zero

iii. (d) remains same
Explanation:

remains same

iv. (a) 1:1
Explanation:

1:1

OR

(c) 4.08 v
Explanation:

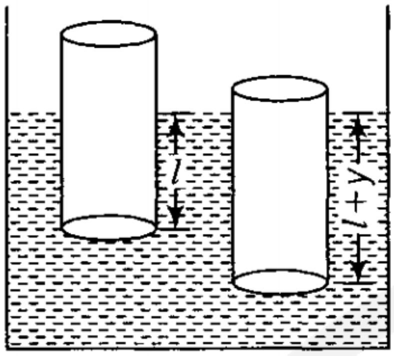
4.08 v

Section E

31. Consider a cylinder of mass m, length L, density of material ρ and uniform area of cross-section A.

Therefore, mass of the cylinder(m) = A Lρ

Let the cylinder is floating in the liquid of density ρ_1



In equilibrium, let l be the length of cylinder dipping in liquid.

In equilibrium, weight of cylinder = Weight of liquid displaced

$\Rightarrow$ mg = A l ρ_1 g

$\Rightarrow$ m = A lρ_1 ...(ii)

Now say the cylinder is pushed down by y into the liquid, then

Total upward thrust, F_2 = A (l + y) ρ_1 g (since effective depth = l+y)

Restoring force, F = - (F_2 - mg)

$\Rightarrow$F = -[A(l + y)ρ_1g - Alρ_1g] = -A$\rho_1$gy........(iii)

We know that In SHM, F $\propto$ - y

$\Rightarrow$ F = - k y ...(iv)

Comparing equation (iii) with equation (iv) we get,

Spring factor, k = Aρ_1g

Inertia factor = mass of the cylinder(m) = ALρ

Now, we know the formula of time period, T = $2\pi\sqrt{\frac{\text{Inertia factor}}{\text{Spring factor}}}$

Hence, T = $2\pi\sqrt{\frac{AL\rho}{A\rho_1 g}} = 2\pi\sqrt{\frac{L\rho}{\rho_1 g}}$..............(v)

Using, m = Alρ_1 = ALρ

So, $l\rho_1 = L\rho$

Using the above value we get time period,

T = $2\pi\sqrt{\frac{l\rho_1}{g\rho_1}} = 2\pi\sqrt{\frac{l}{g}}$

OR

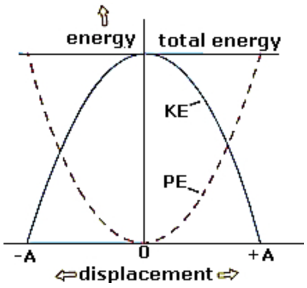
The total energy of the system of a block and a spring is equal to the sum of the potential energy stored in the spring plus the kinetic energy of the block and is proportional to the square of the amplitude.

$\frac{1}{2}m\omega^2\left(A^2-x^2\right)+\frac{1}{2}m\omega^2x^2$

E = $\frac{1}{2}$mω^2A^2

Hence, the total energy of the particle in SHM is constant and it is independent of the instantaneous displacement.

Relationship between potential energy, kinetic energy, and time in Simple Harmonic Motion at t = 0, when x = $\pm$A.



32. i. Incorrect

In order to make $\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$, it is not necessary to have all the four given vectors to be null vectors. There are many other combinations that can give the sum zero.

ii. Correct

$\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$

$\vec{a} + \vec{c} = -(\vec{b} + \vec{d})$

Taking modulus on both the sides, we get:

$|\vec{a} + \vec{c}| = |-(\vec{b} + \vec{d})| = |\vec{b} + \vec{d}|$

Hence, the magnitude of $(\vec{a} + \vec{c})$ is the same as the magnitude of $(\vec{b} + \vec{d})$.

iii. Correct

$\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$

$\vec{a} = (\vec{b} + \vec{c} + \vec{d})$

Taking modulus both sides, we get:

$|\vec{a}| = |\vec{b} + \vec{c} + \vec{d}|$

$|\vec{a}| \leq |\vec{a}| + |\vec{b}| + |\vec{c}|$ ....(i)

Equation (i) shows that the magnitude of a is equal to or less than the sum of the magnitudes of $\vec{b}$, $\vec{c}$, and $\vec{d}$.

Hence, the magnitude of a vector can never be greater than the sum of the magnitudes of b, c, and d.

iv. Correct

For $\vec{a} + \vec{b} + \vec{c} + \vec{d} = 0$

$\vec{a} + (\vec{b} + \vec{c}) + \vec{d} = 0$

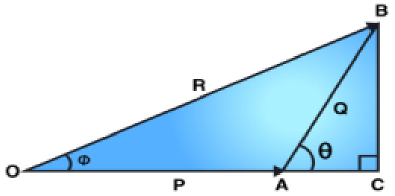
The resultant sum of the three vectors $\vec{a}$, $(\vec{b} + \vec{c})$, and d can be zero only if $(\vec{b} + \vec{c})$ lie in a plane containing a and d, assuming that these three vectors are represented by the three sides of a triangle.

If a and d are collinear, then it implies that the vector $(\vec{b} + \vec{c})$ is in the line of a and d. This implication holds only then the vector sum of all the vectors will be zero.

OR

Triangle law of vector addition states that when two vectors are represented as two sides of the triangle taken in the same order, then the closing side of the triangle taken in the opposite order represents the magnitude and direction of the resultant vector.

Consider two vectors, P and Q, respectively, represented by the sides OA and AB. Let vector R be the resultant of vectors P and Q.



From triangle OCB,

$OB^2 = OC^2 + BC^2$

In triangle ACB with θ as the angle between AC and AB

In $\triangle$ABC,

$\frac{BC}{AB}$ = sin θ

so BC = AB sin θ = Q sin θ

$\frac{AC}{AB}$ = cos θ

AC = AB cos θ = Q cos θ

In $\triangle$OBC, $OB^2 = OC^2 + CB^2$

$OB^2 = (OA + AC)^2 + CB^2$

$R^2 = (P + Q\cos\theta)^2 + (Q\sin\theta)^2$ $R^2 = P^2 + Q^2 + 2PQ\cos\theta$

R = $\sqrt{P^2 + Q^2 + 2PQ\cos\theta}$

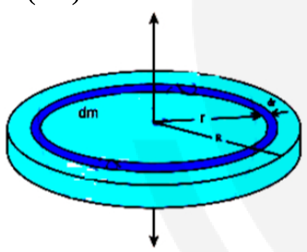
The direction of result tan t vector can be found by following

tan ϕ = $\frac{BC}{OC}$ = $\frac{Q\sin\theta}{P+Q\cos\theta}$

Resultant act in the direction making an angle

$\alpha = \tan^{-1}\left(\frac{\vec{Q}\sin\theta}{\vec{P}+\vec{Q}\cos\theta}\right)$ with direction of vector P.

33. Consider a disc of mass M and radius R. This disc is made up of many infinitesimally small rings, as shown in the figure. Consider one such ring of mass (dm) and thickness (dr) and radius (r). The moment of inertia (dl) of this small ring is, dI = $(dm)R^2$



$I = \int dI$

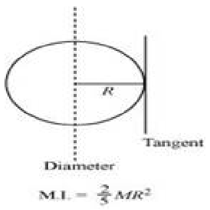
$I = \int_0^R \frac{2M}{R^2} r^3 dr = \frac{2M}{R^2}\int_0^R r^3 dr$

$I = \frac{2M}{R^2}\left[\frac{r^4}{4}\right]_0^R = \frac{2M}{R^2}\left[\frac{R^4}{4} - 0\right]$

$I = \frac{1}{2}MR^2$

OR

a. The moment of inertia (M.I.) of a sphere about its diameter is given by $= \frac{2}{5}MR^2$



Given,

Moment of inertia of the sphere about its diameter is given by $= (\frac{2}{5})mR^2$

Use, parallel axis theorem ,

Moment of inertia of the sphere about tangent is given by $= I + mR^2$

$= (\frac{2}{5})mR^2 + mR^2$

$= (7/5)mR^2$

b. Moment of inertia of disc of mass m and radius R about any of its diameter is = $mR^2/4$

Moment of inertia about diameter is given by $= I_x = I_y = (\frac{1}{4})mR^2$

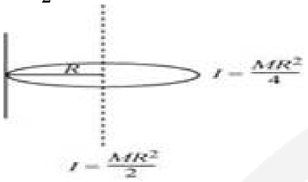
Using , perpendicular axis theorem,

$I_z = I_x + I_y$

Where I_z is moment of inertia about perpendicular axis of plane of disc. Hence,

$I_z = (\frac{1}{4})mR^2 + (\frac{1}{4})mR^2$

$= (\frac{1}{2})mR^2$



Moment of inertia of disc about passing through a point of its edge is given by;

Use , parallel axis theorem, we get

$I = I_z + mR^2$

$= (\frac{1}{2})\ mR^2 + mR^2$

$= (\frac{3}{2})mR^2$