**CBSE Class 11 Physics**

**Sample Paper 02 (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. What is the unit of coefficient of friction?
2. A train is moving on a straight track with acceleration $a$. A passenger drops a stone. What is the acceleration of stone with respect to the passenger?

OR

What causes variation in velocity of a particle?

3. Calculate the ratio of radii of gyration of a circular ring and a disc of the same radius with respect to the axis passing through their centres and perpendicular to their planes.
4. Name two factors which determine whether a planet has atmosphere or not.

OR

Distance between two bodies is increased to three times its original value. What is the effect on the gravitational force between them?

5. Three vessels have the same base area and different neck area. An equal volume of liquid is poured into them, which will possess more pressure at the base?
6. Why does the direction of motion of a projectile become horizontal at the highest point of its trajectory?
7. Find the dimensions of latent heat and specific heat?

OR

Give four important characteristics of a standard unit.

8. If the displacement of two waves at a point is given by:-

   $Y_1 = a \sin \omega t$

   $Y_2 = a \sin\left(\omega t + \frac{\pi}{2}\right)$

   Calculate the resultant amplitude?

OR

A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in the tissue in which the speed of sound is 1.7 km $s^{-1}$? The operating frequency of the scanner is 4.2 MHz.

9. If a refrigerator's door is kept open, will the room become cool or hot? Explain.
10. What is the angle between A and B, if A and B denote the adjacent sides of a parallelogram drawn from a point and the area of the parallelogram is 1/2AB?
11. **Assertion:** Two similar trains are moving along the equatorial line with the same speed but in opposite direction. They will exert equal pressure on the rails.

    **Reason:** In uniform circular motion, the magnitude of acceleration remains constant but the direction continuously changes.

    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 size of a hydrogen balloon increases as it rises in air.

    **Reason:** The material of the balloon can be easily stretched.

    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:** Mean free path of gas molecules, varies inversely as density of the gas.

    **Reason:** Mean free path of gas molecules is defined as the average distance travelled by a molecule between two successive collisions.

    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:** When two moving bodies collide, their temperature rise

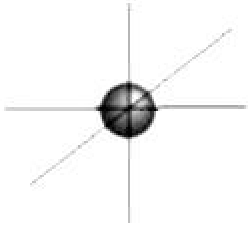
    **Reason:** In collision of two practical bodies, the potential energy of the colliding bodies converts into heat energy.

    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.

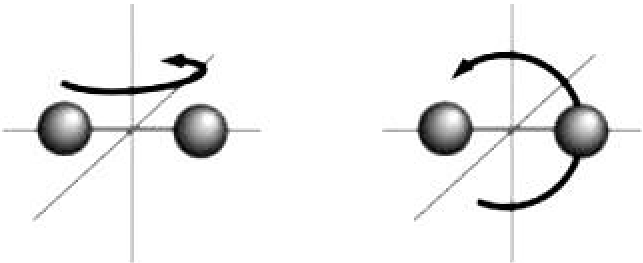
## Section B

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

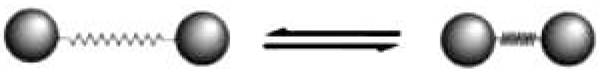
    The number of independent ways by which a dynamic system can move, without violating any constraint imposed on it, is called the number of **degrees of freedom**. According to the law of equipartition of energy, for any dynamic system in thermal equilibrium, the total energy for the system is equally divided among the degree of freedom.



Translational Motion



Rotational Motion



Vibrational Motion

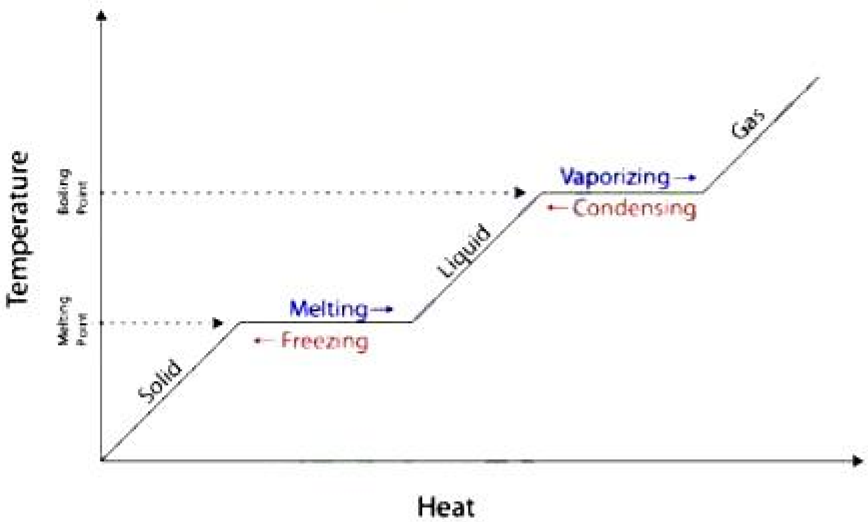
i. If gas has n degree of freedom, the ratio of specific heat is:
   a. $1 + 2/n$
   b. $2n$
   c. $1 - 2/n$
   d. none of these
ii. The kinetic energy, due to translational motion, of most of the molecules of an ideal gas at absolute temperature T, is:
   a. $k/T$
   b. $kT$
   c. $kT^2$
   d. $kT^3$
iii. The mean free path is the:
   a. average distance covered by a molecule between two successive collisions
   b. length of the container that contains the gas
   c. mean of the square of the average distance between two successive collisions
   d. none of these
iv. The law of equipartition of energy is applicable to the system whose constituents are:
   a. in orderly motion

b. in rest
c. in random motion
d. none of these

v. Thermochemical calorie is equal to
a. 4148 joule
b. 414.8 joule
c. 41.48 joule
d. 4.148 joule

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

A **phase change** is when matter changes from one state (solid, liquid, gas, plasma) to another. These changes occur when sufficient energy is supplied to the system (or a sufficient amount is lost), and also occur when the pressure on the system is changed. The temperatures and pressures under which these changes happen differ depending on the chemical and physical properties of the system.




i. The latent heat of vaporization of a substance is always
a. greater than the heat of fusion
b. less than the heat of fusion
c. greater than the heat of sublimation
d. lower than the heat of sublimation.

ii. Specific heat of a substance at the melting point becomes
a. low
b. high
c. remains unchanged
d. infinite

iii. Specific heat of gas in an isothermal process is
   a. zero
   b. finite
   c. infinite
   d. none of these

iv. A quantity of heat required to change the unit mass of a substance, from solid to liquid state, while the temperature remains constant, is known as
   a. sublimation
   b. latent heat of fusion
   c. latent heat
   d. none of these

v. The sprinkling of water reduces the temperature of the closed room because
   a. The water has a large latent heat of vaporization
   b. Water is a bad conductor of heat
   c. Specific heat of water is high
   d. none of these

**Section C**

17. The mean orbital radius of the earth around the sun is $1.5 \times 10^8$ km. Calculate mass of the sun if G = $6.67 \times 10^{11}$ $Nm^2/kg^{-2}$?

18. A bolt of mass 0.3 kg falls from the ceiling of an elevator moving down with a uniform speed of 7 $ms^{-1}$. It hits the floor of the elevator (length of the elevator = 3 m) and does not rebound. What is the heat produced by the impact?

OR

A cyclist comes to a skidding stop in 10 m. During this process, the force on the cycle due to the road is 200 N and is directly opposite to the motion.

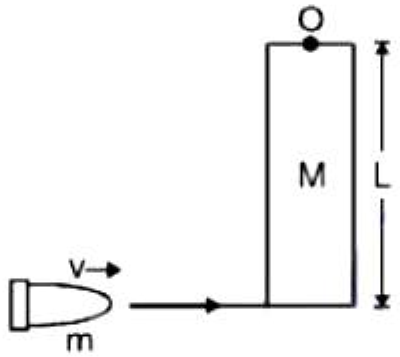
i. How much work does the road do on the cycle?
ii. How much work does the cycle do on the road?

19. The maximum acceleration of a simple harmonic oscillator is $a_0$ and the maximum velocity is $v_0$. What is the displacement amplitude?

OR

Springs with spring constant K, 2K, 4K, K ---- are connected in series. A mass M Kg is attached to the lower end of the last spring and system is allowed to vibrate. What is the time period of oscillation?

20. Force of 16N and 12N are acting on a mass of 200 kg in mutually perpendicular directions. Find the magnitude of the acceleration produced?
21. A particle is moving in a straight line. Its displacement at any instant t is given by $x = 10t + 15t^3$, where x is in metres and t is in seconds. Then find
    i. the average acceleration in the interval t = 0 to t = 2 s
    ii. instantaneous acceleration at t = 2 s.
22. What are transverse waves? Give examples too.
23. A rod of length L and mass M is hinged at point O. A small bullet of mass m hits the rod, as shown in figure. The bullet get embedded in the rod. Find the angular velocity of the system just after the impact.




24. A calorie is a unit of heat or energy and it equals about 4.2 J, where $1 J = 1 kg - m^2/s^2$. Suppose we employ a system of units in which the unit of mass equals $\alpha$ kg, the unit of length is $\beta$ m, the unit of time is $\gamma$ s. Show that calorie has a magnitude $4.2\,\alpha^{-1}\beta^{-2}\gamma^{2}$ in terms of new units.

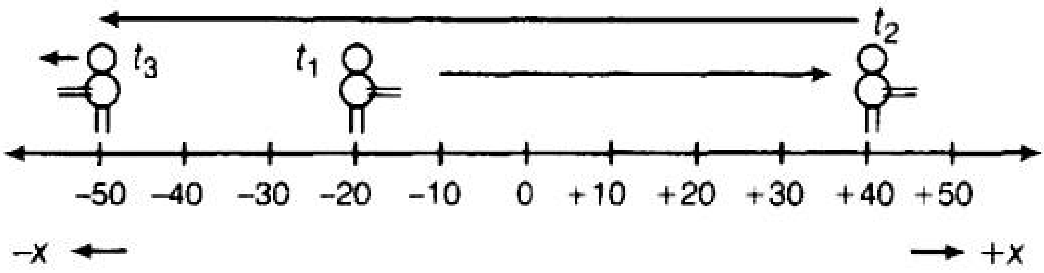
OR

Calculate the angle of

    i. 1°(degree).
    ii. 1'' (second of arc or arc sec) in radian.
25. A boy starts moving from -20 m towards + x-axis as shown in the figure. He turns at time instant $t_2$ and starts moving towards -x-axis. At time $t_3$, reached at -50 m as shown in the figure. Find the displacement and distance for the time interval

i. $t_1$ to $t_2$

ii. $t_1$ to $t_3$.



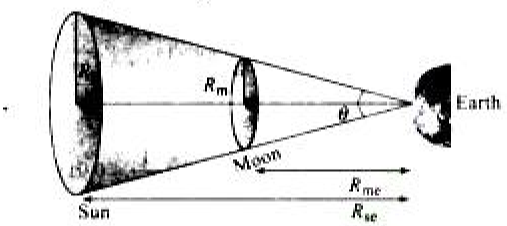

**Section D**

26. An aircraft executes a horizontal loop at a speed of 720 km/h with its wings banked at 15°. What is the radius of the loop?

27. Briefly discuss different types of systematic errors.

OR

During a total solar eclipse the moon almost covers the sphere of the sun. Write the relation between the distances and sizes of the sun and moon.




28. Find the angle between the vectors A = $\hat{\mathbf{i}} - 2\hat{\mathbf{j}} - \hat{\mathbf{k}}$ and B = $-\hat{\mathbf{i}} + \hat{\mathbf{j}} - 2\hat{\mathbf{k}}$.

OR

The position of a particle is given by r = $3.0t\hat{i} + 2.0t^2\hat{j} + 5.0\hat{k}$where t is in seconds and the coefficients have the proper units for r to be in metres.

i. Find v(t) and a(t) of the particles.

ii. Find the magnitude and the direction of v(t) at t = 2.0 s.

29. A thermometer has wrong calibration. It reads the melting point of ice as - $10^0$C. It reads $60^0$C in place of $50^0$C. What is the temperature of boiling point of water on this scale?

30. Two uniform solid spheres of radii R and 2R are at rest with their surfaces just touching.

Find the force of gravitational attraction between them if density of spheres be P?

**Section E**

31. A cylindrical log of wood of height h and area of cross-section A floats in a liquid. It is pressed and then released. Show that the log would execute S.H.M. with a time period $T = 2\pi\sqrt{\frac{m}{A\rho g}}$ where m is mass of the body and ρ is density of the liquid.

OR

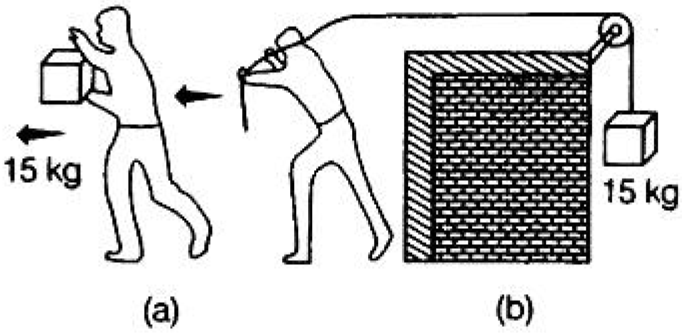
A body of mass *m* is attached to one end of a massless string which is suspended vertically from a fixed point. The mass is held in hand so that the spring is neither stretched nor compressed. Suddenly the support of the hand is removed. The lowest position attained by the mass during oscillation is 4cm below the point, where it was held in hand.

i. What is the amplitude of oscillation?
ii. Find the frequency of oscillation?

32. The nucleus $Fe^{57}$ emits a $\gamma$-ray of energy 14.4 keV. If the mass of the nucleus is 56.935 amu, calculate the recoil energy of the nucleus. [Take, 1 amu = $1.66 \times 10^{-27}$ kg]

OR

i. The casing of a rocket in flight burns up due to friction. At whose expense is the heat energy required for burning obtained ? The rocket or the atmosphere.
ii. Comets move around the Sun in highly elliptical orbits. The gravitational force on the comet due to the Sun is not normal to the comet's velocity in general. Yet the work done by the gravitational force over every complete orbit of the comet is zero. Why?
iii. An artificial satellite orbiting the Earth in very thin atmosphere loses its energy gradually due to dissipation against atmospheric resistance, however small. Why then does its speed increase progressively as it comes closer and closer to the earth?
iv. In Fig. (a) the man walks 2 m carrying a mass of 15 kg on his hands. In Fig. (b) he walks the same distance pulling the rope behind him.
The rope goes over a pulley and a mass of 15 kg hangs at its other end. In which case is the work done greater?




33. A mild steel wire of length 1.0 m and cross-sectional area $0.50 \times 10^{-2} cm^2$ is stretched, well within its elastic limit, horizontally between two pillars. A mass of 100 g is suspended from the mid-point of the wire. Calculate the depression at the midpoint.

OR

Compute the bulk modulus of water from the following data: Initial volume = 100.0 litre, Pressure increase = 100.0 atm (1 atm = $1.013 \times 10^5$ Pa), Final volume = 100.5 litre. Compare the bulk modulus of water with that of air (at constant temperature). Explain in simple terms why the ratio is so large.

**CBSE Class 11 Physics**

**Sample Paper 02 (2020-21)**

## Solution

## Section A

1. It has no unit.
2. When the stone is dropped, it falls freely under the acceleration due to gravity g. With respect to the earth, the acceleration of the stone is g.

   Inside the train, the stone possesses two accelerations:

   (i) Horizontal acceleration $a$ due to the motion of train.

   (ii) Vertical downward acceleration 'g' due to gravity.

   The acceleration of the stone w.r.t. the train is $= \sqrt{a^2 + g^2}$

   OR

   Velocity of a particle changes

   i. if magnitude of velocity changes.
   ii. if the direction of motion changes.

3. M.I. for ring = $MR^2 \Leftrightarrow K = R$

   M.I.for disc = $MR^2/2 \Leftrightarrow K = \frac{R}{\sqrt{2}}$

   $\frac{k_{\text{ring}}}{K_{\text{disc}}} = \frac{R}{\frac{R}{\sqrt{2}}}$

   $= \frac{\sqrt{2}}{1}$

4. There are two main factors that determine whether a planet can develop and keep an atmosphere:

   1. Acceleration due to gravity at the surface of the planet.

   2. The surface temperature of the planet.

   OR

   According to the Newton's law of gravitation

   Since $F \propto \frac{1}{r^2}$

   $r' \rightarrow 3r$

$\mathbf{F}' \propto \frac{1}{r'^2}$

$\mathbf{F}' \propto \frac{1}{(3r)^2}$

$\mathbf{F}' \propto \frac{1}{9r^2}$

$\mathbf{F}' \propto \frac{1}{9F}$

$\therefore$ Force will be decreased to $\frac{1}{9}$ times

5. The vessel having least cross-sectional area at the top possess more pressure at the base because If the volumes are same, then height of the liquid will be highest in which the cross-sectional area is least at the top. ($\because$ p = $\rho$gh).
6. At the highest point vertical component of velocity becomes zero thus the direction of motion of projectile becomes horizontal.
7. i. Latent Heat $= \frac{Q(\text{Heat Energy})}{m(\text{ mass })}$

   Latent Heat $= \frac{ML^2T^{-2}}{M} = [M^0L^2T^{-2}]$

   ii. Specific heat $= S = \frac{Q}{m\times\Delta T} = \frac{ML^2T^{-2}}{M\times K}$

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

OR

   i. It should be of an appropriate size and should not be too large or too small.
   ii. It should be easily accessible and easily reproducible.
   iii. It should be well defined.
   iv. It should not change with time or with a change in physical conditions like temperature, pressure, humidity, etc.

8. $a_1$ = amplitude of first wave

   $a_2$ = amplitude of second wave

   $a_r$ = resultant amplitude

   $\phi$ = phase differece between 2 waves

   then $a_r = \sqrt{a_1^2 + a_2^2 + 2a_1a_2\cos\phi}$

   In our case $a_1$ = a; $a_2$ = a; $\phi = \frac{\pi}{2}$ so

   $a_r = \sqrt{a^2 + a^2 + 2a \times a\cos\left(\frac{\pi}{2}\right)}$

   $= \sqrt{2a^2} \quad \left(\because \cos\left(\frac{\pi}{2}\right) = 0\right) a_r = \sqrt{2a}$

OR

Speed of sound in the tissue, v = 1.7 km/s = $1.7 \times 10^3 \mathrm{m/s}$

Operating frequency of the scanner, V = 4.2 MHz = $4.2 \times 10^6 \mathrm{Hz}$

The wavelength of sound in the tissue is given as:

$\lambda = \frac{v}{V}$

$= \frac{1.7 \times 10^3}{4.2 \times 10^6} = 4.1 \times 10^{-4} \mathrm{m}$

9. If a refrigerator's door is kept open the room will become hotter, because amount of heat absorbed from inside the refrigerator and work done on refrigerator by electricity both will be rejected by refrigerator in room.

10. We know that area of parallelogram is given by the cross product of vectors forming the two adjacent side of a parallelogram.

Therefore, | A × B | = AB sin$\theta$ = $\frac{1}{2}$AB (given)

$\therefore \sin\theta = \frac{1}{2} = \sin 30^\circ$

or $\theta = 30^\circ$

11. (d) Assertion is wrong statement but reason is correct statement.

**Explanation:** Assertion is false but reason is true.

Due to earth's axial rotation, the speed of the trains relative to earth will be different and hence the centripetal forces on them will be different. Thus, their effective weights $\left[mg - \frac{mv^2}{r}\right]$ will be different. So, they exert different pressure on the rails.

12. (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.

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

**Explanation:** Mean nee path of molecules is given by

$\lambda = \frac{1}{\sqrt{2} n \pi d^2}$

where, nis the number of molecules per unit volume, d is diameter of molecules. From this,

$n = \frac{N}{V} = \frac{N}{m}\rho$

Therefore, $\lambda \propto \rho^{-1}$, mean free path is inversely proportional to the density of gas molecules.

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

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

## Section B

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

## Section C

17. Given that :

 R = $1.5 \times 10^8$ Km = $1.5 \times 10^{11}$ m

 Time period of earth to complete one revolution around the sun is(T) = 365 days = $365 \times 24 \times 3600$ s

 Centripetal force = gravitational force

 $$M_s = \frac{4\pi^2 R^3}{GT^2} = \frac{4\times 9.87\times\left(1.5\times 10^{11}\right)^3}{6.64\times 10^{-11}\times(365\times 24\times 3600)^2}$$
 $$= \frac{9.87\times\left(1.5\times 10^{11}\right)^3}{6.64\times 10^{-11}\times(31536000)^2}$$

 $M_s = 2.01 \times 10^{30}$ kg

18. Mass of the bolt, m = 0.3 kg

 Speed of the elevator = 7 m/s

 Height, h = 3 m

 Since the relative velocity of the bolt with respect to the lift is zero, at the time of impact, potential energy gets converted into heat energy.

 Heat produced = Loss of potential energy

 = mgh = $0.3 \times 9.8 \times 3$ = 8.82 J

 The heat produced will remain the same even if the lift is stationary. This is because of the fact that the relative velocity of the bolt with respect to the lift will remain zero.

OR

i. Work done on the cycle by the road is the work done by the stopping (frictional) force on the cycle due to the road. The displacement and the stopping force make an angle of 180° with each other. Thus, work done by the road or the work done by the stopping force is

   $W_r$ = Fs cos $\theta$

   = 200 $\times 10 \times$ cos 180° = - 2000 J (because $cos\pi = -1$ )

   Where negative sign shows that work is done by the road-on cycle.
ii. According to Newton's third law of motion, an equal and opposite force acts on the road due to the cycle. As the road does not move at all, therefore, work done by the cycle on the road is zero.

19. Let A be the displacement amplitude and $\omega$ be the angular frequency of the simple harmonic oscillator.

    Then maximum acceleration, $a_0 = \omega^2 A$ .....(i)

    and maximum velocity, $v_0 = \omega$A .....(ii)

    On dividing the square of eqn (ii) by eqn (i) we get,

    $\frac{v_0^2}{a_0} = \frac{\omega^2 A^2}{\omega^2 A} = A$

    or $A = \frac{v_0^2}{a_0}$

OR

For effective resistance of spring of individual spring constant $k_1$, $k_2$, ------ kn

$\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2} + - - - + \frac{1}{k_{3n}}$

Now, $K_1$ = k; $k_2$ = 2k; $k_3$ = 4k; -----

$\frac{1}{k_{eff}} = \frac{1}{k} + \frac{1}{2k} + \frac{1}{4k} + \frac{1}{8k} + - - -$

$\frac{1}{k_{eff}} = \frac{1}{k}\left[1 + \frac{1}{2} + \frac{1}{4} + \frac{1}{8} + - - - - - -\right]$ $\because$ Sum of infinite G. P. $= \frac{a}{1-r}$

$\frac{1}{k_{eff}} = \frac{1}{k}\left[\frac{1}{1-\frac{1}{2}}\right]$

a = First Term

r = Common on ratio

$\frac{1}{k_{eff}} = \frac{1}{k}\left[\frac{1}{2}\right]$
$\frac{1}{k_{eff}} = \frac{2}{k}$
$k_{eff} = \frac{k}{2}$
Since Time Period, $T = 2\pi\sqrt{\frac{M}{k_{\text{eff}}}}$
$T = 2\pi\sqrt{\frac{M}{\frac{k}{2}}}$
$T = 2\pi\sqrt{\frac{2M}{k}}$

20. $F = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$
$F = \sqrt{F_1^2 + F_2^2} \quad (\theta = 90^\circ)$
$F = \sqrt{(16)^2 + (12)^2}$
F = 20N
$a = \frac{F}{m} = \frac{20}{200}$
a = 0.1 m/s$^2$

21. It is given that a particle is moving in a straight line and its displacement at any instant t is given by, x = 10t + 15t$^3$
    i. Now, the Velocity of particle, $\mathbf{v} = \frac{dx}{dt}$
    $\mathbf{v} = \frac{d}{dt}\left(10t + 15t^3\right)$ = 10 + 45t$^2$
    At t = 0, $v_0$ = 10 + 45(0) = 10 m/s
    At t = 2, $v_2$ = 10 + 45(2)$^2$ = 10 + 180 = 190 m/s
    $\Delta\mathbf{v} = \mathbf{v}_2 - \mathbf{v}_0$ = 190 - 10 = 180 m/s
    $\Delta$t = 2 - 0 = 2 s
    $\therefore \mathbf{a}_{\text{av}} = \frac{\Delta \mathbf{v}}{\Delta t} = \frac{180}{2}$ = 90 m/s$^2$
    ii. Also, a = $\frac{dv}{dt}$ = $\frac{d}{dt}\left(10 + 45t^2\right)$ = 90t
    At t = 2 s, a = 90(2) = 180 m/s$^2$
    Thus, the instantaneous acceleration of a particle at 2 s is 180 m/s$^2$.

22. Transverse waves are the waves in which the medium particles vibrate to and fro about their mean positions at right angles to the direction of wave propagation. Transverse waves travel in the form of crests and troughs. One crest and the adjoining trough constitute one wave.

A simple example is given by the waves that can be created on a horizontal length of string by anchoring one end and moving the other end up and down. Another example is the waves that are created on the membrane of a drum. The waves propagate in directions that are parallel to the membrane plane, but the membrane itself gets displaced up and down, perpendicular to that plane. Light is another example of a transverse wave, where the oscillations are the electric and magnetic fields, which point at right angles to the ideal light rays that describe the direction of propagation.

23. Using conservation of angular momentum

$L_{initial} = L_{final}$

$MVL = \text{I}\omega$

or MVL = $\frac{M+3m}{3} L^2 w$

or $\omega = \frac{3Mv}{(M+3m)L}$

24. The dimensional formula of energy or heat = u = [ $ML^2T^{-2}$ ].

Assume that, $M_1$, $L_1$, $T_1$ and $M_2$, $L_2$, $T_2$ are the units of mass, length and time in given two systems.

$\therefore M_1$ = 1 kg, $M_2 = \alpha$ kg

$L_1$ = 1 m, $L_2 = \beta$ m

$T_1$ = 1 s, $T_2 = \gamma$ s

$n_1$ and $n_2$ are the magnitudes of heat or energy of system one and system two respectively.

For a given physical quantity, the product of its magnitude and unit is always constant.

$n_1u_1 = n_2u_2$

or $n_2 = n_1 \frac{u_1}{u_2} = 4.2 \times \frac{[M_1L_1^2T_1^{-2}]}{[M_2L_2^2T_2^{-2}]}$

$= 4.2 \left[\frac{M_1}{M_2}\right] \times \left[\frac{L_1}{L_2}\right]^2 \times \left[\frac{T_1}{T_2}\right]^{-2}$

$= 4.2 \left[\frac{1}{\alpha}\right] \times \left[\frac{1}{\beta}\right]^2 \times \left[\frac{1}{\gamma}\right]^{-2}$

$n_2 = 4.2\alpha^{-1}\beta^{-2}\gamma^2$ new unit

Therefore, 1 cal = $4.2\alpha^{-1}\beta^{-2}\gamma^2$ new unit

OR

i. $1^\circ = \frac{\pi}{180}\text{rad} = \frac{\pi}{180} = \frac{22}{7\times180}$ = 0.01746 radian = $1.746 \times 10^{-2}$ radian

ii. 1 arc sec = 1'' = $\frac{1'}{60} = \frac{1^\circ}{60\times60}$

as $1^o$ = $\frac{\pi}{180}\text{rad} = \frac{\pi}{180} = \frac{22}{7\times180}$ rad

so 1''$= \frac{1}{60\times60} \times \frac{\pi}{180}\text{rad}$

= 0.0000048 rad = $4.85 \times 10^{-6}$ radian

25. i. For the time interval $t_1$ and $t_2$, we have

Distance covered = 20 + 40 = 60 m

and displacement = 40-(-20) = +60 m (towards positive x - axis)

ii. For the time interval $t_1$ and $t_3$, we have

Distance covered = 60 + 90 = 150 m

and displacement = -50-(-20)

= -30 m (towards x - axis)

**Section D**

26. Speed of the aircraft, $v$ = 720 km/h = 720 × 5 / 18 = 200 m/s, Acceleration due to gravity, g = 10 m/s$^2$

Angle of banking, $\theta$ = 15°

For radius $r$, of the loop, we have the relation:

$\tan\theta = v^2 / rg$

$r = v^2 / g \tan\theta$

= $200^2$ / (10 × tan 15)

= 4000 / 0.26

= 14925.37 m= 14.92 km

27. Systematic errors are those errors that tend to be in one direction, either positive or negative. It is a repeatable error. Different types of systematic errors are:

i. **Instrumental errors:** These arises from the errors due to imperfect design or calibration of the measuring instrument. Zero error present in vernier calliper, backlash error in screw gauge / spherometer, etc., are examples of instrumental errors. Appropriate corrections may be applied for these errors.

ii. **Errors due to imperfection in experimental technique or procedure:** For example, a nurse tries to measure the body temperature of a young child by placing the thermometer under his armpit. Naturally, the temperature is less than the real body temperature and produces an error. Similarly, heat loss due to radiation in calorimetry experiments or effect of buoyancy of air while weighing a body are errors of this type.

iii. **Environmental Errors (Errors due to external cause):** These errors are due to external conditions like change in temperature, atmospheric pressure, humidity, wind velocity etc., during the course of experiment. Effect of these errors may be eliminated by performing experiment under different external conditions spread over a long time and then taking the mean value.

iv. **Personal errors:** These errors arise due to an individual's bias, lack of proper setting of apparatus or carelessness of the observer while taking the observations. To minimize these errors the person performing an experiment should be extremely careful and should follow proper procedures.

OR

**Key point:** In geometry, a solid angle (symbol: Ω or w) is the two bdimensional angle in three-dimensional space that an object subtends at a point. It is a measure of how large the object appears to an observer looking from that point. In the International System of Units (SI), a solid angle is expressed in a dimensionless unit called a Steradian (symbol: Sr). We know that, $\Omega = \frac{A}{r^2}$

In the given diagram, it is shown that moon almost entirely covers the sphere of the sun.

Also, distance of moon from earth $= R_{me}$

and distance of sun from earth $= R_{se}$

Let the solid angle made by sun and moon is $d\Omega$ we can write

$$d\Omega = \frac{A_{\text{sun}}}{R_{\text{se}}^2} = \frac{A_{\text{moon}}}{R_{\text{me}}^2}$$

Here, $A_{\text{sun}}$ = area of the sun and $A_{\text{moon}}$ = area of the moon

$$\Rightarrow \quad \theta = \frac{\pi R_{\text{s}}^2}{R_{\text{se}}^2} = \frac{\pi R_{\text{m}}^2}{R_{\text{me}}^2}$$

$$\Rightarrow \quad \left(\frac{R_{\text{s}}}{R_{\text{se}}}\right)^2 = \left(\frac{R_{\text{m}}}{R_{\text{me}}}\right)^2$$

$$\Rightarrow \quad \frac{R_{\text{s}}}{R_{\text{se}}} = \frac{R_{\text{m}}}{R_{\text{me}}} \quad \text{or} \quad \frac{R_{\text{s}}}{R_{\text{m}}} = \frac{R_{\text{se}}}{R_{\text{me}}}$$

28. Given two vectors A = $\hat{\mathbf{i}} - 2\hat{\mathbf{j}} - \hat{\mathbf{k}}$ and B = $-\hat{\mathbf{i}} + \hat{\mathbf{j}} - 2\hat{\mathbf{k}}$

From the expression of dot product or scalar product.

A.B = AB cos θ..........(i)

The magnitude of $\vec{A}$ is given by

$A=\sqrt{(1)^2+(-2)^2+(-1)^2}=\sqrt{6}$..........(ii)

The magnitude of $\vec{B}$ is given by

$B=\sqrt{(-1)^2+(1)^2+(-2)^2}=\sqrt{6}$........(iii)

Now solving LHS of Eq (i)

A.B = $(\hat{\mathbf{i}}-2\hat{\mathbf{j}}-\hat{\mathbf{k}})\cdot(-\hat{\mathbf{i}}+\hat{\mathbf{j}}-2\hat{\mathbf{k}})$

$=(1.-1)(\hat{\mathbf{i}}\cdot\hat{\mathbf{i}})+(1\cdot 1)(\hat{\mathbf{i}}\cdot\hat{\jmath})+(1\cdot -2)(\hat{\mathbf{i}}\cdot\hat{\mathbf{k}})+(2\cdot -1)$

$(\hat{\jmath}\cdot\hat{\mathbf{i}})+(-2\cdot 1)(\hat{\mathbf{j}}\cdot\hat{\mathbf{j}})+(2\cdot -2)(\hat{\mathbf{j}}\cdot\hat{\mathbf{k}})+(-1\cdot -1)$

$(\hat{\mathbf{k}}\cdot\hat{\mathbf{i}})+(-\mathbf{1}\cdot\mathbf{1})(\hat{\mathbf{k}}\cdot\hat{\mathbf{j}})+(-1\cdot -2)(\hat{\mathbf{k}}\cdot\hat{\mathbf{k}})$

A.B = -1

Substituting the values of A from Eq. (ii) and B from Eq. (iii) and A.B = -1 in Eq. (i), we get

$-1=(\sqrt{6})(\sqrt{6})\cos\theta$

$\Rightarrow\cos\theta=\frac{-1}{6}\Rightarrow\theta=\cos^{-1}\left(\frac{-1}{6}\right)=80.44^{\circ}$ in the third quadrant

OR

Given that the position of particle, r = $3.0t\hat{\mathbf{i}}+2.0t^2\hat{\mathbf{j}}+5.0\hat{\mathbf{k}}$

i. First order differentiation of position vector provide the instantaneous velocity of the particle, v(t) = $\frac{dr}{dt}=\frac{d}{dt}\left(3.0t\hat{\mathbf{i}}+20t^2\hat{\mathbf{j}}+5.0\hat{\mathbf{k}}\right)=3.0\hat{\mathbf{i}}+4.0t\hat{\mathbf{j}}$
ii. Now at time t = 2.0 s

$\mathbf{v}(t)=3.0\hat{\mathbf{i}}-8.0\hat{\mathbf{j}}$

$v=\sqrt{v_x^2+v_y^2}=\sqrt{(3.0)^2+(-8)^2}=\sqrt{73}$ = 8.54 m/s

$\theta=\tan^{-1}\left(\frac{v_y}{v_x}\right)\tan^{-1}\left(\frac{8}{3}\right)$ = -2.667 = 69.5°

$\theta=69.5^{\circ}$ below X - axis

29. Lower fixed point on the wrong scale = -10$^0$C.

if 'n' be the no. of divisions between upper and lower fixed points on this scale and Q is the reading on this scale, then

$\frac{C-O}{100}=\frac{Q-(-10)}{n}$

Here C is the incorrect Reading and Q is the correct reading

C= 50$^0$ C; Q = 60$^0$C

So, $\frac{50-0}{100}=\frac{60-(-10)}{n}$

$\frac{50}{100} = \frac{70}{n}$

$n = 70 \times \frac{100}{50}$ =140

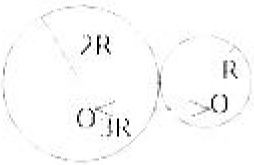
Now, $\frac{C-O}{100} = \frac{Q-(-10)}{140}$

On, the correct Celsius scale, Boiling point of water is $100^0$C

So, $\frac{100-0}{100} = \frac{Q+10}{140}$

Q = 140 - 10 = $130^0$C

30. Two spheres of density p and radii R and 2R




Given, density of each sphere is ρ

For finding mass of each sphere, we have to find volume of each

Volume of sphere of radius R, $V_1 = \frac{4}{3}\pi R^3$

volume of sphere of radius 2R, $V_2 = \frac{4}{3}\pi(2R)^3 = \frac{32\pi R^3}{3}$

Now, mass of 1st sphere, $M_1 = V_1 \times \rho$ [ mass = density × volume ]

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

mass of 2nd sphere, $M_2 = V_2 \times \rho = \frac{32\pi R^3 \rho}{3}$

= 2R + R = 3R

Now, Gravitational force act between $M_1$ and $M_2$, $F = \frac{GM_1M_2}{(R+2R)^2}$

$= \frac{G\frac{4\pi R^3\rho}{32\pi R^3\rho}}{9R^2}$

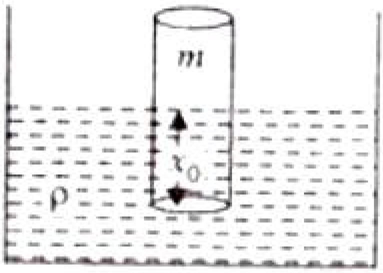
$= \frac{128\pi^2 R^6 \rho^2}{81R^2}$

$= \frac{128\pi 2R^4\rho^2}{81}$

Hence, force between them, $F = \frac{128\pi 2R^4\rho^2}{81}$

**Section E**

31. When log is pressed downward into the liquid then an upward Buoyant force (B.F.) acts on it which moves the block upward and it moves upward from its mean position due to inertia and then again come down due to gravity. So net restoring force on block = Buoyant force on the log by the liquid – weight of the log of wood




Say, V = volume of liquid displaced by the log

When the log floats then

Weight of the log, mg = buoyant force by the liquid or $mg = V\rho g$, [$V\rho g$ is the weight of the displaced liquid by the log]

$mg = Ax_0\rho g$ ...(i) [$x_0$ = depth of the log into the liquid just before the log is pressed and volume displaced by the liquid, V = $Ax_0$]

A = area of cross-section

$x_0 =$ depth of the log into the liquid due to its own weight

Let x height again dip in liquid when pressed into it. Hence total height of log into the liquid $= (x + x_0)$

So net force acting upward on the log $= [A(x + x_0)]\rho \cdot g - mg$

$F_{\text{net}} = Ax_0\rho g + Ax\rho g - Ax_0\rho g$

$F_{\text{restoring}} = -F_{net} = -Ax\rho g$

(as Buoyant force is upward and displacement of the log, x is directed downwards)

$\therefore F_{restoring} \propto -x$

So motion is SHM with proportional constant k = $A\rho g$

Again from SHM equation, $a = -\omega^2 x$....(i)

$F_{\text{restoring}} = -A\rho g x$

$\Rightarrow ma = -A\rho g x$

$\Rightarrow a = \frac{-A\rho g x}{m} \Rightarrow -\omega^2 x = \frac{-A\rho g x}{m}$ [putting the value of a from equation (i)]

$\therefore \omega^2 = \frac{A\rho g}{m}$

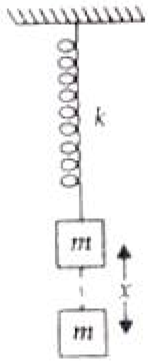
with $k = A\rho g$ and $\omega = \frac{2\pi}{T}$

Hence, $\left(\frac{2\pi}{T}\right)^2 = \frac{A\rho g}{m} \Rightarrow \frac{T}{2\pi} = \sqrt{\frac{m}{A\rho g}} \Rightarrow T = 2\pi\sqrt{\frac{m}{A\rho g}}$

OR

a. Let the mass reaches at its new position $x$ unit displacement from previous.

   Then P.E. of spring or mass = gravitational P.E. lost by man




$PE = mgx$

But P.E. due to spring is $\frac{1}{2}kx^2, k = \omega^2 A$

$\therefore \frac{1}{2}kx^2 = mgx$

$x = \frac{2mg}{k}$

Mean position of spring by block will be when let extension is $x_0$ then

$F = +kx_0$

$F = mg \therefore mg = +kx_0$ or $x_0 = \frac{mg}{k}$ ....(ii)

From (i) and (ii)

$x = 2\left(\frac{mg}{k}\right) = 2x_0$

$x = 4\text{cm} \quad \therefore 4 = 2x_0$

$x_0 = 2\text{cm}$

The amplitude of oscillator is the maximum distance from mean position i.e.,

$x - x_0 = 4 - 2 = 2\text{cm}$

b. Time Period $T = 2\pi\sqrt{\frac{m}{k}}$ which does not depend on amplitude

$\frac{2mg}{k} = x$ from (i)

$\frac{m}{k} = \frac{x}{2g} = \frac{4\times10^{-2}}{2\times9.8}$ or $\frac{k}{m} = \frac{2\times9.8}{4\times10^{-2}}$

$v = \frac{1}{2\pi}\sqrt{\frac{k}{m}} = \frac{1}{2\times3.144}\sqrt{\frac{2\times9.8}{4\times10^{-2}}} = \sqrt{\frac{4.9\times10^2}{6.28}}$

$v = \frac{10\times2.21}{6.28} = 3.52\text{Hz}$

Oscillator will not rise above the positive from where it was released because total extension in spring is 4 cm when released and amplitude is 2 cm. So it oscillates below the released position.

32. The nuclear decay is represented as follows:

$\underset{\text{Excited state}}{Fe^{57}} \longrightarrow \underset{\text{Ground state}}{Fe^{57}} + h\nu$ ($\gamma$-ray photon)

According to the de-Broglie hypothesis, the linear momentum of a photon of energy E is given by:

$p=\frac{E}{c}=\frac{14.4\text{keV}}{c}=\frac{14.4\times1.6\times10^{-16}\text{J}}{3\times10^{8}\text{ms}^{-1}}$

or p = $7.68\times10^{-24}$ kg $ms^{-1}$

According to the law of conservation of linear momentum, the momentum of daughter nucleus, p = momentum of $\gamma$-ray photon = $7.68\times10^{-24}$ kg $ms^{-1}$

Now, $K=\frac{p^2}{2m}=\frac{(7.68\times10^{-24})^2}{2\times56.935\times1.66\times10^{-27}}$

$=0.32\times10^{-21}\text{J}=\frac{0.312\times10^{-21}}{1.6\times10^{-16}}\text{keV}$

K = $1.95\times10^{-6}$ keV, which is the required recoil energy of the nucleus.

OR

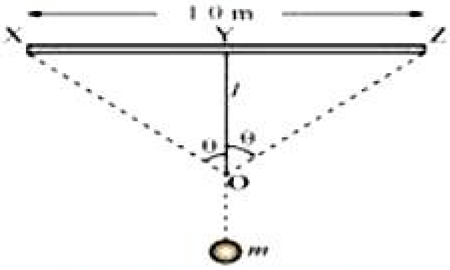
i. The heat energy required for burning of casing of rocket comes from the rocket itself. As a result of work done against friction the kinetic energy of rocket continuously decreases and this work against friction reappears as heat energy.
ii. The gravitational force is a conservative force, hence, work done by the gravitational force over one complete (closed) orbit of comet is zero. Gravitational force is conservative in nature. The work done by a conservative force in a closed cycle is zero. Hence, work done by the gravitational attraction of sun is zero.
iii. As an artificial satellite gradually loses its energy due to dissipation against atmospheric resistance, its potential energy decreases rapidly. As a result, kinetic energy of satellite slightly increases i.e. its speed increases progressively.
iv. In figure, the man carries the mass of 15 kg on his hands and walks 2 m. In this case, he is actually doing work against the friction force.
Friction force contribution by mass
$f=\mu N=\mu mg\times15\times9.8\text{N}$
and work done against friction
$W_1$ = fs = $\mu\times15\times9.8\times2=294\mu J$
In figure (ii) the tension in string, T = mg = $15\times$ 9.8 N Hence, force applied by man for pulling the rope
F = T =$15\times9.8$ N
$\therefore$Work done by man, W2 = Fs = $15\times$ 9.8 $\times$ 2 = 294 J and additional work has to be done against friction also. Thus, it is clear that $W_2 > W_1$.

33. Length of the steel wire, L = 1.0 m

Area of cross-section, A = 0.50 × $10^{-2}$ $cm^2$ = 0.50 ×$10^{-6}$ $m^2$

A mass 100g is suspended from its midpoint. m = 100 g = 0.1 kg

Consider the figure.




Original length = XZ = 1m

Let Depression = l

The length after mass m, is attached to the wire = XO + OZ

Increase in the length of the wire: $\triangle L$ = (XO + OZ) - XZ

where XO = OZ = $\left[(0.5)^2 + l^2\right]^{\frac{1}{2}}$

$$\therefore \Delta L = 2\left[(0.5)^2 + l^2\right]^{\frac{1}{2}} - 1$$

$$\triangle L = 2 \times 0.5\left[1 + \left(\frac{l}{0.5}\right)^2\right]^{\frac{1}{2}} - 1$$

Expanding and neglecting higher terms, we get:

$$\Delta L = \frac{l^2}{0.5}$$

$$\text{Strain} = \frac{\text{Increase in length}}{\text{Original length}}$$

Let T be the tension in the wire.

$$\therefore mg = 2T \cos\theta$$

Using the figure, it can be written as:

$$\cos\theta = \frac{l}{\left[(0.5)^2 + l^2\right]^{\frac{1}{2}}}$$

$$\cos(\theta) = \frac{1}{(0.5)\left[1 + \left(\frac{l}{0.5}\right)^2\right]^{\frac{1}{2}}}$$

Expanding the expression and eliminating the higher terms:

$$\cos\theta = \frac{l}{(0.5)\left[1 + \frac{l^2}{2(0.5)^2}\right]}$$

Now, $\left(1 + \frac{l^2}{2 \times 0.5^2}\right) = 1$ for small l,

$$\therefore \cos\theta = \frac{l}{0.5}$$

$\therefore T=\frac{mg}{2\left(\frac{l}{0.5}\right)}=\frac{mg\times0.5}{2l}=\frac{mg}{4l}$

Stress $=\frac{Tension}{Area}=\frac{mg}{4l\times A}$

Young's modulus Y $=\frac{\text{Stress}}{\text{Strain}}=\frac{\frac{T}{A}}{\frac{\triangle L}{L}}$

On substituting values, we get,

$l=\sqrt[3]{\frac{mg}{8YA}}$

Now, Young's modulus of steel, $Y=2\times10^{11}Pa$

$\therefore l=\sqrt[3]{\frac{0.1\times9.8}{8\times2\times10^{11}\times0.5\times10^{-6}}}$

= 0.0106 m

Hence, the depression at the midpoint is 0.0106 m.

OR

Initial volume, $V_1$ = 100.0 litre = 100.0 $\times$ $10^{-3}$ $m^3$(As, 1 litre = $10^{-3}$ $m^3$)

Final volume, $V_2$ = 100.5 litre = 100.5 $\times$ $10^{-3}$ $m^3$

Increase in volume, $\Delta$V = $V_2$ - $V_1$ = 0.5 $\times$ $10^{-3}$ $m^3$

Increase in pressure, $\Delta$p = 100.0 atm = 100 $\times$ 1.013 $\times$ $10^5$ Pa(Since, 1 atm = 1.013 × $10^5$ Pa)

Bulk modulus, k = $\frac{\Delta p}{\frac{\Delta V}{V}}=\frac{\Delta p\times V}{\Delta V}$

$=\frac{100\times1.013\times10^5\times100\times10^{-3}}{0.5\times10^{-3}}$

$=2.026\times10^9\ Pa$

We know that bulk modulus of air $=1.0\times10^5\text{Pa}$

$\therefore\frac{\text{Bulk modulus of water}}{\text{Bulk modulus of air}}=\frac{2.026\times10^9}{1.0\times10^5}=2.026\times10^4$

We know that compressibility is inverse of bulk modulus. Now the air is much more compressible than water. That means the the compressibility of air is much more greater than water. Hence, bulk modulus of water is much more greater than air. That's why, the ratio of the bulk modulus of water to the bulk modulus of air is very high.