CBSE Class 11 Physics
Sample Paper 05 (2020-21)

Maximum Marks: 70
Time Allowed: 3 hours

General Instructions:

i. All questions are compulsory. There are 33 questions in all.
ii. This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
iii. Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each, Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.
iv. There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

Section A

1. Friction is a self adjusting force. Justify.
2. Two balls of different masses are thrown vertically upward with same initial speed. Which one will rise to a greater height?

OR

An object falling through a fluid is observed to have acceleration given by $a = g - bv$; where g = gravitational acceleration and b is a constant. After a long time of release, it is observed to fall with constant speed. What must be the value of constant speed?
3. The moment of inertia of two rotating bodies A and B are l_A and l_B ($l_A > l_B$) and their angular momenta are equal. Which one has a greater kinetic energy?
4. A binary star system consists of two stars A and B which have time periods T_A and T_B, radius R_A and R_B and masses m_a and m_e which of the three quantities are same for the

stars. Justify.

OR

Does the speed of a satellite remain constant in a particular orbit (circular)?

5. Does Archimedes principle hold in a vessel in a free fall?
6. What is the value of m in $\hat{\mathbf{i}} + m\hat{\mathbf{j}} + \hat{\mathbf{k}}$ to be unit vector?
7. Write the dimensional equation of molar gas constant R.

OR

How many light years make 1 parsec?

8. At what temperature will the speed of sound be double its value at 273' K?

OR

Is Newton's law of motion applicable for material waves? Is this applicable for electromagnetic waves?

9. Write conditions for an isothermal process.
10. State the essential condition for the addition of vectors.
11. **Assertion:** As the frictional force increases, the safe velocity limit for taking a turn on an unbanked road also increases.

    Reason: Banking of roads will increase the value of limiting velocity.
    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.
12. **Assertion:** Identical springs of steel and copper are equally stretched. More work will be done on the steel spring.

    Reason: Steel is more elastic than copper.
    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.

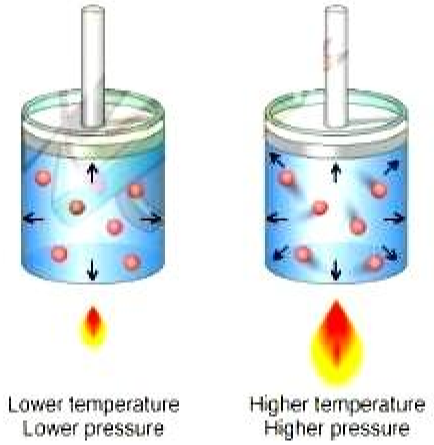
c. Assertion is correct statement but reason is wrong statement.
d. Assertion is wrong statement but reason is correct statement.

13. **Assertion:** A material will have only one specific heat, if and only if its coefficient of thermal expansion is equal to zero.
Reason: An ideal gas has two specific heats (C_V. and C_P) only.
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.

14. **Assertion:** According to the law of conservation of mechanical energy change in potential energy is equal and opposite to the change in kinetic energy.
Reason: Mechanical energy is not a conserved quantity.
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.

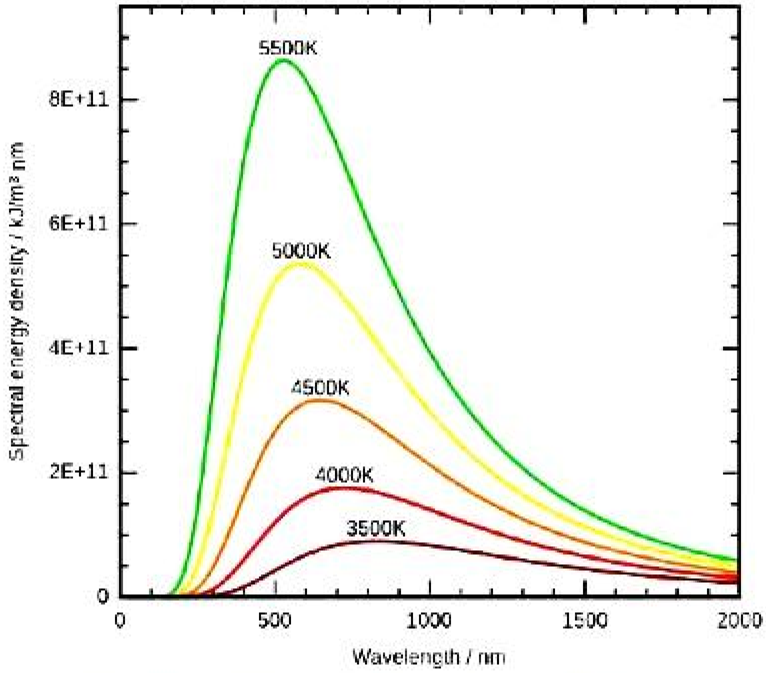
Section B

15. **Read the case study given below and answer any four subparts:**
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 the increase in its kinetic energy.



i. If the temperature of the gas increases from 300 K to 600K then the average kinetic energy becomes:
   a. becomes half
   b. becomes double
   c. same
   d. none of these
ii. What is the average velocity of the molecules of an ideal gas?
   a. infinite
   b. same
   c. zero
   d. none of these
iii. Cooking gas containers are kept in a lorry moving with uniform speed. The temperature of the gas molecules inside will _______
   a. increase
   b. decrease
   c. remains same
   d. none of these
iv. Find the ratio of average kinetic energy per molecule of Oxygen & Hydrogen:
   a. 1:1
   b. 1:2
   c. 1:4
   d. 4:1
v. The velocities of three molecules are 3 v, 4 v, and 5 v. calculate their root mean square velocity?
   a. 4.0 v
   b. 4..02 v
   c. 4.04 v
   d. 4.08 v

16. **Read the case study given below and answer any four subparts:**
Blackbody radiation is a term used to describe the relationship between an object's temperature, and the wavelength of electromagnetic radiation it emits. A black body is an idealized object that absorbs all electromagnetic radiation it comes in contact with. It then emits thermal radiation in a continuous spectrum according to its temperature.



i. As the wavelength of the radiation decreases, the intensity of the black body radiations:
   a. increase
   b. decrease
   c. first increase then decrease
   d. first decrease then increase

ii. The radiations emitted by hot bodies are called as:
   a. X- ray
   b. gamma-ray
   c. black body radiation
   d. visible ray

iii. For a prescribed wavelength a black body radiates how much energy at the temperature of the body?
   a. maximum
   b. minimum
   c. 50%
   d. 20%

iv. Three black bodies A, B and C in the form of cubes of sides in the ratio of 3: 4: 5 are kept at the same high temperature. The ratio of the quantity of heat lost per second by A, B and C will be
   a. 9:16:25

b. 5:4:3

c. 25:16:9

d. none of these

v. The emissive of a perfectly black body is

a. 0

b. 0.5

c. 0.75

d. 1

Section C

17. If radius of earth is 6400km, what will be the weight of 1 quintal body if taken to the height of 1600 km above the sea level?

18. If momentum of a body increased by 300%, then what will be percentage increase in momentum of a body?

OR

Calculate the power of a crane in watts, which lifts a mass of 100 kg to a height of 10 m in 20 seconds.

19. A particle executing S.H.M has a maximum displacement of 4cm and its acceleration at a distance of 1 cm from its mean position is 3 cm/s^2. What will be its velocity when it is at a distance of 2cm from its mean position?

OR

A mass of 2 kg is suspended from a vertical spring. An additional force of 2.5 N stretched it by 1 cm.

i. Calculate the force constant.

ii. Calculate the frequency of oscillations if the spring is stretched by the given force and then released.

20. A block of mass 10kg is sliding on a surface inclined at a angle of 30^o with the horizontal. Calculate the acceleration of the block. The coefficient of kinetic friction between the block and the surface is 0.5.

21. A ball is dropped from a building of height 45 m. simultaneously another ball is thrown up with a speed 40 m/s. Calculate the relative speed of the balls as a function of time.

22. The shortest wavelength of the ultrasonic waves that a bat emits is approximately 3.32

mm at 0 °C. What is the frequency of these waves? Speed of sound in air at 0 °C = 332 ms^{-1}.

23. Show that cross product of two parallel vectors is zero.
24. The wavelength λ associated with a moving particle depends upon its mass m, its velocity v and Planck's constant h. Show dimensional relation between them.

OR

The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{L/g}$. The measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wristwatch of 1 s resolution. What is the accuracy in the determination of g?

25. In which of the following examples of motion, can the body be considered approximately a point object?
    i. A railway carriage moving without jerks between two stations.
    ii. A monkey sitting on the top of a man cycling smoothly on a circular track.
    iii. A spinning cricket ball that turns sharply on hitting the ground.

Section D

26. A constant force acting on a body of mass 3.0 kg changes its speed from 2.0 ms^{-1} to 3.5 ms^{-1} in 25 s. The direction of the motion of the body remains unchanged. What is the magnitude and direction of the force?
27. A physical quantity X is related to four measurable quantities a, b, c and d as follows: $X = a^2b^3c^{\frac{5}{2}}d^{-2}$. The percentage error in the measurement of a, b, c and d are 1%, 2%, 3% and 4% respectively. What is the percentage error in quantity X? If the value of X calculated on the basis of the above relation is 2.763, to what value should you round off the result?

OR

A book with many printing errors contains four different formulas for the displacement y of a particle undergoing a certain periodic motion:

i. $y = a\sin\left(\frac{2\pi t}{T}\right)$
ii. $y = \left(\frac{a}{T}\right)\sin\frac{t}{a}$

iii. $y = (a\sqrt{2})\left(\sin \frac{2\pi t}{T} + \cos \frac{2\pi t}{T}\right)$

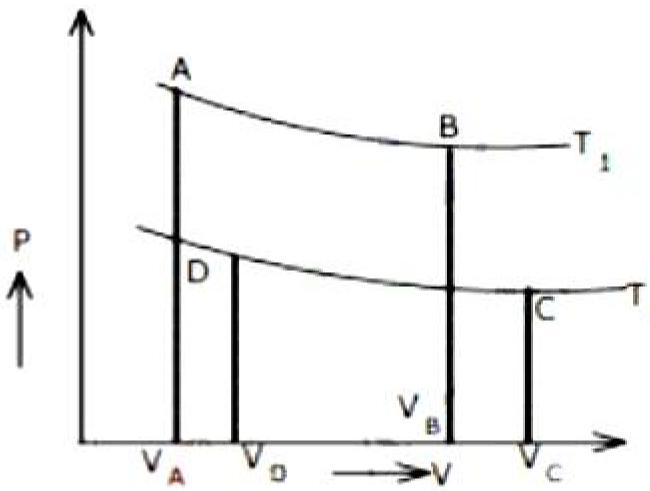
(a = maximum displacement of the particle, v = speed of the particle. T = time-period of motion). Rule out the wrong formulas on dimensional grounds.

28. A bullet fired at an angle of 30° with the horizontal hits the ground 3.0 km away. By adjusting its angle of projection, can one hope to hit a target 5.0 km away? Assume the muzzle speed to the fixed, and neglect air resistance.

OR

On a particular day, rain was falling vertically with a speed of 30 km h^{-1} and wind was blowing from west to east at a speed of 18 kmh^{-1}. Find the relative velocity of rain w.r.t. wind.

29. Two different adiabatic paths for the same gas intersect two thermals at T_1 and T_2 as shown in P-V diagram. How does $\frac{VA}{VD}$ Compare with $\frac{VB}{VC}$?



30. Viscous force increase the velocity of a satellite. Discuss.

Section E

31. A tunnel is dug through the centre of the Earth. Show that a body of mass *'m'* when dropped from rest from one end of the tunnel will execute simple harmonic motion.

OR

A person normally weighing 50 kg stands on a mass less platform which oscillates up and down harmonically at a frequency of 2.0 s^{-1} and an amplitude 5.0 cm. A weighing machine on the platform gives the persons weight against time.

i. Will there be any change in weight of the body, during the oscillation? Figure In extensible string.
ii. If answer to part (a) is yes, what will be the maximum and minimum reading in the machine and at which position?

32. An object of mass 0.4 kg moving with velocity of 4 m/s collides with another object of mass 0.6 kg moving in same direction with a velocity of 2 m/s . If the collision is perfectly inelastic, what is the loss of KE due to impact?

OR

A balloon filled with helium rises against gravity increasing its potential energy. The speed of the balloon also increases as it rises. How do you reconcile this with the law of conservation of mechanical energy? You can neglect the viscous drag of air and assume that the density of air is constant.

33. Determine the volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 7.0×10^6 Pa.

OR

A steel wire and a copper wire of equal length and equal cross-sectional area are joined end to end and the combination is subjected to a tension. Find the ratio of (a) the stresses developed in the two wires, (b) the strains developed in two wires. Given that Y of steel = 2.0×10^{11} N/m^2 and Y of copper = 1.1×10^{11} N/m^2.

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Solution

Section A

1. When we try to move an object on a rough surface, we use to apply a push or pull on it. When the applied force on it is zero, the static frictional force also remains zero. As we go on increasing the applied force, the static frictional resistive force opposing its motion also goes on increasing. But this static frictional force has its maximum limiting value, beyond which it changes to kinetic friction. Thus, static frictional force's value varies from zero to the maximum value to limiting friction. That is why friction is called a self adjusting force.
2. Both of them will rise to equal height as distance travelled by it does not depend on mass.

OR

After long time of released the velocity becomes constant i.e.,

$\frac{dv(t)}{dt} = 0$ or $a = 0$

Given acceleration is, $a = g - bv$ ......(i)

0 = g - bv [from (i)]

bv = g

$v = \frac{g}{b}$

Hence, the constant speed after a long time of release is $\left(\frac{g}{b}\right)$.

3. $k = \frac{L^2}{2I} \Rightarrow K_B > K_A$ .Therefore if the angular momentum are equal,the body with smaller moment of inertia has the greater kinetic energy.
4. Angular velocity of binary stars are same as $w_A = w_B$,

$\frac{2\pi}{T_A} = \frac{2\pi}{T_B} \Rightarrow T_A = T_B$

OR

Yes, the speed of a satellite remain constant in a particular orbit (circular) as $v = \sqrt{\frac{GM}{r}}$, v depends only upon r.

5. Buoyant force acting on a body which is immersed in vessel and vessel is at rest F=mg , where m is mass of body. The apparent weight of system during free fall W=m(g-g)=0. As weight of an object become zero during free fall, the buoyant force also become zero. Thus, Archimedes principle does not hold during free fall.
6. For unit vector, we have
   $|\hat{\mathbf{i}} + m\hat{\mathbf{j}} + \hat{\mathbf{k}}| = \sqrt{1 + m^2 + 1} = 1$
   $m^2 + 2 = 1$
   $m^2 = -1 \Rightarrow m = \sqrt{-1}$
   Hence, m is imaginary number.
7. The dimensional formula for Molar gas constant is given by:
   Molar gas constant [R]= $[ML^2T^{-2}mol^{-1}]$.

   OR

   One parsec is equal to about 3.26 light years.

8. Say v_1 is the velocity of sound at $T_1 = 273^{\circ}k$ and $v_2 = 2v_1$ at temperature T_2
   Now $\frac{v_2}{v_1} = \sqrt{\frac{T_2}{T_1}} \therefore \frac{2v_1}{v_1} = \sqrt{\frac{T_2}{273}}$
   Or $T_2 = 4 \times 273 = 1092^{\circ}K$

   OR

   Newton's laws of motion are applicable for material waves but not applicable for electromagnetic waves. Since electromagnetic waves are produced by accelerated charges.

9. The conditions for an isothermal process are
   i. The process should be quasi-static.
   ii. The walls should be diathermic.
10. The most basic condition for the addition of vectors is that they must represents the physical quantities of the same nature.
11. (b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.
    Explanation: Both assertion and reason are true but reason is not the correct

explanation of assertion.

On an unbanked road, friction provides the necessary centripetal force,

$$\frac{mv^2}{r} = F = \mu R = \mu mg$$

$$\therefore \quad v = \sqrt{\mu r g}$$

Thus, with increase in friction, safe velocity also increases. When the road is banked with angle of θ, then its limiting velocity is its given by,

$$v = \sqrt{\frac{rg(\tan\theta + \mu)}{1 - \mu\tan\theta}}$$

Thus, limiting velocity increases with banking of road.

12. (a) Assertion and reason both are correct statements and reason is correct explanation for assertion.

    Explanation: Both assertion and reason are true and reason is the correct explanation of assertion.

    Work done = $\frac{1}{2} \times$ stress $\times$ strain

    $= \frac{1}{2} \times \gamma \times (\text{ strain })^2$

    Since, elasticity of steel is more than copper, hence more work has to be done in order to stretch the steel.

13. (c) Assertion is correct statement but reason is wrong statement.

    Explanation: Assertion is correct statement but reason is wrong statement.

14. (c) Assertion is correct statement but reason is wrong statement.

    Explanation: For conservative forces, the sum of kinetic and potential energies at any point remains constant throughout the motion. It does not depend upon time, this is known as law of conservation of mechanical energy. According to this rule,

    Kinetic energy + Potential Energy = E = Constant

    or $\Delta T + \Delta U = 0$ or $\Delta T = -\Delta U$

Section B

15. i. b

    ii. c

    iii. c

    iv. a

    v. d

16. i. c
  ii. c
  iii. a
  iv. a
  v. d

Section C

17. R = 6400km = 6400 $\times$ 10^3m

h = 1600km

w = mg = 1 quintal = 100 kg = 100 $\times$ 9.8 N=980N

new weight of body is

weight (w') = mg'

gravity at height

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

$$w' = 100 \times 9.8\left(\frac{6400}{1600+6400}\right)^2$$

w' = 100 $\times$ 9.8N $\times$0.64= 627.2N

w'=627.2/9.8 =64kg

18. Consider a particle having mass m moving with a velocity v so, that its kinetic energy, K.E = $\frac{1}{2}$ mv^2 and momentum, p = mv.

Thus, $\mathrm{K.E} = \frac{p^2}{2m}$ or $p = \sqrt{2mK.E}$

when, kinetic energy is increased by 300%, then new kinetic energy is given by:

K.E' = K.E + 300% of E =KE + 3KE = 4K.E

New momentum p' = $\sqrt{2m\mathrm{K.E'}} = \sqrt{2m \times 4\mathrm{K.E}} = 2\sqrt{2m\mathrm{K.E}} = 2p$

Therefore, the Percentage increase in momentum

$$= \frac{p' - p}{p} \times 100 = \frac{2p-p}{p} \times 100 = 100\%$$

OR

$$P = \frac{WD}{\text{time}} = \frac{FS\cos\theta}{t} = \frac{mg \cdot h\cos\theta}{t}$$

As the direction of displacement (height) and force applied by crane are same.

$$So\ \theta = 0^0$$

$$F = mg = 100 \times 10 \quad h = 10m \quad t = 20s$$

$$P = \frac{100 \times 10 \times 10\cos 0^\circ}{20} = 500\mathrm{Watts}$$

19. The acceleration of a particle executing S.H.M is –

$$A = \omega^2 Y$$

ω = Angular frequency ; Y = Displacement

A = Acceleration

Given A = 3cm / s^2 ; Y = 1cm

So, 3 = ω^2 × 1

$$\omega = \sqrt{3} rad/s$$

The velocity of a particle executing S.H.M is :-

$$V = \omega\sqrt{a^2 - y^2}$$

a = amplitude

$$V = \sqrt{3} \times \sqrt{(4)^2 - (2)^2}$$

$$V = \sqrt{3} \times \sqrt{16 - 4}$$

$$V = \sqrt{3} \times \sqrt{12}$$

$$V = \sqrt{3} \times 2 \times \sqrt{3}$$

$$V = 2 \times 3$$

V = 6 cm/s

OR

Here mass m = 2 kg, force F = 2.5 N and elongation x = 1 cm = 0.01 m.

i. Force constant k = $\frac{F}{x}$ = $\frac{2.5N}{0.01m}$ = 250 N/m
ii. Frequency of oscillations = $\frac{1}{2\pi}\sqrt{\frac{k}{m}}$ = $\frac{1}{2\times3.14} \times \sqrt{\frac{250}{2}}$

= 1.78 Hz.

20. $m = 10kg \quad \theta = 30^\circ \mu k = 0.5$

$$a = g(\sin\theta - \mu k\cos\theta)$$

$$a = 9.8\,(\sin 30^\circ - 0.5\cos 30^\circ)$$

$$a = 9.8(-.5 - 0.5 \times 0.866)$$

a = 0.657m/s^2

21. For the first ball falling from top,

V = v_1 = ?, u_1 = 0, h = 45 m, a = g, t = t

V = u_1 + at

v_1 = 0 + gt or v_1 = gt (downward)

For the second ball thrown upward

$\therefore v_1 = -gt$ ()

$V = v_2$, $u_2 = 40$ m/s, $a = -g$, $t = t$

$V = u_2 + at$

$v_2 = (40 - gt) \times v_2 = (40 - gt)$

Relative velocity of ball Ist with respect to IInd

$$v_{12} = v_1 - v_2 = -gt - (40 - gt)$$

$= -gt - 40 + gt = -40$ m/s (downward)

Relative velocity of ball first with the respect to second is 40 m/s downward.

In this problem due to acceleration, the speed of one increases and of other decreases with the same rate. So their relative speed remains (40 – 0) = 40 m/s.

22. Here velocity of sound, $v = 332\ ms^{-1}$ and shortest wavelength $\lambda_{min} = 3.32\ mm = 3.32 \times 10^{-3}$ m.

$\therefore$ Maximum frequency of waves produced by bat is,

$f = \frac{v}{\lambda_{\min}}$

$= \frac{332ms^{-1}}{3.32 \times 10^{-3}} = 10^5$ Hz.

23. $\overline{A} \times \overline{B} = AB \sin\theta \hat{x}$

If $\overline{A}$ and $\overline{B}$ are parallel to each other

$\theta = 0°$

$\Rightarrow \overline{A} \times \overline{B} = 0$

24. Suppose wavelength λ associated with a moving particle depends upon (i) its mass (m), (ii) its velocity (v) and (iii) Planck's constant (h), then

$\lambda = km^a v^b h^c$..(1)

where, k is a dimensionless constant.

Representing the above equation in terms of its dimensions, we get

$[M^0L^1T^0] = [M]^a[LT^{-1}]^b[ML^2T^{-1}]^c$

$\Rightarrow [M^0L^1T^0] = M^{a+c}L^{b+2c}T^{-b-c}$ ..(2)

Comparing power of M, L and T on both sides of equation (2), we get

$a + c = 0, b + 2c = 1, -b - c = 0$

we get $a = -1, b = -1, c = +1$

putting the value of a,b, and c in equation (1), we get

$\lambda = km^{-1}v^{-1}h^{1}$

$\lambda = \frac{kh}{mv}$

Hence, the relation becomes $\lambda = \frac{kh}{mv}$ and it gives the de broglie wavelength of a moving particle.

OR

As we know that, $T = 2\pi\sqrt{\frac{L}{g}} \Rightarrow T^2 = 4\pi^2\frac{L}{g}$ (By squaring on both sides)

or $g = \frac{4\pi^2 L}{T^2}$

$\therefore \frac{\Delta g}{g} \times 100 = \frac{\Delta L}{L} \times 100 + 2 \times \frac{\Delta T}{T} \times 100$

Now, L = 20.0 cm, ΔL = 1 mm = 0.1 cm.

T for 100 oscillations = 90 s and ΔT = 1 s

$\therefore \quad \frac{\Delta g}{g} \times 100 = \frac{0.1}{20.0} \times 100 + 2 \times \frac{1}{90} \times 100$

= 0.5 + 2.22

= 2.72% = 3%

Thus, the accuracy in the measurement of g is upto 3 %.

25. Any object can be considered as a point object if it covers large distances as compared to the size of it.
   1. The size of a carriage is very small as compared to the distance between two stations. Therefore, the carriage can be treated as a point sized object.
   2. The size of a monkey is very small as compared to the size of a circular track. Therefore, the monkey can be considered as a point sized object on the track.
   3. The size of a spinning cricket ball is comparable to the distance through which it turns sharply on hitting the ground. Hence, the cricket ball cannot be considered as a point object.

Section D

26. Mass of the body, m = 3 kg

Initial speed of the body, u = 2 m/s

Final speed of the body, v = 3.5 m/s

Time, t = 25 s

Acceleration is given by

$a = \frac{v-u}{t}$

$= \frac{3.5-2}{25} = \frac{1.5}{25} = 0.06\mathrm{m/s}^{-2}$

Using Newton's second law of motion, force is given as:

F = ma

$\therefore F = 3 \times 0.06 = 0.18N$

The force acts in the direction of the motion since the direction of the body remains unchanged.

27. Given physical quantity is $X = a^2 b^3 c^{\frac{5}{2}} d^{-2}$

Maximum percentage error in X is:

$\frac{\Delta X}{X} \times 100 = \pm\left[2\frac{\Delta a}{a} + 3\frac{\Delta b}{b} + \frac{5}{2}\frac{\Delta c}{c} + 2\frac{\Delta d}{d}\right] \times 100$

$\frac{\Delta x}{x} \times 100 = \pm\left[\frac{2\times1}{100} + \frac{3\times2}{100} + \frac{5}{2} \times \frac{3}{100} + \frac{2\times4}{100}\right] 100$

$= \pm\frac{100}{100}\left[2 + 6 + \frac{15}{2} + 8\right]$

$\frac{\Delta X}{X} \times 100 = \pm\left[16 + \frac{15}{2}\right] = \pm\left[\frac{32+15}{2}\right] = \pm\frac{47}{2} = \pm 23.5\%$

Mean absolute error = $\pm\frac{23.5}{100} = \pm 0.235$

= 0.24 (rounding off in significant figure)

The calculated value of X = 2.763 should be round-off up to two significant digits i.e, X = 2.8.

OR

a. The given equation is:

   $y = a \sin\frac{2\pi t}{T}$

   Dimension of y = $M^0L^1T^0$

   Dimension of a = $M^0L^1T^0$

   Dimension of $\sin\frac{2\pi t}{T} = M^0L^0T^0$

   $\because$ Dimension of L.H.S = Dimension of R.H.S

   Hence, the given formula is dimensionally correct.

b. The given equation is:

   $y = \left(\frac{a}{T}\right)\sin\left(\frac{t}{a}\right)$

   Dimension of y = $M^0L^1T^0$

   Dimension of $\frac{a}{T} = M^0L^1T^{-1}$

   Dimension of $\frac{t}{a} = M^0L^{-1}T^l$

   But the argument of the trigonometric function must be dimensionless, which is not so in the given case. Hence, the formula is dimensionally incorrect.

c. The given equation is:

$y=(a\sqrt{2})\left(\sin 2\pi \frac{t}{T}+\cos 2\pi \frac{t}{T}\right)$

Dimension of y = $M^0L^1T^0$

Dimension of a = $M^0L^1T^0$

Dimension of $\frac{t}{T}=M^0I^0T^0$

Since the argument of the trigonometric function must be dimensionless (which is true in the given case), the dimensions of y and a are the same. Hence, the given formula is dimensionally correct.

28. Given: Horizontal Range, R = 3 km = 3000 m

Angle of projection, θ = 30°

Acceleration due to gravity, $g=9.8 \mathrm{m}/\mathrm{s}^2$

Horizontal range for the projection velocity u_0, is given by the relation:

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

$3000=\frac{u_0^2}{g} \sin 60^{\circ}$

$3000=\frac{u_0^2}{g} \times \frac{\sqrt{3}}{2}$

$\frac{u_0^2}{g}=2\sqrt{3} \times 1000$ ....(i)

The maximum range (R_{max} is achieved by the bullet when it is fired at an angle of 45° with the horizontal)

$\mathrm{R}_{\max}=\frac{\mathrm{u}_0^2}{g}$ ....(ii)

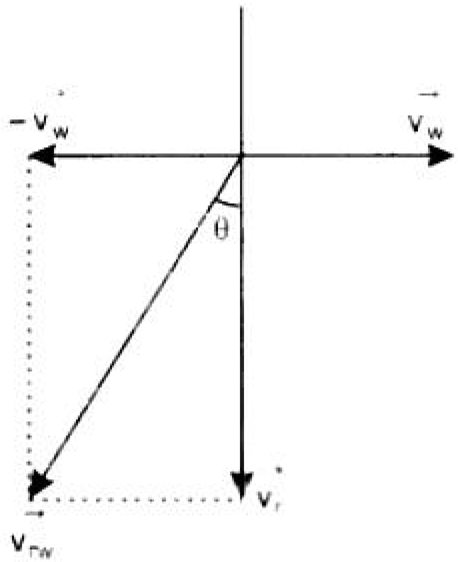
On comparing equations (i) and (ii), we get:

$R_{max}=2\sqrt{3} \times 1000=2 \times 1.732 \times 1000=3.46\ km$

Hence by keeping the same muzzle speed u, one can not hit a target which is 5 km away just by changing projection angle.

OR

The diagrammatic representation of the given problem is shown below. The resultant velocity of raindrops will be the vector sum of the raindrop speed (vertical) and the horizontal wind speed.



Here we have, rain velocity $\vec{v}_r$ = 30 km h^{-1} vertically downward and wind velocity $\vec{v}_w$ = 18 kmh^{-1} due east.

∴ The relative velocity of rain w.r.t. wind $\vec{v}_{rw}$ will have a magnitude,

$v_{rw} = \sqrt{v_r^2 + v_w^2}$ = $\sqrt{(30)^2 + (18)^2}$ = 35 kmh^{-1}

and if v_{rw} subtends an angle θ with vertical towards west, then

$\tan\theta = \frac{v_w}{v_r} = \frac{18}{30} = 0.6$

$\Rightarrow \theta = \tan^{-1}(0.6) = 31^o$

29. let AB and CD are isothermals at temperature T_1 and T_2 respectively

here BC and AD are adiabatic.

from the figure, points A and D lie on the same adiabatic.

for an adiabatic process of an ideal gas

$\therefore PV^\gamma = Const$

we know that, P ∝ T

hence $\therefore TV^\gamma = Const$

$\therefore T_A V_A^{y-1} = T_D V_D^{y-1}$

$T_1 {V_A}^{y-1} = T_2 {V_D}^{y-1}$

$\frac{T_1}{T_2} = \left(\frac{V_D}{V_A}\right)^{y-1}$ ...(1)

Also from the figure, points B and C lie on the same adiabatic,

$T_B V_B^{y-1} = T_C V_C^{y-1}$

or $T_1 V_B^{y-1} = T_2 V_C^{y-1}$

$\because \frac{T_1}{T_2} = \left(\frac{V_C}{V_B}\right)^{\gamma-1}$ ...(2)

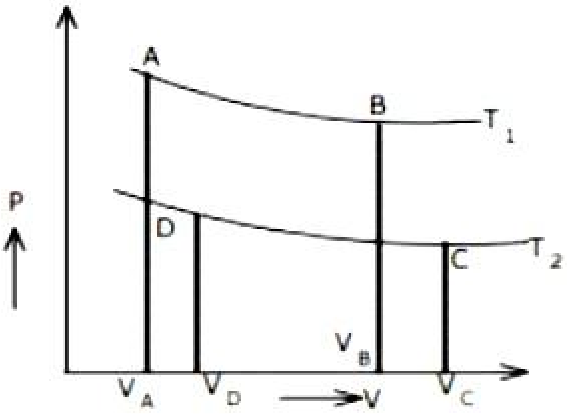
From equation (1) & (2)

$\left(\frac{V_D}{V_A}\right)^{y-1} = \left(\frac{V_C}{V_B}\right)^{y-1}$

$\frac{V_D}{V_A} = \frac{V_C}{V_B}$

$\frac{V_A}{V_D} = \frac{V_B}{V_C}$

$\therefore \frac{(V_A/V_D)}{(V_B/V_C)} = 1$



30. Suppose a satellite of mass m moving with a velocity v in an orbit of radius r around a planet of mass M.

PE of the satellite, $U = -\frac{GMm}{r}$

KE of the satellite, $K = \frac{1}{2}mv^2 = \frac{GMm}{2r}$ [as $v = \sqrt{GM/r}$]

Total energy of the satellite, = $E = K + U = \frac{GMm}{2r}$ - $\frac{GMm}{r}$ = - $\frac{GMm}{2r}$

Put $\frac{GMm}{2r}$ = x

Clearly, $U = -2x, K = x, E = -x$

The orbiting satellite loses energy due to a viscous force acting on it due to the atmosphere and as such it loses height.

Suppose the new orbital radius be $\frac{r}{2}$

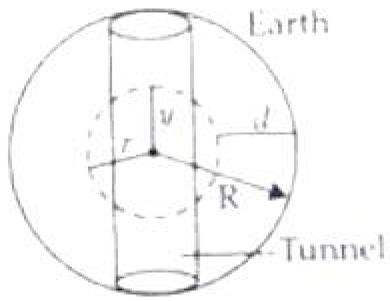
$U' = -4x$

$K' = 2x$

$E' = -2x$

Clearly. $E' < E, U' < U$ and $K' > K$. Since, kinetic energy has increased, the velocity of the satellite increases.

Section E

31. 

If the acceleration due to gravity of earth inside the earth is at a depth of d is g', then we know that,

$g' = g\left(1 - \frac{d}{R}\right) = g\left[\frac{R-d}{R}\right]$ .....(i)(g = acceleration due to gravity on the surface of the earth, R = Radius of earth)

Now if 'y' be distance of the point where acceleration due to gravity is g' from the centre of the earth, then $R - d = y$, and from equation (i) we get,

$\therefore g' = g\frac{y}{R}$

Force on the body of mass m placed at depth d from the surface of the earth is

$F = -mg' = -mg\frac{y}{R}$

$F \propto (-y)$, i.e. the force is proportional to displacement but opposite to the direction of displacement.

So motion of body in tunnel is SHM.

Now to get the time period of this simple harmonic motion we can write,

$ma = -mg'$

$\Rightarrow a = \frac{-g}{R}y$

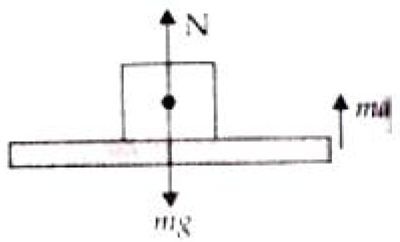
$\therefore -\omega^2 y = \frac{-g}{R}y\,(\because a = -\omega^2 y)$

$\therefore \frac{2\pi}{T} = \sqrt{\frac{g}{R}}$ or $T = 2\pi\sqrt{\frac{R}{g}}$,

This is the time period of the simple harmonic motion executed by the body.

OR

a. Weight in weight machine will be due to the normal reaction (N) by platform. Consider the top position of platform, two forces acting on it are due to weight of person and oscillator. They both act downward.



(mg = weight of the person with the oscillator is acting downwards, ma = force due to oscillation is acting upwards, N = normal reaction force acting upwards)

Now for the downward motion of the system with an acceleration a,

ma = mg - N .....(i)

When platform lifts form its lowest position to upward

ma = N - mg ......(ii)

$a = \omega^2 A$ is value of acceleration of oscillator

$\therefore$ From equation (i) we get,

$N = mg - m\omega^2 A$

Where A is amplitude, ω angular frequency and m mass of oscillator.

$\omega = 2\pi\nu$

$\therefore \omega = 2\pi \times 2 = 4\pi\ rad/\text{sec}$

Again using $A = 5\ cm = 5 \times 10^{-2} m$ we get

$N = 50 \times 9.8 - 50 \times 4\pi \times 4\pi \times 5 \times 10^{-2}$

$= 50\left[9.8 - 16\pi^2 \times 5 \times 10^{-2}\right]$ N

$= 50\left[9.8 - 80 \times 3.14 \times 3.14 \times 10^{-2}\right]$ N

$\Rightarrow N = 50[9.8 - 7.89] = 50 \times 1.91 = 95.50\text{N}$

So minimum weight is 95.50 N(for downward motion of the platform)

From equation (ii), N – mg = ma

For upward motion from the lowest to the highest point of oscillator,

$N = mg + ma$

$= m\left[9.81 + \omega^2 A\right] \quad \because a = \omega^2 A$

$= 50\left[9.81 + 16\pi^2 \times 5 \times 10^{-2}\right]$

$= 50[9.81 + 7.89] = 50 \times 17.70$N = 885 N

Hence, there is a change in weight of the body during oscillation.

b. The maximum weight is 885 N, when platform moves from lowest to upward direction.

And the minimum weight is 95.5 N, when platform moves from the highest point to downward direction.

32. Here it is given that, $m_1 = 0.4$ kg, $u_1 = 4$ m s^{-1}, $m_2 = 0.6$ kg and $u_2 = 2$ ms^{-1}.

Total K.E. of system before collision, $K_i = = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

$= \frac{1}{2} \times (0.4) \times (4)^2 + \frac{1}{2} \times (0.6) \times (2)^2$

= 3.2 + 1.2 = 4.4 J

As collision is perfectly inelastic, the common velocity after collision v is given by

$v = \frac{m_1u_1+m_2u_2}{m_1+m_2} = \frac{0.4\times4+0.6\times2}{0.4+0.6} = 2.8 \text{ ms}^{-1}$

Therefore, total K.E. of system after collision K_f =

$\frac{1}{2}(m_1+m_2)v^2 = \frac{1}{2} \times (0.4+0.6) \times (2.8)^2$

= 3.92 J

Therefore, loss in Kinetic energy = ΔK = $K_i - K_f$ = 4.4 - 3.92 = 0.48 J

OR

As the dragging viscous force of air on balloon is neglected so there is Net Buoyant Force

= Vρg

= Volume of air displaced × net density upward × g

$= V\,(p_{ar} - p_{Hz})\,g(upward)$

Let a be the upward acceleration on balloon then

$ma = V\,(p_{ar} - p_{Hz})\,g$ ...(i)

Where m = mass of balloon

V = Volume of air displacement by balloon = Volume of balloon

p_{air} = density of air

p_{He} = density of helium

$m\frac{dv}{dt} = V \cdot (p_{air} - P_{He})\,g$

$mdv = V \cdot (p_{ar} - p_{Hz})\,g \cdot dt$

Integrating both sides $mv = V \cdot (p_{ar} - p_{H\epsilon})\,gt$

$v = \frac{V}{m}(p_{air} - p_{He})gt$

KE of balloon = $\frac{1}{2}mv^2$

$\frac{1}{2}mv^2 = \frac{1}{2}m\frac{V^2}{m^2}(p_{air} - p_{He})^2g^2t^2 = \frac{V^2}{2m}(p_{air} - p_{He})^2g^2t^2$ ...(ii)

If the balloon rises to a height h, from (i)ņ

$a = \frac{V}{m}(p_{air} - p_{he})\,g$

$h = ut + \frac{1}{2}at^2 = 0.t + \frac{1}{2}\left[\frac{V}{m}(p_{ar} - p_{He})\,g\right]t^2$

$\therefore h = \frac{V}{2m}(p_{ar} - p_{He})\,gt^2$ ...(iii)

From (ii) and (iii) rearranging the terms of (ii) according to h in (iii)

$$\frac{1}{2}mv^2 = \left\{\frac{V}{2m}\left(p_{air} - p_{He}\right)gt^2\right\}.V\left(p_{air} - p_{He}\right)g$$

$$\frac{1}{2}mv^2 = \{h\}.V\left(p_{air} - p_{He}\right)g$$

$$\frac{1}{2}mv^2 = V\cdot\left(p_{air} - p_{He}\right)gh$$

$$\frac{1}{2}mv^2 = Vp_{air}gh - Vp_{He}gh$$

$$\frac{1}{2}mv^2 + p_{He}Vgh = P_{air}Vgh$$

$$KE_{balloon} + PE_{balloon} = Change\ in\ PE\ of\ air.$$

So, as the balloon goes up, an equal volume of air comes down, increases in PE and KE of the balloon is at cost of PE of air (which comes down).

33. Given:

Length of an edge of the solid copper cube, l = 10 cm = 0.1 m

Hydraulic pressure, P = 7.0×10^6 Pa

Bulk modulus of copper, B = 140×10^9 Pa

Bulk modulus, B = $\frac{P}{(\Delta V/V)}$

Where,

$\frac{\Delta V}{V}$ = Volumetric strain

ΔV = change in volume = $\frac{PV}{B}$

V = original volume

Original volume of the cube, V = length^3 = l^3

$$\therefore \Delta V = \frac{Pl^3}{B}$$

$$\triangle V = \frac{7\times10^6\times(0.1)^3}{140\times10^9}$$

$$\triangle V = 5\times10^{-8}\text{m}^3 = 5\times10^{-2}\ \text{cm}^{-3}$$

Therefore, the volume contraction of the solid copper cube is 5×10^{-2} cm^{-3}.

OR

Given, $L_1 = L_2, A_1 = A_2$ and F is same.

a. Stress $\sigma = \frac{F}{A}$ $\therefore$ stress in steel wire and in copper wire are equal.
b. Strain $\varepsilon = \frac{\Delta L}{L} = \frac{\text{stress}}{Y}$ and stress is equal.

$$\frac{\varepsilon_{\text{steel}}}{\varepsilon_{\text{copper}}} = \frac{Y_{\text{copper}}}{Y_{\text{steel}}} = \frac{1.1\times10^{11}}{2.0\times10^{11}} = \frac{11}{20} = 0.55:1$$