CBSE Class 11 Physics

Sample Paper 01 (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. A lift is accelerated upward. Will the apparent weight of a person inside the lift increase, decrease or remain the same relative to its real weight? What will happen to the apparent weight if the lift moves with uniform speed?
2. Why can speed of a particle not be negative?

   OR

   Sameer went on his bike from Delhi to Gurgaon at a speed of 60km/hr and came back at a speed of 40km/hr. what is his average speed for entire journey.
3. How is angular momentum related to linear momentum?
4. How is the gravitational force between two point masses affected when they are dipped in water keeping the separation between them the same?

   OR

Where does a body weight more; at the surface of the earth or in the mine?

5. Why does not the pressure of atmosphere break windows?
6. $\vec{A}, \vec{B}$ and $\vec{C}$ are three non-collinear, non-co-planar vectors. What can you say about direction of $\vec{A} \times (\vec{B} \times \overline{C})$?
7. Name some physical quantities which are dimensionless.

OR

Why do we have different units for same physical quantity?

8. How do wave Velocity and particle Velocity differ from each other?

OR

The displacement of an elastic wave is given by the function $y = 3\sin\omega t + 4\cos\omega t$ where, y is in cm and t is in second. Calculate the resultant amplitude.

9. If air in a cylinder is suddenly compressed by a piston. What happens to the pressure of air?
10. What is motion in a plane?
11. **Assertion:** During a turn, the value of centripetal force should be less than the limiting frictional force.

    Reason: The centripetal force is provided by the frictional force between the tyres and the road.

    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:** The strain produced in a stretched spring is shearing

    Reason: When spring is stretched, the length of wire of spring increases.

    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:** P-T graph of all gases at low density meet at 0 K.

    Reason: Absolute zero kelvin is less than $0^{o}C$ in Celsius scale.

    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:** If two bodies of equal masses undergo elastic collision in one dimension, then after the collision the bodies will exchange their velocities.

    Reason: In elastic collision, velocity of approach is equal and opposite of velocity of separation.

    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.

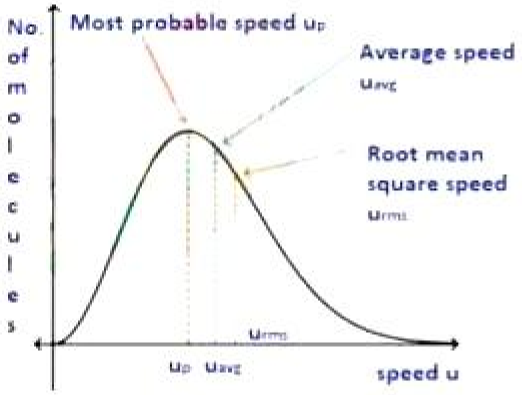
    c. Assertion is correct statement but reason is wrong statement.

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

Section B

15. **Read the case study given below and answer any four subparts:**

    Root mean square velocity (RMS value)is the square root of the mean of squares of the velocity of individual gas molecules and the Average velocity is the arithmetic mean of the velocities of different molecules of a gas at a given temperature.



    i. Moon has no atmosphere because:-

        a. It is far away from the surface of the earth

b. Its surface temperature is 10°C

c. The r.m.s. velocity of all the gas molecules is more than the escape velocity of the moon's surface

d. The escape velocity of the moon's surface is more than the r.m.s velocity of all molecules

ii. For an ideal gas, $\frac{C_P}{C_V}$ is

a. >1

b. <1

c. ≤ 1

d. none of these

iii. The root mean square velocity of hydrogen is $\sqrt{5}$ times than that of nitrogen. If T is the temperature of the gas then:

a. $T(H_2) = T(N_2)$

b. $T(H_2) < T(N_2)$

c. $T(H_2) > T(N_2)$

d. none of these

iv. Suppose the temperature of the gas is tripled and N_2 molecules dissociate into an atom. Then what will be the rms speed of atom:

a. $v_0\sqrt{6}$

b. v_0

c. $v_0\sqrt{3}$

d. none of these

v. The velocities of the molecules are v, 2v, 3v, 4v & 5v. The rms speed will be:

a. 11 v

b. $v(11)^{12}$

c. v

d. $v(12)^{11}$

16. **Read the case study given below and answer any four subparts:**

All three states of matter (solid, liquid and gas) expand when heated. Thermal expansion can be defined as the change in the length, width, height, or volume of any material on changing the temperature. It is a well-known phenomenon now that substances expand on heating and contract on cooling

i. A pendulum clock shows the correct time at a definite temperature. At a higher temperature the clock
   a. loses times
   b. gain time
   c. neither gains nor loses time
   d. none of these
ii. Gaps are left between railway tracks because:
   a. gaps hold the track firmly
   b. gaps give the space to the tracks to expand in the summer
   c. It is customary to leave the gap
   d. none of these
iii. When a copper ball is heated, the largest percentage increase will occur in its:
   a. Diameter
   b. area
   c. volume
   d. all of the above
iv. Expansion during heating:
   a. occurs only in solid
   b. increase the weight of the material
   c. decrease the density of the material
   d. none of these
v. If the length of the cylinder on heating increases by 2 %, the area of the base will increase by:
   a. 2%
   b. 3%
   c. 4%
   d. 5%

Section C

17. If T be the period of a satellite revolving just above the surface of a planet, whose average

density is ρ, show that ρT^2 is a universal constant.

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

OR

A boy of mass 40 kg walks up a flight of stairs to a vertical distance of 12 m, in a time interval of 40 s.

i. At what rate is the boy doing work against the force of gravity?
ii. If energy is transformed by the leg muscles of the students at the rate of 30 kJ every minute, what is the students power output?

19. The length of a second's pendulum on the surface of Earth is 1 m. What will be the length of a second's pendulum on the moon?

OR

What are the two basic characteristics of a simple harmonic motion?

20. A bob of mass 0.1 kg hung from the ceiling of a room by a string 2 m long is set into oscillation. The speed of the bob at its mean position is 1 ms^{-1}. What is the trajectory of the bob if the string is cut when the bob is (a) at one of its extreme positions, (b) at its mean position?
21. Starting from a stationary position, a bus attains a velocity of 6 m/s in 30 s. Then, the driver of the bus applies a brake such that the velocity of the bus comes down to 4 m/s in the next 5 s. Calculate the acceleration of the bus in both cases.
22. State important characteristics of a mechanical wave motion.
23. If earth contracts to half its radius what would be the length of the day at equator?
24. Find the value of 60 J per min on a system that has 100 g, 100 cm and 1 min as the base units.

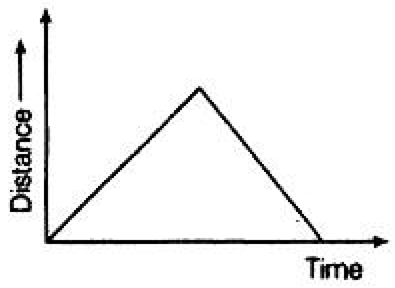
OR

A physical quantity P is related to four observables a, b, c and d as follows:

$$P = \frac{a^3b^2}{(\sqrt{cd})}$$

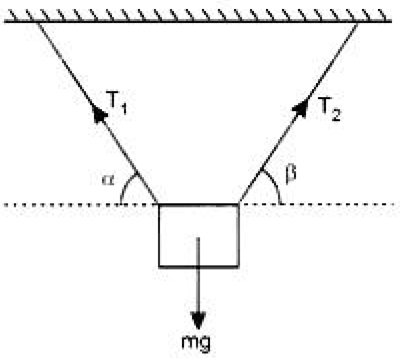
The percentage errors of measurement in a, b, c and d are 1%, 3%, 4% and 2%, respectively. What is the percentage error in the quantity P? If the value of P calculated using the above relation turns out to be 3.763, to what value should you round off the result?

25. The graph between total path length and time for a particle moving along a straight line as shown in figure is not possible. Explain why?



Section D

26. A body of mass m is suspended by two strings making angles α and β with the horizontal as shown in Figure. Calculate the tensions in the two strings.



27. Which of the following is the most precise device for measuring length:
    a. a vernier callipers with 20 divisions on the sliding scale
    b. a screw gauge of pitch 1 mm and 100 divisions on the circular scale
    c. an optical instrument that can measure length to within a wavelength of light?

OR

One mole of an ideal gas at standard temperature and pressure occupies 22.4 L (molar volume). What is the ratio of molar volume to the atomic volume of one mole of hydrogen? (Take the size of hydrogen molecule to be about $1\overset{o}{A}$). Why is this ratio so large?

28. The range of a rifle bullet is 1000 m, when θ is the angle of projection. If the bullet is fired with the same angle from a car travelling at 36 km/h towards the target, show that the range will be increased by $142.9\sqrt{\tan\theta}$ m.

OR

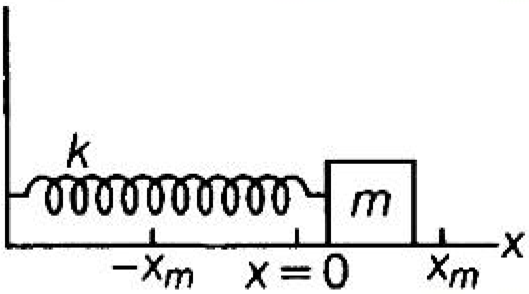
At what point of projectile motion (i) potential energy maximum (ii) Kinetic energy maximum (iii) total mechanical energy is maximum?

29. The density of a solid at 0^0C and 500^0C is in the ratio 1.027 : 1. Find the co-efficient of linear expansion of the solid?

30. Assuming the earth to be a sphere of uniform mass density, how much would body weigh halfway down to the centre of the earth if it weighted 250 N on the surface?

Section E

31. Consider a block of mass 700 g is fastened to a spring having spring constant of 70 N/m. Find out the following parameters if block is pulled a distance of 14 cm from its mean position on a frictionless surface and released from rest at t =0.



i. The angular frequency, the frequency and the period of the resulting motion.
ii. The amplitude of the oscillation.
iii. The maximum speed of the oscillating block.
iv. The maximum acceleration of the block.
v. The phase constant and hence the displacement function x (t).

OR

Find the time period of mass M when displaced from its equilibrium positon and then released for the system shown.

32. An engine is attached to a wagon through a shock absorber of length 1.5 m. The system with a total mass of 50,000 kg is moving with a speed of 36 km/h when the brakes are applied to bring it to rest. In the process of the system being brought to rest, the spring of the shock absorber gets compressed by 1.0 m. If 90% of energy of the wagon is lost due to friction, calculate the spring constant.

OR

A rocket accelerates straight up by ejecting gas downwards. In a small time interval Δt, it ejects a gas of mass Δm at a relative speed u. Calculate KE of the entire system at $(t + \Delta t)$ and t and show that the device that ejects gas does work $= \frac{1}{2}\Delta m u^2$ in this time interval (neglect gravity).

33. A steel rod of length 2 l, cross sectional area A and mass M is set rotating in a horizontal plane about an axis passing through the centre. If Y is the Young's modulus for steel, find the extension in the length of the rod. (Assume the rod is uniform.)

OR

Calculate the percentage increase in the length of a wire of diameter 2.5 mm stretched by a force of 100 kg weight. Young's modulus of elasticity of wire is 12.5×10^{11} dyne/sq cm.

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Solution

Section A

1. In the first case if 'R', 'mg' and 'ma' are the reaction force or apparent weight, real weight and acting force on the person respectively. Then R - mg = ma ⇒ R = m(g + a). Thus the apparent weight will increase.
   Now, If the lift moves with uniform speed upwards or downwards, then a = 0. So, R = mg. So, the apparent weight will remain the same as the real weight.
2. Because speed is distance travelled per second and distance can never be negative.

OR

The average speed is given by
$V_{av} = \frac{2V_1V_2}{V_1+V_2}$
$V_{av} = \frac{2\times60\times40}{60+40} = \frac{4800}{100}$
V_{av} = 48 Km/hr

3. $\overline{L} = \overline{r} \times \overline{p}$

   or $L = rp\sin\theta$
   where θ is the angle between $\overline{r}$ and $\overline{p}$, $\overline{r}$ is the position vector of the moving particle with respect to point of reference.

4. The Newton's Universal law of gravitational force of attraction (F) between two bodies of masses m_1, m_2 separated by distance r is $F = \frac{Gm_1m_2}{r^2}$
   G does not depend upon the medium. So force of attraction does not change if the masses are kept in water or any other medium.

OR

The value of g in mine is less than that on the surface of the earth. Therefore weight will be more on the surface of earth as compared to the mines.

5. As atmospheric Pressure is exerted on both sides of a window, so there is no pressure difference or net force in any direction. Thus atmospheric pressure does not break the window.
6. The direction of the vector $(\vec{B} \times \overline{C})$ will be perpendicular to the plane containing the vectors $\vec{B}$ and $\vec{C}$ by right-hand thumb or right-hand grip rule (RHGR).
The direction of the vector $\vec{A} \times (\vec{B} \times \overline{C})$ will be perpendicular to $\vec{A}$ and in a plane containing $\vec{B}$ and $\vec{C}$ by right-hand grip rule.
7. The physical quantities which are dimensionless are Solid angle, relative density, strain, Reynold's number and Poisson's ratio.

OR

The value of a given physical quantity may vary over a wide range. To express the quantity in proper format, we may need different units. Further, a given quantity may be expressed in terms of different quantites, will have same dimensions. This would lead to different equivalent units of the same quantity.

8. Wave velocity is constant for a given medium and is given by W = W. But particle velocity changes harmonically with time and it is maximum at mean position and zero at extreme position.

OR

Comparing the equation in the question with the general equation
$y = y_1 \sin \omega t + y_2 \cos \omega t$
We get the resultant amplitude will be y = $\sqrt{y_1^2 + y_2^2} = \sqrt{9 + 16}$
$= \sqrt{25}$ = 5 cm

9. Since the sudden compression causes heating and rise in temperature and if the piston is maintained at same Position then the pressure falls as temperature decreases.
10. Motion in a plane means motion in a two-dimensional plane which includes x-axis and y-axis.
11. (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.

The body is able to move on a circular path due to centripetal force. The centripetal force in case of vehicle is provided by frictional force. Thus, if the value of frictional force, μ mg is less than centripetal force, then it is not possible fbr a vehicle to take a turn and the bicycle would overturn. Thus, condition for no overturning of vehicle is,

$\mu mg \geq \frac{mv^2}{r}$

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

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

13. (b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

    Explanation: Assertion and reason both are correct statements but reason is not correct explanation for assertion.

14. (b) Assertion and reason both are correct statements but reason is not correct explanation for assertion.

    Explanation: If m_1 - m_2 = m

    Then, from equations

    $v_1' = \frac{(m_1-m_2)v_1+2m_2v_2}{m_1+m_2}$

    = $\frac{(m-m)v_1+2mv_2}{m+m} = v_2$

    Also, from second equation $v_2' = \frac{(m_2-m_1)v_2+2m_1v_1}{m_1+m_2}$

    = $\frac{(m-m)v_2+2mv_1}{m+m}$ = v_1

    Therefore, from these equations it is proved that if bodies of equal mass collides then their velocities are exchanged.

Section B

15. i. (c)
    ii. (b)
    iii. (b)
    iv. (a)
    v. (b)
16. i. a
    ii. b
    iii. c

iv. c

v. c

Section C

17. If a satellite revolves in a circular orbit of radius r, then its time period is given by

$T = 2\pi\sqrt{\frac{r^3}{GM}}$

If a satellite is revolving very near the planet's surface, then r = R = radius of planet and

M = $\frac{4}{3}\pi R^3 \rho$

Hence $\mathrm{T} = 2\pi\sqrt{\frac{R^3}{G.\frac{4}{3}\pi R^3\rho}} = 2\pi\sqrt{\frac{3}{4\pi G\rho}} = \sqrt{\frac{3\pi}{G\rho}}$

$\mathrm{T}^2 = \frac{3\pi}{\mathrm{G}\rho}$ or $\rho\mathrm{T}^2 = \frac{3\pi}{\mathrm{G}}$

But $\frac{3\pi}{Gp}$ is a universal constant. Hence, it is clear that the product ρT^2 is a universal constant.

18. m_1 = 0.4kg, u_1 = 4m/s, m_2 = 0.6kg u_2 = 2m/s.

Total K.E. before collision

$Ki = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

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

Ki = 4.4J

Since collision is perfectly inelastic

$v = \frac{m_1u_1+m_2u_2}{m_1+m_2} = 2.8m/s$

Total K.E. after collision

$Kf = \frac{1}{2}(m_1 + m_2)v^2$

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

Kf = 3.92 J

Loss in K.E. (ΔK) = Ki - Kf = 4.4 - 3.92 = 0.48J

OR

i. Here it is given that given, m =40 kg and t =40 s

   Also Energy = 30 kJ, power = ?

   Student's output power = ?

   Work done by the student against the force of gravity is equal to the gain in gravitational potential energy, so

   Work done (W) = mg$\triangle$h

and Rate of doing work i.e, Power = $\frac{\text{Work done}}{\text{Time taken }(\Delta t)}$

$P = \frac{W}{\Delta t} = \frac{40\times10\times12}{40} = 120\text{W}$

ii. Student's output power can be calculated as:

Power (P) $= \frac{\text{Energy transferred}}{\text{Time taken}}$

P = 30 kJ/min = $\frac{30000\text{J}}{60\text{s}} = 500W$

19. A pendulum of time period (T) of 2 sec is called second pendulum.

$T_e = 2\pi\sqrt{\frac{l_e}{g_e}} \Rightarrow T_e^2 = 4\pi^2\frac{l_e}{g_e}$ ...(i)

$T_m = 2\pi\sqrt{\frac{l_m}{g_m}} \because g_m = \frac{g_e}{6}$

$\therefore T_m^2 = 4\pi^2\frac{l_m\times6}{g_e}$ ...(ii)

For second pendulum $T_e = T_m = 2\,\text{sec}$

$4\pi^2 6l_m$

$\frac{T_m^2}{T_e^2} = \frac{g_e}{4\pi^2\frac{l_e}{g_e}}$ or $\frac{(2)^2}{(2)^2} = \frac{6l_m}{l_e}\ l_e = 1m\,\frac{1}{1} = \frac{6l_m}{1m} \Rightarrow l_m = \frac{1}{6}m$

OR

Two basic characteristics of a simple harmonic motion are:

i. Acceleration is directly proportional to displacement from mean position, and the direction of acceleration is towards mean position.

ii. Restoring force is directly proportional to displacement, the direction of force and displacement are opposite i.e., $F = -kx$.

20. a. At the extreme position, the velocity of the bob becomes zero. If the string is cut at this moment, then the bob will fall vertically downwards due to force of gravity .

b. At the mean position, the velocity of the bob is 1 m/s(maximum).If the string is cut at the mean position, then it will fall towards the Earth but under combined effect of gravity & horizontal velocity of the bob which is similar to the motion of projectile projected with some initial velocity. Hence, it will follows a parabolic path.

21. **<u>Case I:</u>** In this case Initial velocity of the bus is equal to zero i.e, u = 0

Final velocity, v = 6 m/s and time taken, t = 30 s

We know that, acceleration = $\frac{\text{Change in velocity}}{\text{Time taken}}$

$= \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time taken}}$

$= \frac{v-u}{t} = \frac{6-0}{30}$ = 0.2 m/s^2

Case II: In this case Initial velocity, u = 6 m/s

Final Velocity = $\frac{v-u}{t} = \frac{4-6}{5}$

= - 0.4 m/s

Hence, the acceleration in both the cases are 0.2 m/s^2 and -0.4 m/s^2 respectively.

22. Important characteristics of mechanical wave motion are as given below :
    i. Wave motion is a form of disturbance which travels from one point to another through a medium.
    ii. The medium particles, through which the disturbance propagates, vibrate to and fro about their mean positions harmonically and suffer no permanent displacement.
    iii. Wave motion is both periodic in space and periodic in time. Hence it is a doubly periodic phenomenon.
    iv. The motion of each particle begins a little later than that of its predecessor. In other words, there is always a constant phase difference between any two neighbouring particles. The wave always advances in that direction in which it meets particles with decreasing phase.
    v. The velocity of the wave is the rate at which the disturbance spreads in the medium. The wave velocity is different from particle velocity.The velocity of a wave is constant in a given medium , whereas the velocity of the particles changes, being maximum in the mean position.
    vi. For wave motion, a medium must be elastic and must possess mass. Moreover, frictional resistance due to the medium should be negligible.
    vii. Waves travels from one medium to another , the wave speed and wavelength change but the frequency remains the same because the frequency is determined by the source.

23. $I_1 = \frac{2}{5}MR^2$

    $\Rightarrow I_2 = \frac{2}{5}M\left(\frac{R}{2}\right)^2 \Rightarrow I_2 = \frac{1}{4}I_1$

    Angular momentum is given by:

    $L = I \times \omega$

    $L = I_1\omega_1 = I_2\omega_2$

    or $I\left(\frac{2\pi}{T_1}\right) = \frac{1}{4}\left(\frac{2\pi}{T_2}\right)$

    or $T_2 = \frac{T_1}{4} = \frac{24}{4} = 6\ hours$

24. We are given that, P = $\frac{60 \text{ joule}}{1\text{min}} = \frac{60 \text{ joule}}{60\ s}$ = 1 watt

which is the SI unit of power.

Also the dimensional formula of power = $[ML^2T^{-3}]$

SI	New System
$n_1 = 1$	$n_2 = ?$
$M_1 = 1$ kg = 1000 g	$M_2 = 10$ g
$L_1 = 1$ m = 100 cm	$L_2 = 100$ cm
$T_1 = 1$ s	$T_2 = 1$ min = 60 s

Using the formula $n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$, we have

$n_2 = 1\left[\frac{1000}{100}\right]^{-1}\left[\frac{100}{100}\right]^{-2}\left[\frac{1}{60}\right]^{-3}$

$= 2.16 \times 10^6$

Therefore, 60 J $min^{-1} = 2.16 \times 10^6$

That is the value of 60 J per minute in new units of power.

OR

Here, $P = \frac{a^3b^2}{(\sqrt{cd})}$

Maximum fractional error in P is given by:

$\frac{\Delta P}{P} = \frac{3\Delta a}{a} + \frac{2\Delta b}{b} + \frac{1}{2}\frac{\Delta c}{c} + \frac{\Delta d}{d}$

$\left(\frac{\Delta P}{P} \times 100\right)\%$

$= \left(3 \times \frac{\Delta a}{a} \times 100 + 2 \times \frac{\Delta b}{b} \times 100 + \frac{1}{2} \times \frac{\Delta c}{c} \times 100 + \frac{\Delta d}{d} \times 100\right)\%$

$= 3 \times 1 + 2 \times 3 + \frac{1}{2} \times 4 + 2$

= 3 + 6 + 2 + 2 = 13%

As the above result (13%error) has two significant figures, therefore, if P turns out to be 3.763, the result would

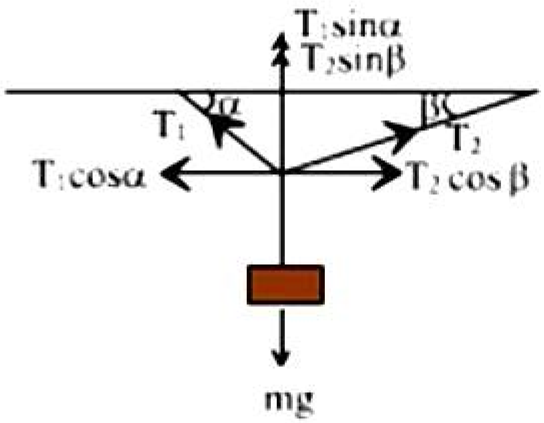
be rounded off to 3.8.

25. From the graph, it is clear that with the passage of time, total path length first increases and then decreases.

The path length of a particle moving along a straight line remains constant or increases with the passage of time and it does not decrease with time as shown in the figure. Hence, the graph shown in the figure is not possible.

Section D

26. Resolving the tension of two strings i.e. T_1 and T_2 into two rectangular components. See the figure below.



Considering components of tensions T_1 and T_2 along the horizontal and vertical directions, we have

$-T_1 \cos \alpha + T_2 \cos \beta = 0$ or $T_1 \cos \alpha = T_2 \cos \beta$ .... (i)

and $T_1 \sin \alpha + T_2 \sin \beta = mg$ .... (ii)

From (i), $T_2 = \frac{T_1 \cos \alpha}{\cos \beta}$

and substituting it in (ii), we obtain

$T_1 \sin \alpha + \left(\frac{T_1 \cos \alpha}{\cos \beta}\right) \sin \beta = mg$

or $T_1 \left[\frac{\sin \alpha \cos \beta + \cos \alpha \sin \beta}{\cos \beta}\right] = mg$

or $T_1 \frac{\sin(\alpha+\beta)}{\cos \beta} = mg$

$\Rightarrow T_1 = \frac{mg \cos \beta}{\sin(\alpha+\beta)}$

and hence $T_2 = \frac{T_1 \cos \alpha}{\cos \beta}$

$= \frac{mg \cos \beta}{\sin(\alpha+\beta)} \cdot \frac{\cos \alpha}{\cos \beta}$

$= \frac{mg \cos \alpha}{\sin(\alpha+\beta)}$

27. The most precise device is that whose least count is minimum.
    a. Least count of vernier calliper
       = 1 standard division (SD) - 1 vernier division (VD)
       1 S D - 19 / 20 S D = 1 / 20 m m = 0.005 c m

b. Least count of screw gauge = $\frac{\text{Pitch}}{\text{No of divisions}}$

$= \frac{1}{100} mm = \frac{1}{1000} cm = 0.001\text{cm}$

c. Least count of an optical device = Wavelength of light $(\lambda) \sim 10^{-5}\text{cm}$

= 0.00001 cm

Hence, it can be inferred that an optical instrument is the most suitable device to measure length.

OR

Radius of one single hydrogen atom, r = 0.5 $\overset{0}{A}$ = 0.5×10^{-10} m (1 $\overset{0}{A}$ = 10^{-10} m)

Volume of one single hydrogen atom $= \frac{4}{3}\pi r^3$

$= \frac{4}{3} \times \frac{22}{7} \times \left(0.5 \times 10^{-10}\right)^3$

$= 0.524 \times 10^{-30} m^3$

Now, 1 mole of hydrogen atoms means 6.023×10^{23} number of hydrogen atoms. (according to Avogadro's hypothesis)

∴ Atomic volume of 1 mole of hydrogen atoms, V_{H_2} = Avogadro's number × volume of one single hydrogen atom $= 6.023 \times 10^{23} \times 0.524 \times 10^{-30}\text{m}^3$

$= 3.16 \times 10^{-7} m^3$

Molar volume of 1 mole of hydrogen atoms at STP,

$V_m = 22.4L = 22.4 \times 10^{-3} m^3$ (1 litre = 10^{-3} m^3)

Now, ratio of molar volume of 22.4 L of H_2 to the atomic volume of 1 mole of H_2,

$\therefore \frac{V_m}{V_{H_2}} = \frac{22.4 \times 10^{-3}}{3.16 \times 10^{-7}} = 7.08 \times 10^4$

Hence, the molar volume is 7.08×10^4 times higher than the atomic volume. This ratio is very high due to the fact that the inter-atomic distance is very high as compared to the size of atoms in hydrogen gas.

28. Here it is given, that R = 1000 m

Horizontal range of the bullet fired at an angle θ

$R = \frac{u^2 \sin 2\theta}{g} \Rightarrow 1000 = \frac{u^2 2 \sin\theta \cos\theta}{g}$ ....(i)

Bullet is fired from the car moving with 36 km/h i.e.,10 m/s, then the horizontal component of the velocity of bullet = u sin θ + 10

Vertical component of the velocity of the bullet = u sinθ

Then, new range of the bullet is given by

$R_1 = \frac{2}{g}(u\sin\theta)(u\cos\theta + 10) = \frac{2}{g}u^2\sin\theta\cos\theta + \frac{20}{g}u\sin\theta$

$\Rightarrow R_1 = R + \frac{20}{g}u\sin\theta$

$\Rightarrow R_1 - R = \frac{20}{g}u\sin\theta$............(ii)

From Eq.(i), we have $u = \sqrt{\frac{1000\times g}{2\sin\theta\cos\theta}}$ ....(iii)

Now, substituting the value of u in Equation (ii), we obtain

$R_1 - R = \frac{20}{g}\sqrt{\frac{1000\times g}{2\sin\theta\cos\theta}}\sin\theta$

$= 20\sqrt{\frac{500\times\sin\theta}{g\cos\theta}}$

$= 20\sqrt{\frac{500}{9.8}\tan\theta}$

$= 142.9\sqrt{\tan\theta}$

Hence proved.

OR

(i) Potential Energy will be maximum at the highest point.

(P.E.) highest point = mgH, where H $\Rightarrow$ maximum height above ground that projectile will attain.

maximum height $H = \frac{u^2\sin^2(\theta)}{2g}$

(P.E.) highest point $mg\left(\frac{u^2\sin^2(\theta)}{2g}\right) = \frac{1}{2}mu^2\sin^2(\theta)$

(ii) K.E will be maximum at the highest point

$(K.E.)_H = \frac{1}{2}m(u_H)^2$

(Vertical component of velocity is zero)

$(K.E.)_H = \frac{1}{2}mu^2\cos^2\theta$

(iii) Total mechanical energy= $(K.E.)_H + (P.E.)_H$

$E = \frac{1}{2}mu^2\cos^2\theta + \frac{1}{2}mu^2\sin^2\theta$

$E = \frac{1}{2}mu^2\left(\cos^2\theta + \sin^2\theta\right)$

$E = \frac{1}{2}mu^2$

29. let $density\ at\ 0^0\ C\ =\ \rho_0$

$density\ at\ 500^0\ C\ =\ \rho_{500}$

As $\rho_0 =\ \rho_{500}(1 + Y\triangle T)$ ..... (i)

Where, Y = Co-efficient of volume expansion

ΔT = Change in temperature

$\because \frac{\rho_O}{\rho_{500}} = \frac{1.027}{1}$ .... (ii)

ΔT = rise in temperature = Final Temperature - Initial temperature

ΔT = 500 - 0^{0}C = 500 ^{0}C

From (i) and (ii) we have $1.027 = 1 \times (1 + Y\Delta T)$

$1.027 = 1 + \gamma\Delta T$

$1.027 - 1 = \gamma\Delta T$

$0.027 = \gamma\Delta T$

$\gamma = \frac{0.027}{500}$

$\gamma = 54 \times |10^{-6}|^0 C$

Now, Co-efficient of linear expansion (α) and co-efficient of volume expansion (γ) are related as:-

$\alpha = \frac{\gamma}{3}$

$\alpha = \frac{54 \times 10^{-6}}{3}$

$\alpha = 18 \times 10^{-6}|^0 C$

30. Weight of the body at the earth's surface

$w = mg = 250N$...............(i)

Acceleration due to gravity at depth d from the earth's surface

$g' = g\left(1 - \frac{d}{R}\right)$

here, $d = \frac{R}{2}$

$\therefore g' = g\left(1 - \frac{R/2}{R}\right)$ = g $\left(1 - \frac{1}{2}\right)$

$\Rightarrow g' = \frac{g}{2}$

$\therefore$ The weight of the body at depth d

$\Rightarrow w' = mg' = \frac{mg}{2}$

Using Eq. (i) we get

$w' = \frac{250}{2} = 125N$

$\therefore$ Weight of the body will be $125N$.

Section E

31. i. The angular frequency is given by

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{70\text{N/m}}{0.700\text{kg}}}$ = 10 rad/s

Frequency, $f = \frac{\omega}{2\pi} = \frac{10}{2\pi} \simeq 1.59\text{Hz}$

The time period, T = $\frac{1}{f} = \frac{1}{1.59}$ = 0.63 = 630 ms

ii. The maximum amplitude of the oscillation = maximum displacement

$\therefore x_m = 14$ cm $= 0.14$ m

iii. The maximum speed of the oscillation v_m is given by

$v_m = \omega x_m = 10 \times 0.14 = 1.4$ m/s

iv. The magnitude of maximum acceleration of the block is given by

$a_m = \omega^2 x_m = 100 \times 0.14 = 14$ m/s^2

At time t = 0, the block is located at position, $x = x_m$

v. Then, from general equation of oscillation, $x(t) = x_m \cos(\omega t + \phi)$

$\Rightarrow x_m = x_m \cos(0 \times \omega + \phi)$

$\therefore \cos\phi = 1 \Rightarrow \phi = 0$

The required displacement function of the given oscillation with all the above values becomes,

$x(t) = x_m \cos(\omega t + \phi)$

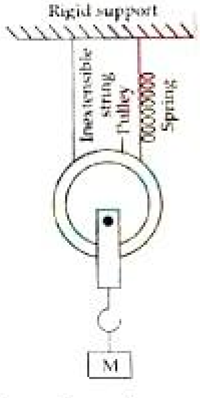
$\Rightarrow x(t) = 0.14 \times \cos(10t + 0)$

$\Rightarrow x(t) = 0.14 \cos 10t$

OR

When mass M is pulled and released then mass M oscillates up and down along with pulley

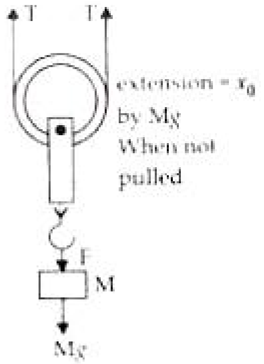
Let the spring extends by x_0 when loaded by mass M. The extension and compression of spring from initial position is larger and smaller respectively due to acceleration due to gravity by same amount of forces always. So effect of gravitational force can be neglected.



Now let the mass 'M' is pulled by force 'F' downward by displacement x. Then extension in spring will be $2x$ as string can not be extended.

So, total extension in spring $= (x_0 + 2x)$

$T' = k(x_0 + 2x)$ (when pulled downward by x)



$T = kx_0$ (when no pulling)

$F = 2T$

$F = 2kx_0$

And,

$F' = 2T'$

$\rightarrow F' = 2k(x_0 + 2x)$

Restoring force

$\rightarrow F_{rest} = -(F' - F)$

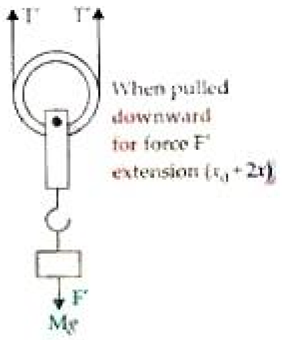
$\rightarrow f_{rest} = -[2k(x_0 + 2x) - 2kx_0)]$

$\rightarrow F_{rest} = -2k.2x$

$\rightarrow Ma = -4kx$

$a \propto -x$

$\rightarrow$ Hence, the motion is simple harmonic motion(SHM).



$\rightarrow a = -\omega^2 x$

$\therefore \omega^2 = \frac{-a}{x} = \frac{+4k}{M}$

$\omega = 2\sqrt{\frac{k}{M}}$

$\Rightarrow \frac{2\pi}{T} = 2\sqrt{\frac{k}{M}}$

$T = \pi\sqrt{\frac{M}{k}}$.

$\rightarrow$Therefore, Time period is given by relation $\rightarrow T = \pi\sqrt{\frac{\mathrm{M}}{\mathrm{k}}}$

32. According to the question , mass of the engine , m = 50,000 Kg

velocity of the engine $v = 36km/h = 10m/s$

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

$KE = \frac{1}{2} \times 50,000 \times 10 \times 10 = 2500000J$

According to 90% of Kinetic Energy of wagon lost due to friction by breaks so only 10% are passed to spring.

Kinetic Energy of the spring = 10% of Kinetic Energy of the wagon

$\frac{1}{2}kx^2 = \frac{10}{100} \times 2500000$

K = 500000 N/M

= 5 $\times 10^5$ N/m.

OR

Let mass of rocket at any time t = M

Velocity of rocket at any time t = v

Δm is the mass of gas ejected in time interval Δt

$(KE)_{z+\Delta t} = \frac{1}{2}(M - \Delta m)(v + \Delta v)^2 + \frac{1}{2}\Delta m(v - u)^2$

$= \frac{1}{2}\left[(M - \Delta m)\left(v^2 + \Delta v^2 + 2v\Delta v\right) + \Delta m\left(v^2 + u^2 - 2uv\right)\right]$

$$(KE)_{\tau+\Delta t} = \frac{1}{2}\begin{bmatrix} Mv^2 + M\Delta v^2 + 2Mv\Delta v - \Delta mv^2 \\ -\Delta m\Delta v^2 - 2v\Delta m\Delta v + \Delta mv^2 + \\ \Delta mu^2 - 2uv\Delta m \end{bmatrix}$$

$(KE)_{t+\Delta t} = \frac{1}{2}Mv^2 + Mv\Delta v + \frac{1}{2}\Delta mu^2 - uv\Delta m$

[neglecting the very small terms $M\Delta v^2, \Delta m\Delta v^2, 2v\Delta m\Delta v$contains Δv^2 and $\Delta m\Delta v$]

$(KE)_\tau = \frac{1}{2}Mv^2$

$(KE)_{t+\Delta t} - (KE)_t = \frac{1}{2}Mv^2 + Mv\Delta v + \frac{1}{2}\Delta mu^2 - uv\Delta m - \frac{1}{2}Mv^2$

$\Delta K = \frac{1}{2}\Delta mu^2 + v(M\Delta v - u\Delta m)$

By Newton's third law,

Reaction force on Rocket (upward) = Action force by burnt gases (downward)

$M\frac{dv}{dt} = \frac{dm}{dt}|u|(\because F = ma)$

Or $M\Delta v = \Delta mu \Rightarrow M\Delta v - u\Delta m = 0$

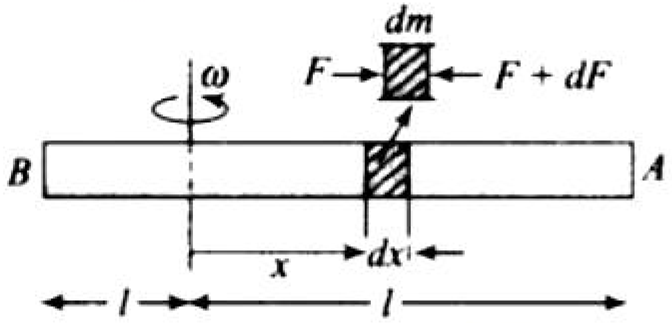
Substitute this value in (i)

$K = \frac{1}{2}u^2\Delta m$

By work energy theorem $\Delta(KE) = WD$

Or $W = \Delta K = \frac{1}{2}\Delta m u^2$.

33. Consider an element of width dx at a distance x from the given axis of rotation as shown in the figure:



As rod is uniform, so mass per unit length, $\mu = \frac{M}{2l}$

Mass of small element dm = $\left(\frac{M}{2l}\right) dx$

Centripetal force acting on this element,

dF = dm.xω^2

$\Rightarrow \quad dF = \left(\frac{M}{2l}\right) dx \cdot x\omega^2$

Let tension in the rod be F at a distance x from the axis of rotation. F is due to centripetal force acting on all the elements from x to l, i.e.

$F = \frac{M\omega^2}{2l}\int_x^l x dx = \frac{M\omega^2}{4l}\left(l^2 - x^2\right)$

If d(r) is the extension in the element of length dx at position x, then,

$d(r) = \frac{Fdx}{YA}\left[\because Y = \frac{F/A}{d(r)/dx}\right]$ where Y is Young's Modulus.

Hence, extension in the half on the rod (from axis to point A) is given by

$\Delta r = \int_0^l d(r) = \int_0^l \frac{Fdx}{YA}$

$= \frac{M\omega^2}{4YAl}\left[l^2(x) - \frac{x^3}{3}\right]_0^l = \frac{M\omega^2}{4YAl}\left[l^3 - \frac{l^3}{3}\right] = \frac{M\omega^2 l^2}{6YA} = \frac{\mu\omega^2 l^3}{3YA}$ (putting M = 2μl)

Hence, total extension in whole rod of length 2l = 2$\triangle$r = $\frac{2}{3YA}\mu\omega^2 l^3$

OR

Here' $2r = 2.5mm = 0.25cm$

or $r = 0.125cm$

$\therefore$ a = πr^2 = $\frac{22}{7} \times (0.125)^2 sq.cm$

$F = 100kg = 100 \times 1000g$

$p = 10 \times 1000 \times 980\ dyne$

$Y = 12.5 \times 10^{11}\ dyne/sq.cm$

As Y = $\frac{F \times l}{a \times \Delta l}$

$\therefore \frac{\Delta l}{l} = \frac{F}{aY}$

Hence, % increase in length

= $\frac{\Delta l}{l} \times 100 = \frac{F}{aY} \times 100$

= $\frac{(100 \times 1000 \times 980) \times 7 \times 100}{22 \times (0.125)^2 \times 12.5 \times 10^{11}}$

= 0.1812 %