The potential energy of asteroid at a distance 10 R_E is

$$U_i = -\frac{GM_E m}{10R_E} \quad \ldots(\text{ii})$$

where, M_E is mass of earth.

$\therefore$ Initial energy of the asteroid is

$$E_i = K_i + U_i = \frac{1}{2}mv_i^2 - \frac{GM_E m}{10R_E}$$

As it hits earth with a speed of v_f (R_E and M_E are radius and mass of earth), then

Final energy of the asteroid is

$$E_f = \frac{1}{2}mv_f^2 - \frac{GM_E m}{R_E}$$

According to law of conservation of energy,

$$E_i = E_f$$

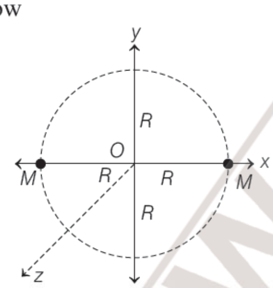
$$\frac{1}{2}mv_i^2 - \frac{GM_E m}{10R_E} = \frac{1}{2}mv_f^2 - \frac{GM_E m}{R_E}$$

$$\Rightarrow \quad v_f^2 - \frac{2GM_E}{R_E} = v_i^2 - \frac{2GM_E}{10R_E}$$

$$\Rightarrow \quad v_f^2 = v_i^2 + \frac{2GM_E}{R_E}\left(1 - \frac{1}{10}\right)$$

74 (*d*) As we know that, force on satellite is only gravitational force which will always be towards the centre of earth. Thus, the acceleration of S is always directed towards the centre of the earth.

75 (*a*) Let us assume that stars are moving in x y-plane with origin as their centre of mass as shown in the figure below



According to question,

mass of each star, $M = 3 \times 10^{31}$ kg

and diameter of circle, $2R = 2 \times 10^{11}$ m

$$\Rightarrow \quad R = 10^{11} \text{ m}$$

Potential energy of meteorite at O, origin $\hat{\mathbf{j}}$ is,

$$U_{\text{total}} = -\frac{2\,GMm}{r}$$

If v is the velocity of meteorite at O then

Kinetic energy K of the meteorite is

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

To escape from this dual star system, total mechanical energy of the meteorite at infinite distance from stars must be at least zero.

By conservation of energy, we have

$$\frac{1}{2}mv^2 - \frac{2\,GMm}{R} = 0$$

$$\Rightarrow \quad v^2 = \frac{4\,GM}{R} = \frac{4 \times 6.67 \times 10^{-11} \times 3 \times 10^{31}}{10^{11}}$$

$$\Rightarrow \quad v = 2.83 \times 10^5 \text{ m/s}$$

76 (*a*) Given, escape velocity on the surface of earth, $v_e = 11.1$ km/h.

Escape velocity on the surface of the earth,

$$v_e = \sqrt{2gR_E}$$

or

$$v_e = \sqrt{\frac{2GM_E}{R_E}}$$

Mass of moon, $M_m = \dfrac{M_E}{81}$

Radius of moon, $R_m = \dfrac{R_E}{4}$

$\therefore$ Escape velocity on the surface of moon,

$$v_m = \sqrt{\frac{2G\,M_m}{R_m}} = \sqrt{\frac{2G\dfrac{M_E}{81}}{\dfrac{R_E}{4}}}$$

$$= \frac{2}{9}\sqrt{\frac{2GM_E}{R_E}} = \frac{2}{9}v_e$$

$$= \frac{2}{9} \times 11.1 = 2.46 \text{ km/h}$$

77 (*a*) Since, the escape velocity of earth can be given as

$$v_e = \sqrt{2gR}$$

$$\Rightarrow \quad v_e = R\sqrt{\frac{8}{3}\pi G\rho} \quad (\rho = \text{density of earth}) \ldots(\text{i})$$

As it is given that the radius and mean density of planet are twice as that of earth. So, escape velocity at planet will be

$$v_p = 2R\sqrt{\frac{8}{3}\pi G 2\rho} \quad \ldots(\text{ii})$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{v_e}{v_p} = \frac{R\sqrt{\frac{8}{3}\pi G\rho}}{2R\sqrt{\frac{8}{3}\pi G 2\rho}} \Rightarrow \frac{v_e}{v_p} = \frac{1}{2\sqrt{2}} = 1 : 2\sqrt{2}$$

78 (*d*) $\because$ Angular momentum,

$$L = mvr = m\sqrt{\frac{GM}{r}}\,r = m\sqrt{GMr}$$

$$\left(\because v = \sqrt{\frac{GM}{r}}\right)$$

$$\therefore \quad L \propto \sqrt{r}$$

If r is increased to $16r$, then new angular momentum,

$$L' \propto \sqrt{16r} \quad \Rightarrow \quad L' = 4L$$

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79 (*d*) Orbital speed of a satellite in a circular orbit is

$$v_0 = \sqrt{\left(\frac{GM}{r_0}\right)}$$

where r_0 is the radius of the circular orbit.

So, kinetic energies of satellites A and B are

$$T_A = \frac{1}{2} m_A v_{OA}^2 = \frac{GMm}{2R}$$

$$T_B = \frac{1}{2} m_B v_{OB}^2 = \frac{GM(2m)}{2(2R)} = \frac{GMm}{2R}$$

So, ratio of their kinetic energies is

$$\frac{T_A}{T_B} = 1$$

80 (*c*) KE of satellite, $K = \frac{1}{2} mv_o^2$

$$= \frac{1}{2} m \left(\sqrt{\frac{GM_E}{(R_E + h)}}\right)^2 = \frac{1}{2} \frac{GmM_E}{(R_E + h)}$$

$$\left[\because \text{ orbital velocity of satellite, } v_o = \sqrt{\frac{GM_E}{(R_E + h)}}\right]$$

81 (*b*) KE of a satellite, $K = \frac{GmM_E}{2(R_E + h)}$.

$$\Rightarrow \quad K = \frac{GmM_E}{2r} \qquad [\because R_E + h = r(\text{let})]$$

$$\text{Since,} \quad K \propto \frac{1}{r}$$

$$\Rightarrow \quad \frac{K_1}{K_2} = \frac{r_2}{r_1}$$

$$\Rightarrow \quad \frac{K}{K_2} = \left(\frac{2r}{r}\right)$$

(since, radius is doubled and $K_1 = K$)

$$\therefore \quad K_2 = \frac{K}{2}$$

82 (*b*) Gravitational potential energy of a body of mass m at a distance r from the centre of the earth is

$$= -\frac{GmM_E}{r}$$

$$\because \quad r = R_E + h$$

$$\therefore \quad \text{PE} = -\frac{GmM_E}{(R_E + h)}$$

83 (*a*) PE of satellite $= \frac{-GmM_E}{(R_E + h)}$ ...(i)

KE of satellite $= +\frac{1}{2} \frac{GmM_E}{(R_E + h)}$ ...(ii)

From Eqs. (i) and (ii), we get

$$\text{PE} = -2\,\text{KE}$$

$$\Rightarrow \quad \lambda = -2$$

84 (*d*) Orbital velocity of the satellite is given as,

$$v_O = \sqrt{\frac{GM}{R + h}}$$

Since, $R >> h$

$$\therefore \quad v_O = \sqrt{\frac{GM}{R}} = \sqrt{gR} \qquad \left[\because g = \frac{GM}{R^2}\right]$$

Escape velocity of the satellite,

$$v_e = \sqrt{\frac{2GM}{R + h}} = \sqrt{\frac{2GM}{R}} = \sqrt{2gR}$$

Since, we know that in order to escape the earth's gravitational field a satellite must get escape velocity.

$\therefore$ Change in velocity,

$$\Delta v = v_e - v_O$$

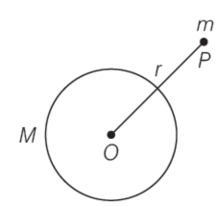
$$= \sqrt{gR}\,(\sqrt{2} - 1)$$

86 (*b*) According to the given condition in the question, after collision the mass of combined system is doubled. Also, this system would be displaced from its circular orbit.

So, the combined system revolves around centre of mass of 'system + earth' under action of a central force.

Hence, orbit must be elliptical.

87 (*a*) For point outside the spherical shell, the gravitational force on point mass placed at that point P is just as if the entire mass of the shell is situated at the centre O, i.e. as if a point mass M is placed at centre O.

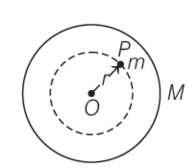


Gravitational force have two components along the line joining the centre of masses as well as along the direction perpendicular to this line.

Only gravitational forces due to various regions of the shell along the line joining P and O remains while components perpendicular to OP cancel out.

Therefore Assertion and Reason are correct and Reason is the correct explanation of Assertion.

88 (*a*) A point P (mass m) is situated inside the hollow spherical shell is shown in the figure.



For point P inside the hollow spherical shell,

$$F_P = \text{zero}$$

The force of gravitation due to various region of the spherical shell be attractive and hence from symmetry it can be seen that these forces cancel each other completely.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

89 (*a*) Henry-Cavendish experiment helped to determine the value of G ($G = 6.67 \times 10^{-11}$ Nm^2 kg^{-2}).

From the value of g (acceleration due to gravity on the surface of the earth) and R_E(radius of the earth)

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using the relation $g = \frac{GM_E}{R_E^2}$ (by using Newton's law), the mass of the earth (M_E) can be estimated

$$\Rightarrow \quad M_E = \frac{gR_E^2}{G}$$

where, $g = 9.8\,\text{ms}^{-2}$,

$R_E = 6400 \times 10^3$ m

and $G = 6.67 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

90 (a) Since, acceleration due to gravity decreases above the surface of the earth and weight is directly proportional to the acceleration due to gravity, so as we go up, we feel light weighted than on the surface of the earth.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

91 (a) Escape speed for moon $= \sqrt{2g'R_m}$, where g' and R_m both are much smaller than corresponding values on the earth, hence on substituting the values.

Escape speed on the moon comes out to be 2.3 kms^{-1} as calculated below

$$\because \quad g' = g/6 \text{ and } R_m = 1760\,\text{km}$$

$$\Rightarrow \text{Escape speed} = \sqrt{2 \times \frac{9.8}{6} \times 1760 \times 10^3}\ \text{ms}^{-1}$$

$$= 2.3\ \text{kms}^{-1}$$

$$\because \quad (v_i)_{\min}\ (\text{earth}) = 11.2\ \text{kms}^{-1}$$

and $(v_i)_{\min}$ (moon) $= 2.3\ \text{kms}^{-1}$

Thus, escape speed for the moon is five times smaller than that of earth.

Therefore, Assertion and Reason are correct and Reason is the correct explainetion of Assertion.

92 (a) The escape speed for the moon is much smaller and hence any gas molecule formed having thermal velocity larger than escape speed will escape the gravitational pull of the moon.
So, moon has no atmosphere.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

93 (d) Escape velocity, $v_e = \sqrt{2gR}$, where $g = \frac{GM}{R^2}$.

$$\Rightarrow \quad v_e = \sqrt{\frac{2GM}{R}}$$

i.e. $\quad v_e \propto \frac{1}{\sqrt{R}}$

So, if radius is doubled, i.e. $R' = 2R$

$$v'_e = \sqrt{\frac{2GM}{(2R)}} = \frac{1}{\sqrt{2}}\sqrt{\frac{2GM}{R}} = \frac{v_e}{\sqrt{2}}$$

Therefore, Assertion is incorrect but Reason is correct.

94 (a) Orbital velocity of satellite, $v_o = \sqrt{\frac{GM_E}{(R_E + h)}}$

$$\Rightarrow \quad v_o \propto \frac{1}{\sqrt{R_E + h}}$$

Thus, v_o is maximum near the surface of the earth for $h = 0$.

$$(v_o)_{\max} = \sqrt{\frac{GM_E}{R_E}}$$

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

95 (a) Total energy of a satellite is always negative irrespective of the nature of its orbit. It indicates that the satellite is bound to the earth. At infinity, the potential energy and kinetic energy of satellite is zero.
Hence, total energy at infinity is zero, therefore only negative energy of satellite is possible when it is revolved around the earth.
If it is positive or zero, the satellite would leave its definite orbit and escape to infinity.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

96 (a) The geo-stationary satellite goes around the earth in west-east direction.

It is because it orbits around earth in the equatorial plane with a time period of 24 h same as that of rotation of the earth around its axis.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

97 (c) In a satellite around the earth, every part and parcel of the satellite has an acceleration towards the centre of the earth which is exactly the value of earth's acceleration due to gravity at that position.
Thus, in the satellite, everything inside it is in a state of free fall.
Therefore, Assertion is correct but Reason is incorrect.

98 (a) An object is weightless when it is in free fall as during free fall, there is no upward force acting on the body and this phenomenon is called weightlessness.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

99 (a) The pattern of motion of the planets was put forward by Ptolemy. According to his scheme of motion, the planets are moving in circles with the centre of the circles themselves moving in larger circles.

So, statement I is correct but II and III are incorrect.

100 (d) In a 'geocentric model' all celestial objects, stars, the sun and the planets, all revolve around the earth. The only possible motion for celestial objects was motion in a circle.

So, statements I and II are correct but III is incorrect.

101 (a) With reference to the 'heliocentric model' of planetary motions, the planets revolve around the sun as its centre.

So, statement I is correct but II, III and IV are incorrect.

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102 (*a*) For the gravitational force between an extended object (like the earth) and a point mass, the Newton's universal law of gravitation is not directly applicable.

So, statement I is correct but II and III are incorrect.

104 (*d*) Time period of satellite $= \dfrac{2\pi\,(R_E + h)^{3/2}}{\sqrt{GM_E}}$

From the above equation, it is evident that the time period of a satellite depends on mass of the earth (M_E), radius of the orbit $(r = R_E + h)$ and height of the satellite from the surface of the earth (h).

So, statements II, III and IV are correct but I is incorrect.

106 (*d*) Let the original mass of sun was M_s and gravitational constant G.

According to the question,

New mass of sun, $M'_s = \dfrac{M_s}{10}$

New gravitational constant, $G' = 10G$

As, the acceleration due to gravity is given as

$$g = \frac{GM_E}{R^2} \quad \ldots\text{(i)}$$

where, M_E is the mass of earth and R is the radius of the earth.

Now, new acceleration due to gravity,

$$g' = \frac{G'M_E}{R^2} = \frac{10M_E G}{R^2} \quad \ldots\text{(ii)}$$

$$\therefore \quad g' = 10g \quad \text{[from Eqs. (i) and (ii)]}$$

This means the acceleration due to gravity has been increased. Hence, force of gravity acting on a body placed on the surface of the earth increases.

Due to this, rain drops will fall faster and walking on ground would become more difficult.

As, time period of the simple pendulum is

$$T = 2\pi\sqrt{\frac{l}{g}} \quad \text{or} \quad T \propto \frac{1}{\sqrt{g}}$$

Thus, time period of the pendulum also decreases with the increase in g.

Thus, the statement given in option (d) is incorrect, rest are correct.

107 (*b*) Since, cavities are symmetrical w.r.t. O. So, the gravitational force at the centre is zero,

but gravitational force at the point $B(2,0,0)$ is not zero due to lack of symmetry.

The radius of the circle $z^2 + y^2 = 36$ is 6. For all points for $r \geq 6$, the body behaves such that whole of its mass is concentrated at the centre. So the gravitational potential is same.

Above is true for $z^2 + y^2 = 4$ as well.

Thus, the statement given in option (b) is incorrect, rest are correct.

108 (*b*) Acceleration due to gravity at altitude h,

$$g_h = \frac{g}{(1 + h/R)^2} \approx g\left(1 - \frac{2h}{R}\right)$$

At depth d, $g_d = g\left(1 - \dfrac{d}{R}\right)$

In both cases with increase in h and d, g decreases.

At latitude ϕ, $\quad g_\phi = g - \omega^2 R\cos^2\phi$

As ϕ increases, g_ϕ increases.

Also, we can conclude from the formulae, that it is independent of mass.

Thus, the statement given in option (b) is incorrect, rest are correct.

109 (*a*) As we know that,

$$g = \frac{GM}{R^2} \Rightarrow v_e = \sqrt{\frac{2GM}{R}}$$

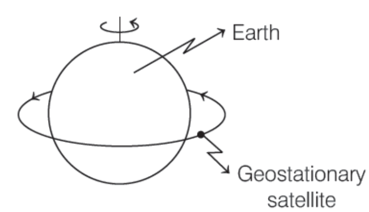
and $\quad U = \dfrac{-GMm}{R} \Rightarrow g \propto \dfrac{M}{R^2}$

$$v_e \propto \sqrt{\frac{M}{R}} \quad \text{and} \quad U \propto \frac{M}{R}$$

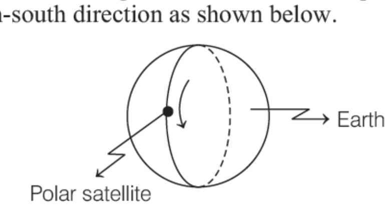
If both mass and radius are increased by 0.5%, then v_e and U remains unchanged whereas g decrease by 0.5%.

Thus, the statement given in option (a) is incorrect, rest are correct.

110 (*a*) A geo-stationary satellite is having same sense of rotation as that of earth, i.e. west-east direction as shown below



A polar satellite goes around the earth's pole in north-south direction as shown below.



Thus, the statement given in option (a) is correct, rest are incorrect.

111 (*b*) For stable orbit, plane of orbit of satellite must pass through the centre of earth.

Geo-stationary satellites are launched in the equatorial plane.

We need more than one satellite for global communication.

Orbital speed of satellite, $v_o = \sqrt{\dfrac{GM_e}{r}}$

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So, orbital speed of satellite decrease with the increase in the radius of its orbit.

Thus, the statement given in option (b) is correct, rest are incorrect.

112 (*d*) The statement given in option (d) is correct, rest are incorrect and these can be corrected as

The energy required to rocket an orbiting satellite out of earth's gravitational influence is less than the energy required to project a stationary object at the same height (as the satellite) out of earth's influence.

If the potential energy is zero at infinity, the total energy of an orbiting satellite is negative of its kinetic energy.

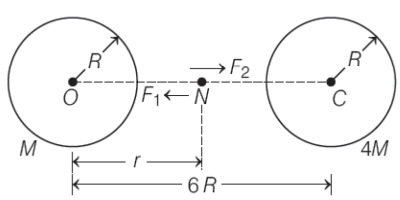
The first artificial satellite was launched by Soviet scientists in the year 1957.

113 (*c*)

A. The projectile is acted upon by two mutually opposing gravitational forces of the two spheres.

Hence, there must be a point on the line OC, where $F_{ext} = 0$, i.e. net external force due to gravitational attraction force vanishes. The point is called neutral point N. Let it be at a distance r from O.

$$\Rightarrow \quad ON = r$$



At N, $\quad F_1 = F_2$

$$\Rightarrow \quad \frac{GmM}{r^2} = \frac{Gm(4M)}{(6R - r)^2} \Rightarrow r = 2R \text{ or } -6R$$

The neutral point $r = -6R$ is not relevant.

Thus, $ON = r = 2R$.

B. To project the projectile with minimum speed from M. It is sufficient to project the particle with a speed which would enable it to reach N. After N, projectile will be attracted by 4 M.

At the neutral point, speed approaches zero,

i.e. $\quad v_N = 0$

Total energy of the particle at $N = E_N$

$$\Rightarrow \quad E_N = \text{GPE due to } M + \text{ GPE due to } 4M$$

$$E_N = \frac{-GmM}{2R} - \frac{4GMm}{4R} \quad \ldots\text{(i)}$$

$$\left[\because \text{GPE due to } M = -\frac{GmM}{2R}; r = 2R\right.$$

$$\left.\text{GPE due to } 4M = -\frac{4GMm}{4R}; r = 4R\right]$$

From the principle of conservation of mechanical energy,

$$\frac{1}{2}mv^2 - \frac{GmM}{R} - \frac{4GMm}{5R} = -\frac{GMm}{2R} - \frac{4GMm}{4R}$$

$$\Rightarrow \quad v = \sqrt{\frac{3GM}{5R}}$$

$$\Rightarrow \quad v_{min} = \sqrt{\frac{3GM}{5R}}$$

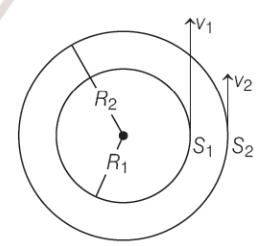
Therefore, minimum speed of the projectile with which it reaches the surface of second sphere is $\sqrt{\frac{3GM}{5R}}$.

C. Let v_f be the speed with which projectile hits the second sphere. Applying principle of conservation of energy, we get

$$\Rightarrow v_f = \sqrt{\frac{27GM}{5R}}$$

Hence, A $\rightarrow$ 2, B $\rightarrow$ 1 and C $\rightarrow$ 3.

114 (*a*) Let the mass of the planet be M, that of S_1 be m_1 and of S_2 be m_2. Let the radius of the orbit of S_1 be R_1 ($= 10^4$ km) and of S_2 be R_2. Let v_1 and v_2 be the linear speeds of S_1 and S_2 with respect to the planet. The figure shows the situation.



If the period of revolutions of satellites S_1 and S_2 are T_1 (1h) and T_2 (8h), respectively.

As the square of the time period is proportional to the cube of the radius,

$$\left(\frac{R_2}{R_1}\right)^3 = \left(\frac{T_2}{T_1}\right)^2 = \left(\frac{8\text{ h}}{1\text{ h}}\right)^2 = 64$$

$$\Rightarrow \quad \frac{R_2}{R_1} = 4 \Rightarrow R_2 = 4R_1 = 4 \times 10^4 \text{ km}$$

Now, the time-period of S_1 is 1 h. So, $\frac{2\pi R_1}{v_1} = 1$

$$\Rightarrow \text{Speed of } S_1, v_1 = \frac{2\pi R_1}{1} = 2\pi \times 10^4 \text{ km h}^{-1} \ldots\text{(i)}$$

Similarly, speed of

$$S_2, v_2 = \frac{2\pi R_2}{8} = \pi \times 10^4 \text{ kmh}^{-1} \quad \ldots\text{(ii)}$$

At the closest separation, they are moving in the same direction. Hence, the velocity of S_2 with respect to S_1 is

$$v_2 - v_1 = \pi \times 10^4 \text{ km h}^{-1} - 2\pi \times 10^4 \text{ kmh}^{-1}$$

$$= -\pi \times 10^4 \text{ km h}^{-1} \quad \ldots\text{(iii)}$$

As seen from S_1, the satellite S_2 is at a distance $R_2 - R_1 = 3 \times 10^4$ km at the closest separation. Also, it

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is moving at $\pi \times 10^4$ km h^{-1} in a direction perpendicular to the line joining them. Thus, the angular speed of S_2 as observed by S_1 is

$$\omega = \frac{v}{r} = \frac{\pi \times 10^4 \text{ km h}^{-1}}{3 \times 10^4 \text{ km}} = \frac{\pi}{3} \text{ rad h}^{-1}$$

Hence, A $\to$ 3, B $\to$ 2, C $\to$ 4 and D $\to$ 1.

115 (*a*)

A. Initially, energy of satellite $E_i = -\dfrac{GM_e m}{4R_e}$

Finally, energy of satellite, $E_f = \dfrac{-GM_e m}{8R_e}$

Change in total energy, $\Delta E = E_f - E_i$

$$= \left(-\frac{GM_e m}{8R_e}\right) - \left(-\frac{GM_e m}{4R_e}\right)$$

$$= \frac{GM_e m}{8R_e} \text{ or } \frac{gR_e m}{8} \qquad \left[\because g = \frac{GM}{R_e^2}\right]$$

Thus, $\Delta E = \dfrac{gR_e m}{8} = \dfrac{9.8 \times 400 \times 6.37 \times 10^6}{8}$

$[\because g = 9.8 \text{ ms}^2, m = 400 \text{ kg}, R = 6.37 \times 10^6$ m]

$= 3.13 \times 10^9$ J

B. The kinetic energy is reduced and change in KE is just negative of ΔE.

$\Rightarrow \quad \Delta K = K_f - K_i = -3.13 \times 10^9$ J

C. The change in potential energy is twice the change in the total energy namely,

$\Delta \text{PE} = \text{PE}_f - \text{PE}_i = -6.26 \times 10^9$ J

Hence, A $\to$ 2, B $\to$ 3 and C $\to$ 1.

116 (*b*)

A. If the velocity of satellite is v and mass m, then

$$\text{KE} = \frac{1}{2} mv^2 \qquad \text{...(i)}$$

B. Since, potential energy of the satellite
$= -2$ kinetic energy of satellite

$\Rightarrow \quad \text{PE} = -mv^2 \qquad$ ...(ii)

C. Also, total energy = KE + PE $= \dfrac{1}{2} mv^2 - mv^2$

$$= -\frac{1}{2} mv^2$$

Hence, A $\to$ 2, B $\to$ 3 and C $\to$ 1.

118 (*a*) Given, orbital period of Jupiter's satellite

$T = 1.769 \text{ days} = 1.528 \times 10^5$ s

Radius of orbit, $r = 4.22 \times 10^8$ m

$$G = 6.67 \times 10^{-11} \text{ N-m}^2/\text{kg}^2$$

Mass of the sun, $M_S = 2 \times 10^{30}$ kg

Let mass of the Jupiter be M_J.

$\because$ Centripetal force = Gravitation force

$$\frac{mv^2}{r} = \frac{GM_J m}{r^2} \text{ or } v^2 = \frac{GM_J}{r}$$

$$(r\omega)^2 = \frac{GM_J}{r} \qquad (\because v = r\omega)$$

$$\therefore \quad \omega^2 = \frac{GM_J}{r^3}$$

But $\omega = \dfrac{2\pi}{T}$, where T is the time period.

$$\therefore \quad \left(\frac{2\pi}{T}\right)^2 = \frac{GM_J}{r^3}$$

or $\quad M_J = \dfrac{4\pi^2 r^3}{T^2 G} = \dfrac{4 \times (3.14)^2 \times (4.22 \times 10^8)^3}{(1.528 \times 10^5)^2 \times 6.67 \times 10^{-11}}$

$= 1.9 \times 10^{27}$ kg $\approx 2 \times 10^{27}$ kg

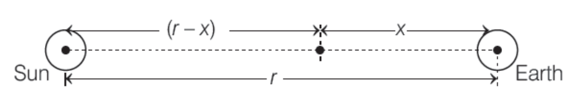
Now, $\quad \dfrac{M_J}{M_S} = \dfrac{2 \times 10^{27}}{2 \times 10^{30}} \approx \dfrac{1}{1000} \Rightarrow M_J = \dfrac{1}{1000} M_S$

119 (*d*) Since, potential energy is equal to twice the negative of kinetic energy of satellite.

Total energy of satellite = Potential energy + Kinetic energy.

$$E = V + K = -2K + K = -K$$

120 (*b*) Consider r is the distance between sun and earth and rocket is at distance x from the earth as shown below



Let gravitational force acting on the rocket be zero at a distance x from earth's centre and the mass of the rocket be m.

Gravitational force between rocket and the sun
= Gravitational force between rocket and the earth

$$\Rightarrow \quad \frac{GM_s m}{(r-x)^2} = \frac{GM_E m}{x^2} \Rightarrow \frac{M_s}{(r-x)^2} = \frac{M_E}{x^2}$$

Given, $M_s = 2 \times 10^{30}$ kg and $M_E = 6.0 \times 10^{24}$ kg

$$\Rightarrow \quad \frac{(r-x)^2}{x^2} = \frac{M_s}{M_E} = \frac{2 \times 10^{30}}{6.0 \times 10^{24}}$$

(On putting values of M_s and M_E)

$$\Rightarrow \quad \frac{(r-x)^2}{x^2} = \frac{10^6}{3}$$

Taking square root on both sides, we get

or $\quad \dfrac{r-x}{x} = \dfrac{10^3}{\sqrt{3}} \Rightarrow \dfrac{r}{x} - 1 = \dfrac{10^3 \times \sqrt{3}}{3}$

or $\quad x = \dfrac{3}{1735} \times r = \dfrac{3 \times 1.5 \times 10^{11}}{1735}$

$= 2.594 \times 10^8$ m

$x = 2.6 \times 10^8$ m

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121 (*d*) Earth year, $T_E = 1\,\text{yr}$

Saturn year, $T_S = 29.5\,\text{yr}$

Radius of earth's orbit, $R_E = 1.5 \times 10^8$ km

Radius of saturn's orbit, $R_S = ?$

According to Kepler's planetary law of period,

$$T^2 \propto R^3 \Rightarrow \frac{T_E^2}{T_S^2} = \frac{R_E^3}{R_S^3}$$

$$\left(\frac{1}{29.5}\right)^2 = \left(\frac{1.5 \times 10^8}{R_S}\right)^3$$

$$R_S^3 = (29.5)^2 \times (1.5 \times 10^8)^3$$

$$= 2.947 \times 10^{27} \text{ km}$$

$$\Rightarrow \quad R_S = 1.43 \times 10^9 \text{ km}$$

122 (*a*) Given, height, $h = \frac{R_E}{2}$

Acceleration due to gravity at altitude h is given by

$$g' = \frac{g}{\left(1 + \frac{h}{R_E}\right)^2}$$

$$= \frac{g}{\left(1 + \frac{R_E/2}{R_E}\right)^2} = \frac{g}{\left(1 + \frac{1}{2}\right)^2} = \frac{g}{(3/2)^2} = \frac{4}{9} g$$

Weight of the body at earth's surface

$$w = mg = 63 \text{ N}$$

Weight of the body at altitude $h = R_E / 2$,

$$w' = mg' = \frac{4}{9} mg = \frac{4}{9} \times 63 = 28 \text{ N}$$

123 (*c*) Let a rocket of mass m be fired vertically with a speed v and it reach at height h from earth's surface.

$$\text{KE of the rocket} = \frac{1}{2} mv^2$$

PE of the rocket at earth's surface, $V_0 = -\frac{GM_E m}{R_E}$

PE of the rocket at height h from earth's surface,

$$V_h = -\frac{GM_E m}{(R_E + h)}$$

$\therefore$ Increase in PE $(\Delta V) = V_h - V_0$

$$\Delta V = GM_E m \times \frac{h}{R_E (R_E + h)} \quad \ldots \text{(i)}$$

But $\quad GM_E = gR_E^2 \quad \ldots$ (ii)

From Eqs. (i) and (ii)

$$\therefore \quad \Delta V = \frac{gR_E^2 mh}{R_E^2 \left(1 + \frac{h}{R_E}\right)} = \frac{mgh}{\left(1 + \frac{h}{R_E}\right)}$$

According to law of conservation of energy,

KE of the rocket = Increase in PE

$$\frac{1}{2} mv^2 = \frac{mgh}{\left(1 + \frac{h}{R_E}\right)} \Rightarrow h = \left(\frac{v^2 R_E}{2gR_E - v^2}\right)$$

On putting the values, we get

$$h = 1600 \times 10^3 \text{ m} = 1.6 \times 10^6 \text{ m} = 1600 \text{ km}$$

$\therefore$ Distance from the centre of earth,

$$r = R_E + h = 6.4 \times 10^6 + 1.6 \times 10^6 = 8 \times 10^6 \text{ m}$$

124 (*a*) Initial KE of the body $= \frac{1}{2} mv^2$

Initial gravitational PE of the body $= -\frac{GM_E m}{R_E}$

At very far away from earth's surface,

KE of the body $= \frac{1}{2} mv'^2$

Gravitational PE of the body = 0

Then from conservation of energy

$$\therefore \quad \frac{1}{2} mv'^2 = \frac{1}{2} mv^2 - \frac{GM_E m}{R_E} \quad \ldots \text{(i)}$$

If v_e is the escape velocity, then

$$\frac{1}{2} mv_e^2 = \frac{GM_E m}{R_E} \quad \ldots \text{(ii)}$$

Substituting values from Eq. (ii) in Eq. (i), we get

$$\frac{1}{2} mv'^2 = \frac{1}{2} mv^2 - \frac{1}{2} mv_e^2$$

$$v'^2 = v^2 - v_e^2 = (3v_e)^2 - v_e^2 = 8v_e^2$$

$$[\because v = 3v_e]$$

$$v' = 2\sqrt{2} v_E = 2 \times 1.414 \times 11.2 \text{ kms}^{-1}$$

$$= 31.68 \text{ kms}^{-1} \simeq 31.7 \text{ kms}^{-1}$$

125 (*d*) Energy required to send a satellite out of earth's gravitational influence is called its binding energy.

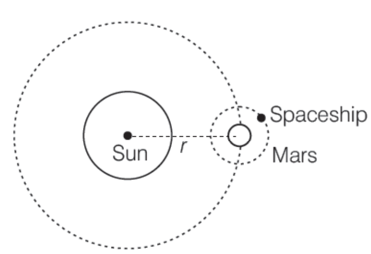
Given, mass of the satellite = 200 kg

Binding energy of a satellite $= \frac{GM_E m}{2(R_E + h)}$

$$= \frac{6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 200}{2(6.4 \times 10^6 + 0.4 \times 10^6)}$$

$$= 5.9 \times 10^9 \text{ J}$$

126 (*a*) Spaceship is present in gravitational field of the sun as well as in the gravitational field of the mars.



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Hints & Explanations

∴ Total potential energy of the spaceship due to sun as well as mars

$$= \left(\frac{-GM_s m}{r}\right) + \left(\frac{-GM_m m}{R_m}\right)$$

[where, M_s is mass of sun and M_m is mass of mars]

$$= -Gm\left[\frac{M_s}{r} + \frac{M_m}{R_m}\right]$$

Potential energy of the spaceship outside the solar system = 0

∴ Energy imparted to the spaceship to rocket it out of solar system

$$= 0 - \left[-Gm\left(\frac{M_s}{r} + \frac{M_m}{R_m}\right)\right]$$

$$= Gm\left[\frac{M_s}{r} + \frac{M_m}{R_m}\right]$$

$$= 6.67 \times 10^{-11} \times 1000\left[\frac{2 \times 10^{30}}{2.28 \times 10^{11}} + \frac{6.4 \times 10^{23}}{3.395 \times 10^{6}}\right]$$

$$\approx 3.1 \times 10^{11}\ \text{J}$$

127 (*c*) Given, speed of rocket = $2\ \text{kms}^{-1}$

As 20% of KE is lost due to martian atmospheric resistance.

∴ Total KE available $= \frac{1}{2}mv^2 \times \frac{80}{100} = \frac{2}{5}mv^2$

Let the rocket be reached at height h from the surface of mars

$$\text{Increase in PE} = \frac{GM_m m}{(R_m + h)} - \left(\frac{-GM_m m}{R_m}\right)$$

$$= GM_m m \times \frac{h}{R_m(R_m + h)}$$

$$\Rightarrow \quad GM_m m \times \frac{h}{R_m(R_m + h)} = \frac{2}{5}mv^2$$

(law of conservation of energy)

Solving it, we get

$$\frac{R_m + h}{h} = \frac{5GM_m}{2R_m v^2}$$

$$\frac{R_m}{h} + 1 = \frac{5GM_m}{R_m v^2} \Rightarrow \frac{R_m}{h} = \frac{5GM_m}{2R_m v^2} - 1$$

On putting values, we get

$$h = \frac{R_m}{6.85862} \approx 495\ \text{km}$$

128 (*d*) If the earth is considered as a sphere of different density, in that case value of g will be different at different points and cannot be zero at any point.

129 (*c*) As observed from the earth, the sun appears to move in an approximate circular orbit. As, the gravitational force of attraction between the earth and the sun always follows inverse square law. However, due to relative motion between the earth and mercury, the orbit of mercury, as observed from the earth will not be approximately circular, since the major gravitational force on mercury is due to the sun.

Hence, it revolve around sun and not around earth.

130 (*a*) As the earth is revolving around the sun in a circular motion due to gravitational attraction. The force of attraction will be of radial nature, i.e. angle between position vector **r** and force **F** is zero. So, torque $= |\tau| = |\mathbf{r} \times \mathbf{F}| = rF\sin 0° = 0$

131 (*c*) As the total energy of the earth satellite bounded system is negative $\left(\text{i.e.} \frac{-GM}{2a}\right)$, where a is radius of the satellite and M is mass of the earth. So, due to the viscous force acting on satellite, energy decreases continuously and radius of the orbit or height gradually decreases.

Therefore, debris of satellites fall to the earth.

132 (*b*) As observed from the sun, two types of forces are acting on the moon one is due to gravitational attraction between the sun and the moon and the other is due to gravitational attraction between the earth and the moon. Therefore, net force on the moon is the resultant of these two forces. Hence on observing from the sun, the orbit of the moon will not be strictly elliptical because total gravitational force on the moon is not central.

133 (*d*) Asteroids are also being acted upon by central gravitational forces, hence they are moving in circular orbits like planets and obey Kepler's laws.

134 (*d*) Gravitational mass of proton is equivalent to its inertial mass and is independent of presence of neighbouring heavy objects.

135 (*c*) Particles of masses $2M, m$ and M are respectively at points A, B and C as shown below

Force on B due to A, $F_{BA} = \frac{G(2Mm)}{(AB)^2}$ towards BA

Force on B due to C, $F_{BC} = \frac{GMm}{(BC)^2}$ towards BC

As, $BC = 2AB$

$$\Rightarrow \quad F_{BC} = \frac{GMm}{(2AB)^2} = \frac{GMm}{4(AB)^2} < F_{BA}$$

Hence, m will move towards BA, (i.e., $2M$).

136 (*d*) For small objects, say of sizes less than 100 m centre of mass is very close with the centre of gravity of the body. But when the size of object increases, its weight changes and its CM and CG become far from each other.

137 (*b*) Given, $e = 0.0167$

Ratio of maximum speed to minimum speed is

$$\frac{v_{\max}}{v_{\min}} = \frac{1+e}{1-e}$$

$$= \frac{1 + 0.0167}{1 - 0.0167} = 1.033$$

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CHAPTER › 09

Mechanical Properties of Solids

KEY NOTES

- The property of a body by virtue of which it tends to regain its original size and shape when the applied force is removed, is known as **elasticity** and the deformation caused is known as **elastic deformation**.
- Those substances which do not have a tendency to regain their shape and hence gets permanently deformed are called **plastic** and this property is called **plasticity**.

Elastic Behaviour of Solids

- In solid, each atom or molecule is surrounded by neighbouring atoms or molecules. These are bonded together by interatomic or intermolecular forces and stay in a stable equilibrium position.
- When a solid is deformed, the atoms or molecules are displaced from their equilibrium positions causing a change in interatomic or intermolecular distances.
- When the deforming force is removed, the interatomic force tend to drive them back to their original position. Thus, the body regains its original shape and size.

Stress

- When a body is subjected to a deforming force, a restoring force is developed in the body.

  The restoring force per unit cross-sectional area set-up within a body is called **stress**.

$$\text{Stress} = \frac{\text{Restoring force } (F)}{\text{Area of cross-section} (A)}$$

  Its SI unit is Nm^{-2} or Pascal (Pa) and dimensional formula of stress is $[\text{ML}^{-1}\text{T}^{-2}]$.

- Stresses are of three types as given below
  - (i) **Longitudinal Stress** When the stress is normal to the surface of object, then it is known as longitudinal stress. It is of two types
    - (a) **Tensile Stress** When an object is stretched by two equal forces applied normal to its cross-sectional area, then restoring force per unit area is called tensile stress.
    - (b) **Compressive Stress** If an object is compressed under the action of applied forces, the restoring force per unit area is known as compressive stress.
  - (ii) **Tangential or Shearing Stress** The restoring force per unit area developed due to the applied tangential force is known as tangential or shearing stress.
  - (iii) **Hydraulic or Volumetric Stress** If the equal normal forces are applied on an object all over its surfaces, then its volume changes.

    The internal restoring force per unit area in this case is known as hydraulic or volumetric stress and in magnitude is equal to the hydraulic pressure (applied force per unit area).

Strain

- When the size or shape of a body is changed under the effect of an external force, the body is said to be strained. The change occurred in the unit size of the body is called **strain**.

  i.e. $\text{Strain} = \frac{\text{Change in dimension } (\Delta x)}{\text{Original dimension} (x)}$

  It is a dimensionless quantity.

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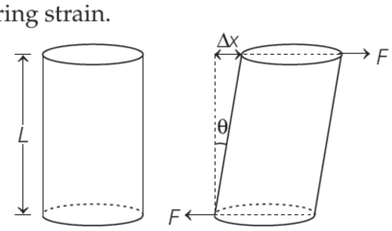
- Strains are of three types as given below
  (i) **Longitudinal Strain** The change in length ΔL to the original length L of the body is known as longitudinal strain.

  Longitudinal strain $= \dfrac{\Delta L}{L}$

  (ii) **Shearing Strain** The ratio of relative displacement of faces Δx to the length of the cylinder L is called shearing strain.



  Shearing strain $= \dfrac{\Delta x}{L} = \tan\theta$

  where, θ is the angular displacement of the cylinder from vertical. Usually θ is very small, i.e. $\tan\theta \simeq \theta$.

  (iii) **Volume Strain** The strain produced by a hydraulic pressure is called volume strain and is defined as the ratio of change in volume ΔV to the original volume V.

  i.e. Volume strain $= \dfrac{\Delta V}{V}$

Note The strain perpendicular to the applied force is known as **lateral strain**.

Hooke's Law

It states that for small deformations, the stress and strain are proportional to each other, i.e.

Stress $\propto$ Strain $\Rightarrow$ Stress $= k \times$ Strain

where, k is the proportionality constant and is known as **modulus of elasticity**.

Elastic Moduli

- The ratio of stress and strain, called **modulus of elasticity** or **elastic moduli** is found to be a characteristic of the material.

It has same units and dimensions as that of stress.

- Depending on the types of stresses and strains, there are three types of modulus of elasticity as given below
  (i) **Young's Modulus** It is the ratio of tensile (or compressive) stress σ to the longitudinal strain ε.

  So, $$Y = \frac{\sigma}{\varepsilon} = \frac{FL}{A\,\Delta L} = \frac{Mg\,L}{\pi r^2 \Delta L}$$

  where, M = mass of the body, A = area of the body,
  ΔL = change in the length due to the strain,
  g = acceleration due to gravity
  and L = length of the body.

  Metal have larger values of Young's modulus than alloys and elastomers.

  (ii) **Shear Modulus** It is the ratio of shearing stress σ_S to the corresponding shearing strain. It is also called **modulus of rigidity**.

  $\therefore \quad \eta$ or $G = \dfrac{FL}{A\Delta x} = \dfrac{F}{A\theta}$

  or $\quad \sigma_S = G \times \theta \qquad \left[\because \sigma_s = \dfrac{F}{A}\right]$

  where, θ = shearing angle.

  For most materials, $Y > G$ and mostly $G \approx Y/3$.

  The Young's modulus and shear modulus are relevant only for solids, since only solids have lengths and shape.

  (iii) **Bulk modulus** (B) It is the ratio of hydraulic stress to the corresponding hydraulic strain.

  $$\therefore \quad B = \frac{-\Delta p}{\left(\dfrac{\Delta V}{V}\right)}$$

  $$\text{or} \quad B = \frac{-\Delta pV}{\Delta V}$$

  where, Δp = change in pressure
  and ΔV = change in volume.

The negative sign indicates the fact that with increase in pressure, a decrease in volume occurs.

The reciprocal of the bulk modulus is called **compressibility**. It is defined as the fractional change in volume per unit increase in pressure.

Compressibility, $K = \dfrac{1}{B} = \dfrac{-\Delta V}{V\Delta p}$

Bulk modulus is relevant for solids, liquids and gases.

Bulk moduli for solids are much larger than for liquids, which are again much larger than the bulk modulus for gases (air).

Poisson's Ratio

- Within the elastic limit, the ratio of the lateral strain to the longitudinal strain in a stretched wire is called Poisson's ratio.

  $$\text{Poisson's ratio, } \sigma = \frac{\text{Lateral contraction strain}}{\text{Longitudinal elongation strain}} = \frac{\Delta d / D}{\Delta l / l}$$

  where, Δd = change in diameter, D = original diameter, Δl = change in length and l = original length.

- It is a pure number and has no dimensions or units. Its value depends only on the nature of material.

  For steels, its value is between 0.28 and 0.30 and for aluminium alloys, it is about 0.33.

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- Relations among Young's modulus Y, bulk modulus B, shear modulus G and Poisson's ratio σ are given as

  (i) $Y = 2G(1+\sigma)$ (ii) $\frac{9}{Y} = \frac{3}{G} + \frac{1}{B}$

  (iii) $\sigma = \frac{3B - 2G}{2(G + 3B)}$

Elastic Potential Energy in a Stretched Wire

- When a wire is put under a tensile stress, work is done against the interatomic forces. This work is stored in the wire in the form of **elastic potential energy**.

  Elastic potential energy in a stretched wire

  $= \frac{1}{2} \times \text{Young's modulus} \times (\text{Strain})^2 \times \text{Volume of the wire}$

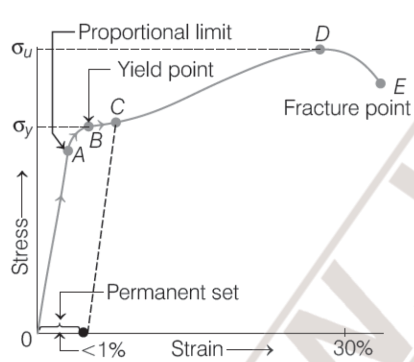
  $= \frac{1}{2} \times \text{Stress} \times \text{Strain} \times \text{Volume of the wire}$

- Elastic potential energy per unit volume,

  $U = \frac{1}{2} \times \text{Stress } (\sigma) \times \text{Strain } (\varepsilon) = \frac{1}{2}\sigma\varepsilon$

Stress-Strain Curve

- When a wire is stretched by an applied force, then a typical graph is obtained (especially in case of metals) as shown below



(i) Stress is found to be proportional to strain upto point A. Thus, Hooke's law is fully obeyed in this region, hence the point A is known as **point of proportional limit**.

Hooke's law is valid only in the linear part of stress-strain curve.

(ii) In the region from A to B, stress and strain are not proportional. Nevertheless, the body still returns to its original dimension when the load is removed.

The point B is known as **yield point** or **elastic limit** and the corresponding stress is known as **yield strength** σ_y of the material.

(iii) If the load is increased further, the stress developed exceeds the yield strength and strain increases rapidly even for small change in the stress.

When the load is removed, say at some point C between B and D, the body does not regain its original dimension.

In this case, even when the stress is zero and the strain is non-zero, then the material is said to have a **permanent set**. The deformation is said to be **plastic deformation**.

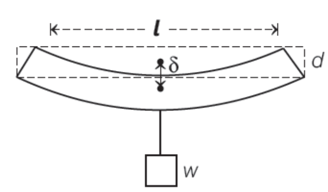
(iv) The point D on the graph is **ultimate tensile strength** or **breaking stress** of material. Beyond this point, additional strain is produced even by reduced applied force and fracture occurs at point E.

- The stress-strain behaviour varies from material to material, e.g. rubber can be pulled to several times its original length and still returns to its original shape.
- The material for which ultimate strength and fracture points D and E are close, called **brittle material**.
- The material for which ultimate strength and fracture points D and E are far apart, called **ductile material**.
- Substances which can be stretched to cause large strains are called **elastomers.**

Applications of Elastic Behaviour of Materials

- If a beam is fixed at its ends and loaded with weight at its middle (as shown below), then depression at the centre,

$$\delta = \frac{wl^3}{4bd^3 Y}$$



where, Y = Young's modulus, w = weight of beam,
l = length of beam, b = breadth of beam
and d = thickness of beam.

- To reduce the bending for a given load, one should use a material with a large Young's modulus Y.

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Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Elastic Behaviour of Materials, Stress and Strain*

1 Elasticity is the property of the body, in which
(a) it does not regain its original size
(b) it regain its original size and shape
(c) its shape changed but size remains same
(d) None of the above

2 Elasticity is shown by materials because interatomic or intermolecular force is
(a) increases when a body is deformed
(b) decreases when a body is deformed
(c) remains same when a body is deformed
(d) becomes non-zero when a body is deformed

3 A uniform bar of square cross-section is lying along a frictionless horizontal surface. A horizontal force is applied to pull it from one of its ends, then
(a) the bar is under same stress throughout its length
(b) the bar is not under any stress because force has been applied only at one end
(c) the bar simply moves without any stress in it
(d) the stress developed gradually reduces to zero at the end of the bar where no force is applied

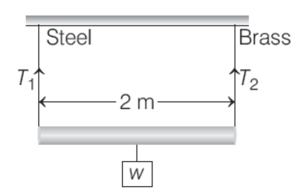
4 A and B are two wires and the radius of A is twice that of B. They are stretched by the same load, then the stress on B is
(a) equal to that on A (b) four times that on A
(c) two times that on A (d) half that on A

5 A steel wire having a radius of 2.0 mm, carrying a load of 4 kg, is hanging from a ceiling. Given that $g = 3.1\pi \text{ ms}^{-2}$, what will be the tensile stress that would be developed in the wire? ***JEE Main 2019***
(a) $6.2\times10^6 \text{Nm}^{-2}$ (b) $5.2\times10^6 \text{Nm}^{-2}$
(c) $3.1\times10^6 \text{Nm}^{-2}$ (d) $4.8\times10^6 \text{Nm}^{-2}$

6. On suspending a weight Mg, the length l of elastic wire having area of cross-section A, becomes double the initial length. The instantaneous stress action on the wire is
(a) Mg/A (b) $Mg/2A$
(c) $2Mg/A$ (d) $4Mg/A$

7. One end of a uniform wire of length L and of weight w is attached rigidly to a point in the roof and a weight w_1 is suspended from its lower end. If S is the area of cross-section of the wire, the stress in the wire at a height $3L/4$ from its lower end is
(a) $\frac{w_1}{S}$ (b) $\frac{w_1 + (w/4)}{S}$
(c) $\frac{w_1 + (3w/4)}{S}$ (d) $\frac{w_1 + w}{S}$

8 A 2 m long rod is suspended with the help of two wires of equal length. One wire is of steel & its cross-sectional area is 0.1 cm^2 and another wire is of brass & its cross-sectional area is 0.2 cm^2. If a load w is suspended from the rod and stress produced in both the wires is same, then the ratio of tensions in them will be



(a) depend on the position of W
(b) $T_1/T_2 = 2$
(c) $T_1/T_2 = 1$
(d) $T_1/T_2 = 0.5$

9 A wire is stretched to double of its length. The strain is
(a) 2 (b) 1 (c) zero (d) 0.5

10 The length of a wire increases by 1% by a load of 2 kg-wt. The linear strain produced in the wire will be
(a) 0.02 (b) 0.001 (c) 0.01 (d) 0.002

11 A cube of aluminium of side 0.1 m is subjected to a shearing force of 100 N. The top face of the cube is displaced through 0.02 cm with respect to the bottom face. The shearing strain would be
(a) 0.02 (b) 0.1 (c) 0.005 (d) 0.002

12 A uniform cube is subjected to volume compression. If each side is decreased by 1%, then bulk strain is
(a) 0.01 (b) 0.06
(c) 0.02 (d) 0.03

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TOPIC 2 ~ *Hooke's Law and Elastic Moduli*

13 While studying the relationship between stress and strain in an experiment, it has been observed that the ratio of stress to strain is a constant quantity (for a particular material), this constant is usually referred as

(a) Poisson's ratio (b) Reynold number
(c) Modulus of elasticity (d) Force

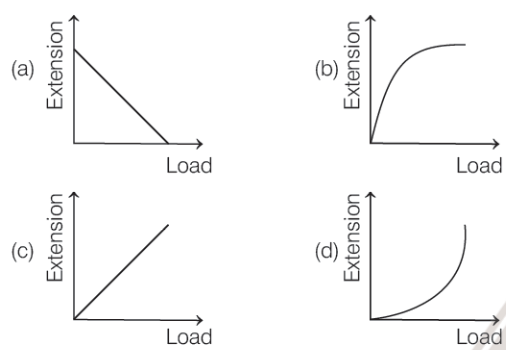
14 If F force is applied to a body, with in elastic limit, then it is proportional to (where, x is extension produced in body)

(a) $1/x$ (b) $1/x^2$ (c) x (d) x^2

15 If stress on a body is increased, then as per Hooke's law of elasticity, the ratio of stress to strain is

(a) increases (b) decreases
(c) becomes zero (d) remain constant

16 Within the limit of elasticity, which of the following graph obey Hooke's law?



17 A copper and a steel wire of the same diameter are connected end to end. A deforming force F is applied to this composite wire which causes a total elongation of 1 cm. The two wires will have

(a) the same stress and strain
(b) the same stress but different strain
(c) the same strain but different stress
(d) different strains and stress

18 On applying a stress of 20×10^8 Nm^{-2}, the length of a perfectly elastic wire is doubled. Its Young's modulus will be

(a) 40×10^8 Nm^{-2} (b) 20×10^8 Nm^{-2}
(c) 10×10^8 Nm^{-2} (d) 5×10^8 Nm^{-2}

19 A wire of length 2 m is made from 10 cm^3 of copper. A force F is applied so that its length increases by 2 mm. Another wire of length 8 m is made from the same volume of copper. If the force F is applied to it, its length will increase by

(a) 0.8 cm (b) 1.6 cm (c) 2.4 cm (d) 3.2 cm

20 The diameter of a brass rod is 4 mm and Young's modulus of brass is 9×10^{10} Nm^{-2}. The force required to stretch by 0.1% of its length, is

(a) 360πN (b) 36 N
(c) $144\pi \times 10^3$ N (d) $36\pi \times 10^5$ N

21 The following four wires of length L and radius r are made of the same material. When they are under same tension, the largest extension is produced in

(a) $L = 200$ cm, $r = 0.5$ mm (b) $L = 150$ cm, $r = 0.3$ mm
(c) $L = 250$ cm, $r = 0.1$ mm (d) $L = 400$ cm, $r = 0.2$ mm

22 A wire of length L and area of cross-section A is stretched by a load. The elongation produced in the wire is l. If Y be the Young's modulus of the material of the wire, then force constant of the wire is

(a) $\frac{YL}{A}$ (b) $\frac{YA}{L}$ (c) $\frac{YA}{l}$ (d) $\frac{Yl}{A}$

23 One end of a nylon rope of length 4.5 m and diameter 6 mm is fixed to a free limb. A monkey weighing 100 N jumps to catch the free end and stay there. Find the elongation of the rope (given, Young's modulus of nylon $= 4.8 \times 10^{11}$ Nm^{-2} and Poisson's ratio of nylon $= 0.2$).

(a) 0.332 μm (b) 0.521 μm
(c) 0.285 μm (d) 0.712 μm

24 Two wires of same material having radius in ratio 2 : 1 and lengths in ratio 1 : 2. If same force is applied on them, then ratio of their change in length will be

JIPMER 2019

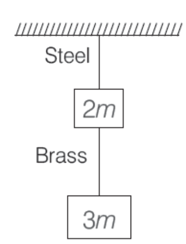
(a) 1 : 1 (b) 1 : 2
(c) 1 : 4 (d) 1 : 8

25 Two wires are made of the same material and have the same volume. The first wire has cross-sectional area A and the second wire has cross-sectional area $3A$. If the length of the first wire is increased by Δl on applying a force F, how much force is needed to stretch the second wire by the same amount?

NEET 2018

(a) $4F$ (b) $6F$ (c) $9F$ (d) F

26 If the ratio of diameters, lengths and Young's moduli of steel and brass wires shown in the figure are p, q and r, respectively. Then, the corresponding ratio of increase in their lengths would be



(a) $\frac{3q}{5p^2r}$ (b) $\frac{5q}{3p^2r}$ (c) $\frac{3q}{5pr}$ (d) $\frac{5q}{3pr}$

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27 The Young's modulus of steel is twice that of brass. Two wires of same length and of same area of cross-section, one of steel and another of brass are suspended from the same roof. If we want the lower ends of the wires to be at the same level, then the weight added to the steel and brass wires must be in the ratio of *CBSE AIPMT 2015*

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

28 Young's moduli of two wires A and B are in the ratio 7 : 4. Wire A is 2 m long and has radius R. Wire B is 1.5 m long and has radius 2 mm. If the two wires stretch by the same length for a given load, then the value of R is close to *JEE Main 2019*

(a) 1.3 mm (b) 1.5 mm
(c) 1.9 mm (d) 1.7 mm

29 A stone of mass m is tied to one end of a wire of length L. The diameter of the wire is D and it is suspended vertically. The stone is now rotated in a horizontal plane and makes an angle θ with the vertical. If Young's modulus of the wire is Y, then the increase in the length of the wire is

(a) $\frac{4mgL}{\pi D^2 Y}$ (b) $\frac{4mgL}{\pi D^2 Y \sin\theta}$
(c) $\frac{4mgL}{\pi D^2 Y \cos\theta}$ (d) $\frac{4mgL}{\pi D^2 Y \tan\theta}$

30 One end of a horizontal thick copper wire of length $2L$ and radius $2R$ is welded to an end of another horizontal thin copper wire of length L and radius R. When the arrangement is stretched by applying forces at two ends, the ratio of the elongation in the thin wire to that in the thick wire is

(a) 0.25 (b) 0.50 (c) 2 (d) 4

31 At 40°C, a brass wire of 1 mm radius is hung from the ceiling. A small mass M is hung from the free end of the wire. When the wire is cooled down from 40°C to 20°C, it regains its original length of 0.2 m. The value of M is close to

[Coefficient of linear expansion and Young's modulus of brass are 10^{-5}/°C and 10^{11} N/m^2 respectively, $g = 10$ ms^{-2}] *JEE Main 2019*

(a) 9 kg (b) 0.5 kg
(c) 1.5 kg (d) 0.9 kg

32 A boy's catapult is made of rubber cord which is 42 cm long, with 6 mm diameter of cross-section and of negligible mass. The boy keeps a stone weighing 0.02 kg on it and stretches the cord by 20 cm by applying a constant force. When released the stone flies off with a velocity of 20 ms^{-1}. Neglect the change in the area of cross-section of the cord while stretched. The Young's modulus of rubber is closest to *JEE Main 2019*

(a) 10^6 Nm^{-2} (b) 10^4 Nm^{-2}
(c) 10^8 Nm^{-2} (d) 10^3 Nm^{-2}

33 The upper end of a wire of radius 4 mm and length 100 cm is clamped and its other end is twisted through an angle of 30°. Then, angle of shear is

(a) 12° (b) 0.12° (c) 1.2° (d) 0.012°

34 For a perfectly rigid body,

(a) Young's modulus is infinite and bulk modulus is zero
(b) Young's modulus is zero and bulk modulus is infinite
(c) Young's modulus is infinite and bulk modulus is also infinite
(d) Young's modulus is zero and bulk modulus is also zero

35 When a pressure of 100 atmosphere is applied on a spherical ball of rubber, then its volume reduces to 0.01%. The bulk modulus of the material of the rubber in dyne cm^{-2} is

(a) 10×10^{12} (b) 100×10^{12}
(c) 1×10^{12} (d) 20×10^{12}

36 A solid sphere of radius R made of a material of bulk modulus B is surrounded by a liquid in a cylindrical container. A massless piston of area A floats on the surface of the liquid. When a mass M is placed on the piston to compress the liquid, the fractional change in the radius of the sphere $\frac{\delta R}{R}$ is *JEE Main 2018*

(a) $\frac{Mg}{BA}$ (b) $\frac{Mg}{2BA}$ (c) $\frac{Mg}{3BA}$ (d) $\frac{Mg}{4BA}$

37 If compressibility of material is 4×10^{-5} per atm, pressure is 100 atm and volume is 100 cm^3, then find ΔV. *JIPMER 2018*

(a) 0.4 cm^3 (b) 0.8 cm^3 (c) 0.6 cm^3 (d) 0.2 cm^3

38 The approximate depth of an ocean is 2700 m. The compressibility of water is 45.4×10^{-11} Pa^{-1} and density of water is 10^3 kg/m^3. What fractional compression of water will be obtained at the bottom of the ocean? *CBSE AIPMT 2015*

(a) 0.8×10^{-2} (b) 1.0×10^{-2}
(c) 1.2×10^{-2} (d) 1.4×10^{-2}

39 If the volume of a wire remains constant when subjected to tensile stress, the value of Poisson's ratio of the material of the wire is

(a) 0.1 (b) 0.2
(c) 0.4 (d) 0.5

40 A material has Poisson's ratio 0.5. If a uniform rod suffers a longitudinal strain of 2×10^{-3}, then the percentage change in volume is

(a) 0.6 (b) 0.4
(d) 0.2 (d) zero

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41 The Poisson's ratio of a material is 0.4. If a force is applied to a wire of this material, there is a decrease of cross-sectional area is 2%. The percentage increase in its length is

(a) 3% (b) 2.5% (c) 1% (d) 0.5%

42 A uniform cylindrical rod of length L and radius r, is made from a material whose Young's modulus of elasticity equals Y. When this rod is heated by temperature T and simultaneously subjected to a net longitudinal compressional force F, its length remains unchanged. The coefficient of volume expansion of the material of the rod, is (nearly) equal to **JEE Main 2019**

(a) $9F/(\pi r^2 YT)$ (b) $6F/(\pi r^2 YT)$

(c) $3F/(\pi r^2 YT)$ (d) $F/(3\pi r^2 YT)$

43 Identical springs of steel and copper ($Y_{\text{steel}} > Y_{\text{copper}}$) are equally stretched. It implies,

(a) less work is done on copper spring
(b) less work is done on steel spring
(c) equal work is done on both the springs
(d) Data is incomplete

44 When the load on a wire is increased from 3 kg-wt to 5 kg-wt, the elongation increases from 0.61 mm to 1.02 mm. The required work done during the extension of the wire is

(a) 16×10^{-3} J (b) 8×10^{-2} J

(c) 20×10^{-2} J (d) 11×10^{-3} J

45 If the work done in stretching a wire by 1 mm is 2 J, the necessary work for stretching another wire of same material but with double radius of cross-section and half the length by 1 mm is

(a) 16 J (b) 8 J (c) 4 J (d) (1/4) J

46 When a block of mass M is suspended by a long wire of length L, the length of the wire becomes $(L + l)$. The elastic potential energy stored in the extended wire is **NEET 2019**

(a) MgL (b) $\frac{1}{2}Mgl$ (c) $\frac{1}{2}MgL$ (d) Mgl

47 Two wires of the same material and length but diameter in the ratio 1 : 2 are stretched by the same load. The ratio of elastic potential energy per unit volume for the two wires is

(a) 1 : 1 (b) 2 : 1 (c) 4 : 1 (d) 16 : 1

TOPIC 3 ~ *Stress-Strain Curve and Applications of Elastic Behaviour of Materials*

48 The linear portion of a stress-strain curve obeys Hooke's law. The upper limit of this linear curve represents

(a) yield point (b) permanent set

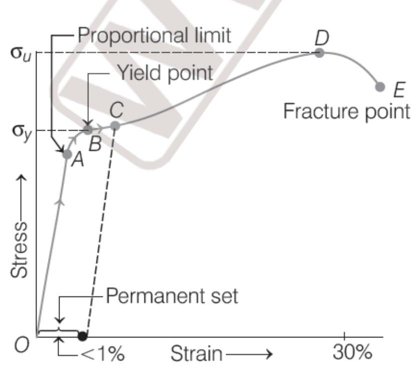
(c) fracture point (d) proportional limit

49 Within the elastic limit, the corresponding stress is known as

(a) tensile strength (b) yield strength

(c) elastic fatigue (d) yield point

50 A graph is plotted between the stress (which is equal in magnitude to the applied force per unit area) and the strain produced for a metal is shown in figure.

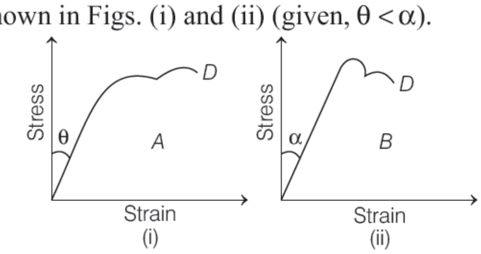


From the graph, we can see in the region from O to A, the curve is linear. In this region, Hooke's law is obeyed. Thus, from O to A, the solid body behaves as a/an

(a) elastic body (b) partially elastic body

(c) plastic body (d) inelastic body

51 The stress-strain graphs for materials A and B are shown in Figs. (i) and (ii) (given, $\theta < \alpha$).



The graphs are drawn to the same scale.

Which of the two is the stronger material?

(a) A (b) B

(c) Both A and B (d) None of these

52 Over bridges are constructed with steel but not with aluminium because steel is

(a) more elastic than aluminium
(b) less elastic than aluminium
(c) more plastic than aluminium
(d) less plastic than aluminium

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53 Two steel wires having same length are suspended from a ceiling under the same load. If the ratio of their energy stored per unit volume is 1 : 4, the ratio of their diameters is ***JEE Main 2020***

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

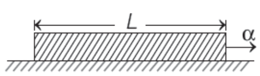
54 A wire of diameter 1 mm breaks under a tension of 1000 N. Another wire of same material as that of the first one, but of diameter 2 mm breaks under a tension of

(a) 500 N (b) 1000 N (c) 10000 N (d) 4000 N

55 In steel, the Young's modulus and the strain at the breaking point are 2×10^{11} Nm^{-2} and 0.15, respectively. The stress at the breaking point for steel is

(a) 1.33×10^{11} Nm^{-2} (b) 1.33×10^{12} Nm^{-2}
(c) 7.5×10^{-13} Nm^{-2} (d) 3×10^{10} Nm^{-2}

56 A uniform rod of length L and density ρ is being pulled along a smooth floor with a horizontal acceleration α. The magnitude of the stress at the transverse cross-section through the mid-point of the rod is ***JEE Main 2013***



(a) $L\rho\alpha$ (b) $\frac{L\rho\alpha}{2}$
(c) $\frac{2}{3}L\rho\alpha$ (d) None of these

57 The elastic limit of brass is 379 MPa. What should be the minimum diameter of a brass rod, if it is to support a 400 N load without exceeding its elastic limit? ***JEE Main 2019***

(a) 0.90 mm (b) 1.00 mm (c) 1.16 mm (d) 1.36 mm

58 A beam of length l, breadth b and depth d supported at its end is loaded at the centre by a load of weight w. If Young's modulus of beam is Y, then sagging of beam will be

(a) $\frac{wd^3}{4bl^3Y}$ (b) $\frac{wl^3}{4b^3dY}$
(c) $\frac{wl^3}{4bd^3Y}$ (d) $\frac{wb^3}{4l^3dY}$

59 A metal bar is supported at two ends. If metal bar is loaded at centre with a heavy load, the depression in bar at the centre is proportional to [Y = Young's modulus of bar]

(a) $\frac{1}{Y^2}$ (b) $\frac{1}{Y}$ (c) Y (d) Y^2

60 If the load hanging from middle position of a metal beam is increased to double, then depression in the bar at the centre is

(a) increased to four times
(b) decreased to four times
(c) increased to double
(d) decreased to half

SPECIAL TYPES QUESTIONS

I. Assertion and Reason

■ **Direction** (Q. Nos. 61-70) *In the following questions, a statement of Assertion is followed by a corresponding statement of Reason. Of the following statements, choose the correct one.*

(a) Both Assertion and Reason are correct and Reason is the correct explanation of Assertion.
(b) Both Assertion and Reason are correct but Reason is not the correct explanation of Assertion.
(c) Assertion is correct but Reason is incorrect.
(d) Assertion is incorrect but Reason is correct.

61 **Assertion** For rubber, strain is more as compared to steel.

Reason Rubber is less elastic than steel.

62 **Assertion** When a spring is loaded, then shearing stress is produced in it.

Reason Shape of spring remains unchanged under the application of tangential stress.

63 **Assertion** Spring balance shows incorrect readings after using it for a long time.

Reason Spring in the spring balance loses its elastic strength over the period of time.

64 **Assertion** When a solid sphere is placed in the fluid under high pressure, then it is compressed uniformly on all sides.

Reason The force applied by fluids acts in perpendicular direction at each point of surface.

65 **Assertion** The strain produced by a hydraulic pressure is volumetric in nature.

Reason It is a ratio of change in volume ΔV to the original volume V.

66 **Assertion** Elongation produced in a body is directly proportional to the applied force.

Reason Within the elastic limit, stress is inversely proportional to the strain.

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67 **Assertion** Young's modulus for a perfectly plastic body is zero.

Reason For a perfectly plastic body, restoring force is zero.

68 **Assertion** Gases have large compressibility.

Reason Compressibility is defined as the fractional change in volume per unit decrease in pressure.

69 **Assertion** Ropes are always made of a number of thin wires braided together.

Reason It helps to ease in manufacturing, flexibility and strength.

70 **Assertion** Maximum height of a mountain on earth is ~ 10 km.

Reason A mountain base is not under uniform compression and provides some shearing stress to rock under which it can flow.

II. Statement Based Questions

71 If a force is applied to a plastic substance, then

I. they have no gross tendency to regain their original shape.
II. permanently deformed.
III. they have tendency to regain their original shape.
IV. not permanently deformed.

Which of the following statement(s) is/are correct?

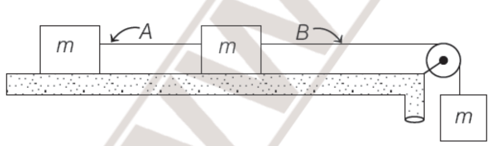
(a) Only I (b) Both I and II
(c) Only III (d) Both III and IV

72 Which of the following statement (s) is/are correct regarding to elastomers?

I. It can be elastically stretched to a large value of strain.
II. These materials do not obey Hooke's law.
III. Young's modulus of elastomers is very large.

(a) Both I and II (b) Both II and III
(c) Both I and III (d) I, II and III

73 Three blocks are connected with wires A and B of same cross-section area x and Young's modulus Y. All three blocks are of mass m each.



With reference to the given situation, which of the following statement is correct?

I. Tension in wire $A = \frac{2}{3}mg$

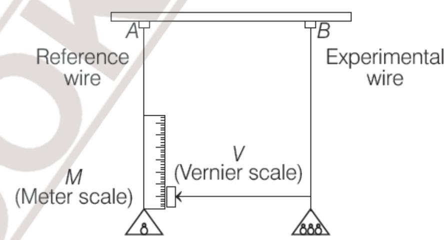
II. Tension in wire $B = \frac{2}{3}mg$

III. Stress in wire $A = \frac{2mg}{3x}$

IV. Strain in wire $B = \frac{2mg}{3xY}$

(a) Both I and II
(b) Both II and III
(c) Both III and IV
(d) Both II and IV

74 A typical experimental arrangement to determine the Young's modulus of a material of wire under tension is shown in figure. It consists of two long straight wires of same length and equal radius suspended side by side from a fixed rigid support. The wire A (called the reference wire) carries a millimeter main scale M and a pan to place a weight.



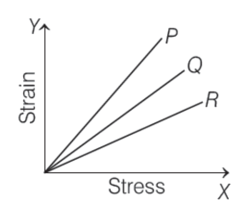
The wire B (called the experimental wire) of uniform area of cross-section also carries a pan in which known weights can be placed, vernier scale is attached to a pointer at the bottom of experimental wire B and main scale is fixed to the reference wire A.

With reference to the above description, which of the following statement is correct?

I. The elongation of the wire is measured by the vernier arrangement.
II. The reference wire is used to compensate for any change in lengths.

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

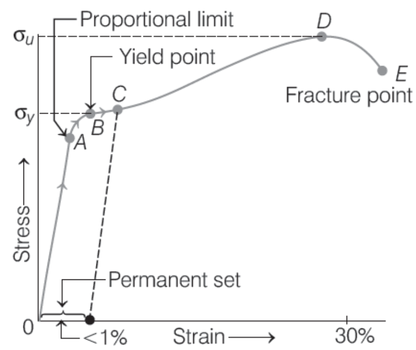
75 The stress-strain curves of three wires of different materials are shown in figure. P, Q and R are the elastic limits of the wires.



I. Elasticity of wire P is minimum.
II. Elasticity of wire Q is maximum.
III. Tensile strength of R is maximum.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both I and III
(c) Only II (d) None of these

76 

With reference to the above graph, which of the following statement is correct?

I. The point E on the graph is the ultimate tensile strength σ_u of the material.

II. If the ultimate strength and fracture points D and E are close to B, then the material is said to be brittle.

III. If points D and E are far apart, then material is said to be ductile.

(a) Only I (b) Only II (c) Both II and III (d) Only III

77 I. The use of pillars or columns is very common in building and bridges.

II. A pillar with rounded ends supports less load than that with a distributed shape at ends.

III. Building has to take into account the conditions under the cost and long period, reliability of usable materials, etc.

Which of the following statement(s) is/are correct?

(a) Only I (b) Both II and III
(c) Only III (d) I, II and III

78 Which of the following statement is incorrect?

(a) Young's modulus and shear modulus are relevant only for solids.
(b) Bulk modulus is relevant for liquids and gases.
(c) Metals have larger values of Young's modulus than elastomers.
(d) Alloys have larger values of Young's modulus than metals.

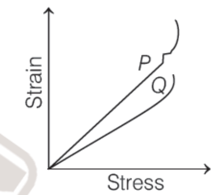
79 Which of the following statement is incorrect?

(a) The bulk modulus for solid is much larger than for liquids.
(b) Gases are least compressible.
(c) For a system in equilibrium, the value of bulk modulus is always positive.
(d) The SI unit of bulk modulus is same as that of pressure.

80 Which of the following statement is correct regarding Poisson's ratio?

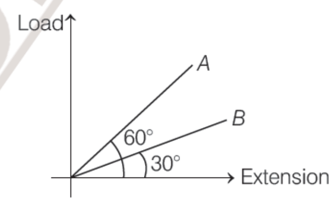
(a) It is the ratio of longitudinal strain to the lateral strain.
(b) Its value is independent of the nature of the material.
(c) It is a unitless and dimensionless quantity.
(d) The practical value of Poisson's ratio lies between 0 and 1.

81 In plotting stress *versus* strain curves for two materials P and Q, a student by mistake puts strain on the Y-axis and stress on the X-axis as shown in the figure. Then, which of the following statement(s) is/are correct?



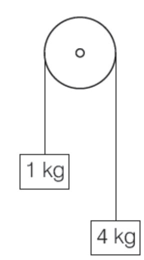
(a) P has more tensile strength than Q.
(b) P is more ductile than Q.
(c) P is more brittle than Q.
(d) The Young's modulus of P is more than that of Q.

82 Two stress-strain graphs A and B are drawn by a student (as shown below) but he forgets to specify what are the conditions for A and B. Which of the following statement shows the incorrect conditions for A and B?



(a) If A and B are made for two different wires of identical dimensions, then $Y_A : Y_B = \sqrt{3} : 1$.
(b) If A and B are made for two different wires of equal length and of same material, then wire A is more thicker than B.
(c) Extension of A is less than that of B.
(d) None of the above

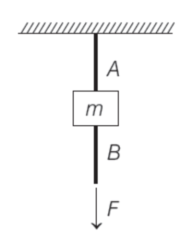
83 Two blocks are tied with a wire and are hanged over a pulley as shown. Masses of blocks are 1 kg and 4 kg and pulley is frictionless.



With reference to the above situation, which of the following is an incorrect statement?

(a) Tension in wire is 10 N.
(b) Tension in wire is 16 N.
(c) If breaking stress is 3.18×10^9 Nm^{-2}, then wire must be of 4×10^{-5} m radius so that wire does not break.
(d) None of the above

84 Wires A and B are connected with mass m as shown in figure. Wires are of same material and have radii r_A and r_B. End of B is pulled with a force of $mg/3$. With reference to the above situation, which of the following statement is correct?



(a) A breaks before B when $r_A = r_B$
(b) A breaks after B when $r_A < 2r_B$
(c) Neither A nor B will break if $r_A = 2r_B$
(d) None of the above

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85 A metal wire of length L is suspended vertically from a rigid support. When a body of mass M is attached to the lower end of wire, the elongation of the wire is l, then Which of the following statement(s) is/are incorrect?

(a) The loss of gravitational potential energy of mass m is mgl.
(b) The elastic potential energy stored in the wire is mgl.
(c) The elastic potential energy stored in the wire is $(1/2)\,mgl$.
(d) Heat produced is $\frac{1}{2}mgl$.

III. Matching Type

86 Match the Column I (stress) with Column II (characteristic) and select the correct answer from the codes given below.

Column I	Column II
A. Longitudinal stress	1. Independent of area of cross-section of wire.
B. Shear stress	2. Change in pressure
C. Breaking stress	3. Length of wire increases or decreases
D. Bulk stress	4. Shape changes

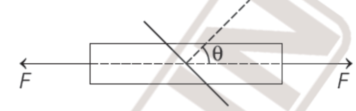
	A	B	C	D
(a)	3	4	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	1	2	3	4

87 Match the Column I (quantity) with Column II (units) and select the correct answer from the codes given below.

Column I	Column II
A. Stress × Strain	1. J
B. YA/l	2. Nm^{-1}
C. Yl^3	3. Jm^{-3}
D. Fl/AY	4. m

	A	B	C	D		A	B	C	D
(a)	3	2	1	4	(b)	2	1	3	4
(c)	3	4	1	2	(d)	1	2	4	3

88 A bar of cross-section A is subjected to equal and opposite tensile forces at its ends. Consider a plane section of the bar, whose normal makes an angle θ with the axis of the bar.



Match the Column I (stress) with Column II (value) and select the correct answer from the codes given below.

Column I	Column II
A. The tensile stress on this plane will be	1. 0
B. The shearing stress on this plane will be	2. $(F/A)\cos^2\theta$
C. The tensile strength will be maximum at $\theta =$	3. $\left(\frac{F}{2A}\right)\sin 2\theta$
D. The shearing stress will be maximum at $\theta =$	4. 45°

	A	B	C	D
(a)	3	2	4	1
(b)	2	3	1	4
(c)	2	3	4	1
(d)	3	2	1	4

89 Match the Column I (elastic moduli) with Column II (value) and select the correct answer from the codes given below.

Column I	Column II
A. Young's modulus for perfectly elastic body	1. Maximum
B. For most material, modulus of rigidity	2. Minimum
C. Bulk modulus for solid	3. $Y/3$
D. Bulk modulus for gas	4. Infinite

	A	B	C	D		A	B	C	D
(a)	4	1	2	1	(b)	4	3	1	2
(c)	1	2	4	3	(d)	3	4	1	2

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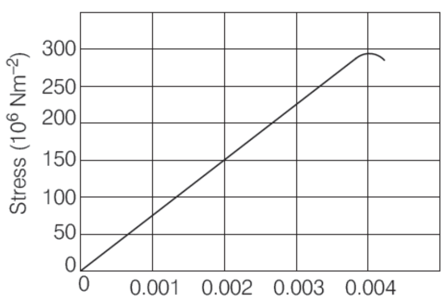
MULTIPLE CHOICE QUESTIONS

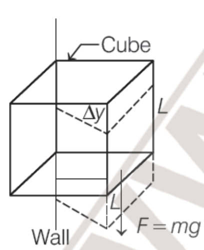
NCERT

90 Figure shows the strain-stress curve for a given material. What are (i) Young's modulus and (ii) approximate yield strength for this material?



(a) 5×10^5 Nm^{-2}, 3×10^6 Nm^{-2}
(b) 2×10^{-6} Nm^{-2}, 4×10^4 Nm^{-2}
(c) 7.5×10^{10} Nm^{-2}, 3×10^8 Nm^{-2}
(d) 7.5×10^{10} Nm^{-2}, 3×10^6 Nm^{-2}

91 The edge of an aluminium cube is 10 cm long. One face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is then attached to the opposite face of the cube. The shear modulus of aluminium is 25 GPa. What is the vertical deflection of this face?

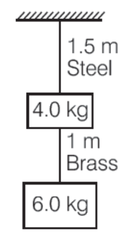


(a) 4.8×10^{-5} m (b) 6.2×10^{-3} m
(c) 3.92×10^{-7} m (d) 5×10^{-5} m

92 A rigid bar of mass 15 kg is supported symmetrically by three wires each 2 m long. These at each end are of copper and middle one is of iron. Determine the ratio of their diameters, if each is to have the same tension. Young's modulus of elasticity for copper and steel are 110×10^9 Nm^{-2} and 190×10^9 Nm^{-2}, respectively.

(a) 1.31 : 1 (b) 2.4 : 5
(c) 1.2 : 3 (d) 3.2 : 1

93 Two wires of diameter 0.25 cm, one made of steel and other made of brass are loaded as shown in figure. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. Young's modulus of steel is 2.0×10^{11} Pa. The elongations of steel and brass wires respectively are (1 Pa = 1 Nm^{-2}).



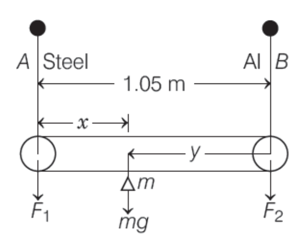
(a) 1.3×10^{-4} m, 1.5×10^{-4} m (b) 1.5×10^{-4} m, 1.3×10^{-4} m
(c) 2.4×10^{-5} m, 1.5×10^{-4} m (d) 3.5×10^{-6} m, 1.3×10^{-4} m

94 The Marina trench is located in the pacific ocean and at one place, it is nearly 11 km beneath the surface of water. The water pressure at the bottom of the trench is about 1.1×10^8 Pa. A steel ball of initial volume 0.32 m^3 is dropped into the ocean and falls to the bottom of trench. What is the change in the volume of the ball when it reaches to the bottom?

(a) 2.2×10^{-4} m^3 (b) 6.2×10^{-4} m^3
(c) 4×10^{-2} m^3 (d) 10^{-4} m^3

95 A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminium (wire B) of equal lengths as shown in figure. The cross-sectional areas of wires A and B are 1 mm^2 and 2 mm^2, respectively.

At what point from A, along the rod should a mass to be suspended in order to produce equal stress in both steel and aluminium wires?



(a) 0.50 m (b) 0.95 m
(c) 0.70 m (d) 0.32 m

96 Anvils made of single crystals of diamond, with the shape as shown in figure, are used to investigate the behaviour of materials under very high pressures. Flat faces at the narrow end of the anvil have a diameter of 0.5 mm and the wide ends are subjected to a compressional force of 50000 N.

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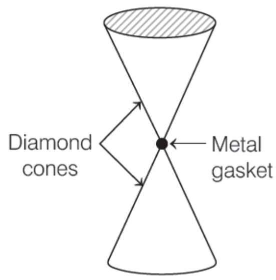
What is the pressure at the tip of anvil?



(a) 2.5×10^9 Pa (b) 7×10^5 Pa
(c) 2.5×10^{11} Pa (d) 4×10^6 Pa

97 The fractional change in volume of glass slab, when subjected to a hydraulic pressure of 10 atm, will be
(a) 4×10^{-4} (b) 2.74×10^{-5}
(c) 3×10^{-2} (d) 7×10^{-4}

98 A 14.5 kg mass, fastened to one end of a steel wire of unstretched length 1 m is whirled in a vertical circle with an angular frequency of 2 revs^{-1} at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm^2. The elongation of the wire when the mass is at the lowest point of its path will be
(a) 1.87 mm (b) 2.4 mm
(c) 6.7 mm (d) 9.2 mm

99 A steel wire of length 4.7 m and cross-sectional area $3.0\times 10^{-5}\text{ m}^2$ stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area $4.0\times 10^{-5}\text{ m}^2$ under a given load. What is the ratio of the Young's modulus of steel to that of copper?
(a) 1.2 (b) 1.8
(c) 3.2 (d) 4.6

100 What is the density of water at a depth where pressure is 80.0 atm? Given that its density at the surface is $1.03\times 10^3\text{ kg m}^{-3}$, the compressibility of water is $45.8\times 10^{-11}\text{ Pa}^{-1}$.
(a) $1.034\times 10^2\text{ kg m}^{-3}$ (b) $1.034\times 10^6\text{ kg m}^{-3}$
(c) $1.034\times 10^3\text{ kg m}^{-3}$ (d) $2.42\times 10^5\text{ kg m}^{-3}$

101 Compute the bulk modulus of water from the following data.
Initial volume = 100 L, pressure increase = 100 atm ($1\text{ atm} = 1.013\times 10^5$ Pa),
Final volume = 100.5 L. The ratio of the bulk modulus of water with that of air is
(a) 4×10^9 (b) 2.026×10^4
(c) 2.026×10^9 (d) 1×10^5

102 Four identical hollow cylindrical columns of mild steel support a big structure of mass 50000 kg. The inner and outer radii of each column are 30 cm and 60 cm, respectively. Assuming the load distribution to be uniform, calculate the compressional strain of each column. Young's modulus, $Y = 2.0\times 10^{11}$ Pa.
(a) 4×10^{-6} (b) 9×10^{-3}
(c) 8.2×10^{-4} (d) 7.22×10^{-7}

103 Two strips of metal are riveted together at their ends by four rivets, each of diameter 6 mm. What is the maximum tension that can be exerted by the riveted strip, if the shearing stress on the rivet is not to exceed 6.9×10^7 Pa? Assume that each rivet is to carry one-quarter of the load.
(a) 9×10^2 N (b) 1.23×10^2 N
(c) 7.8×10^3 N (d) 8×10^2 N

104 How much should the pressure on a litre of water be changed to compress it by 0.10%? Bulk modulus of elasticity of water is $2.2\times 10^9\text{ Nm}^{-2}$.
(a) $2.4\times 10^3\text{ Nm}^{-2}$ (b) $2.2\times 10^6\text{ Nm}^{-2}$
(c) $4\times 10^4\text{ Nm}^{-2}$ (d) $6\times 10^5\text{ Nm}^{-2}$

105 What is the volume of contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 7×10^6 Pa?
B for copper = 140×10^9 Pa.
(a) $5\times 10^{-6}\text{ m}^3$ (b) $5\times 10^{-8}\text{ m}^3$
(c) $9\times 10^{-4}\text{ m}^3$ (d) $3\times 10^{-6}\text{ m}^3$

106 A steel cable with a radius of 1.5 cm supports a chair lift. If the maximum stress is not to exceed 10^8 Nm^{-2}, what is the maximum load that cable can support?
(a) 9×10^3 N (b) 7×10^3 N
(c) 7.1×10^4 N (d) 4×10^6 N

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107 Modulus of rigidity of ideal liquid is
(a) infinity
(b) zero
(c) unity
(d) some finite small non-zero constant value

108 The maximum load, a wire can withstand without breaking, when its length is reduced to half of its original length, will
(a) be double (b) be half
(c) be four times (d) remain same

109 A spring is stretched by applying a load to its free end. The strain produced in the spring is
(a) volumetric (b) shear
(c) longitudinal and shear (d) longitudinal

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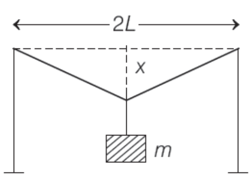
110 A rigid bar of mass M is supported symmetrically by three wires each of length l. Those at each end are of copper and the middle one is of iron. The ratio of their diameters, if each is to have the same tension, is equal to

(a) $\frac{Y_{copper}}{Y_{iron}}$ (b) $\sqrt{\frac{Y_{iron}}{Y_{copper}}}$

(c) $\frac{Y^2_{iron}}{Y^2_{copper}}$ (d) $\frac{Y_{iron}}{Y_{copper}}$

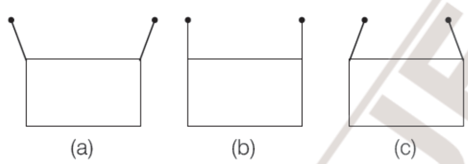
111 A mild steel wire of length $2L$ and cross-sectional area A is stretched, well within elastic limit, horizontally between two pillars (figure). A mass m is suspended from the mid-point of the wire, strain in the wire is



(a) $\frac{x^2}{2L^2}$ (b) $\frac{x}{L}$

(c) x^2 / L (d) $x^2 / 2L$

112 A rectangular frame is to be suspended symmetrically by two strings of equal length on two supports (figure). It can be done in one of the following three ways.



The tension in the strings will be

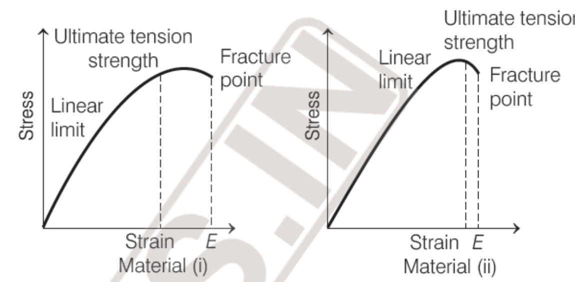
(a) same in all cases (b) least in (a)

(c) least in (b) (d) least in (c)

113 Consider two cylindrical rods of identical dimensions, one of rubber and the other of steel. Both the rods are fixed rigidly at one end to the roof. A mass M is attached to each of at the centre of the rods. Then,

(a) both the rods will elongate but there shall be no perceptible change in shape
(b) the steel rod will elongate and change shape but the rubber rod will only elongate
(c) only rubber rod will elongate
(d) the steel rod will elongate, without any perceptible change in shape, but the rubber rod will elongate with the shape of the bottom edge tappered to a tip at the centre

114 The stress-strain graphs for two materials are shown in figure, then (assume same scale)

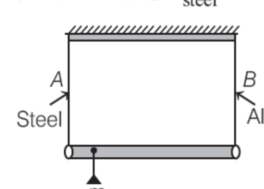


(a) material (ii) is more elastic than material (i) and hence material (ii) is more ductile
(b) material (i) and (ii) have the same elasticity and the same brittleness
(c) material (ii) is elastic over a larger region of strain as compared to (i)
(d) material (ii) is less brittle than material (i)

115 A wire is suspended from the ceiling and stretched under the action of a weight F suspended from its other end. The force exerted by the ceiling on it is equal and opposite to the weight, then

(a) tensile stress at any cross-section A of the wire is $\frac{F}{2A}$
(b) tensile stress at any cross-section is zero
(c) tensile stress at any cross-section A of the wire is $2F/A$
(d) tension at any cross-section A of the wire is F

116 A rod of length l and negligible mass is suspended at its two ends by two wires of steel (wire A) and aluminium (wire B) of equal length (figure). The cross-sectional areas of wires A and B are 1.0 mm^2 and 2.0 mm^2, respectively. Then,
($Y_{Al} = 70 \times 10^9 \, Nm^{-2}$ and $Y_{steel} = 200 \times 10^9 \, Nm^{-2}$)



(a) Mass m should be suspended close to wire A to have equal stresses in both the wires
(b) Mass m should be suspended close to B to have equal stresses in both the wires
(c) Mass m should be suspended at the middle of the wires to have equal stresses in both the wires
(d) Mass m should be suspended close to wire B to have equal strain in both wires

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117 A copper and a steel wire of the same diameter are connected end to end. A deforming force F is applied to this composite wire which causes a total elongation of 1 cm. The two wires will have

(a) the same stress (b) the different stress
(c) the same strain (d) None of these

118 A wire of length L and radius r is rigidly fixed at one end. On stretching the other end of the wire with a force F, the increase in its length is l. If another wire of same material but of length $2L$ and radius $2r$ is stretched with a force of $2F$, the increase in its length will be

(a) l (b) $2l$
(c) $l/2$ (d) $l/4$

119 Two identical solid balls, one of ivory and the other of wet clay are dropped from the same height on the floor. After striking the floor,

(a) ivory ball will rise to a greater height than wet clay ball
(b) ivory ball will rise to a lesser height than wet clay ball
(c) both balls will rise to the same height
(d) Data is insufficient

120 To what depth must a rubber ball be taken in deep sea so that its volume is decreased by 0.1%?
(Take, density of sea water $=10^3$ kgm^{-3}, bulk modulus of rubber $=9\times10^8$ Nm^{-2}, $g=10$ ms^{-2})

(a) 9 m (b) 18 m
(c) 90 m (d) 180 m

Answers

> Mastering NCERT with MCQs

1 (b)	2 (d)	3 (d)	4 (b)	5 (c)	6 (d)	7 (c)	8 (d)	9 (b)	10 (c)
11 (d)	12 (d)	13 (c)	14 (c)	15 (d)	16 (c)	17 (b)	18 (b)	19 (d)	20 (a)
21 (c)	22 (b)	23 (a)	24 (d)	25 (c)	26 (b)	27 (b)	28 (d)	29 (c)	30 (c)
31 (a)	32 (a)	33 (b)	34 (c)	35 (c)	36 (c)	37 (a)	38 (c)	39 (d)	40 (d)
41 (b)	42 (c)	43 (b)	44 (a)	45 (a)	46 (b)	47 (d)	48 (d)	49 (b)	50 (a)
51 (b)	52 (a)	53 (a)	54 (d)	55 (d)	56 (b)	57 (c)	58 (c)	59 (b)	60 (c)

> Special Types Questions

61 (a)	62 (c)	63 (a)	64 (a)	65 (b)	66 (c)	67 (a)	68 (a)	69 (a)	70 (a)
71 (b)	72 (a)	73 (d)	74 (c)	75 (b)	76 (c)	77 (d)	78 (d)	79 (b)	80 (c)
81 (b)	82 (a)	83 (a)	84 (a)	85 (b)	86 (c)	87 (a)	88 (b)	89 (b)	

> NCERT & NCERT Exemplar MCQs

90 (c)	91 (c)	92 (a)	93 (b)	94 (a)	95 (c)	96 (c)	97 (b)	98 (a)	99 (b)
100 (c)	101 (b)	102 (d)	103 (c)	104 (b)	105 (b)	106 (c)	107 (b)	108 (d)	109 (c)
110 (b)	111 (a)	112 (c)	113 (d)	114 (c)	115 (d)	116 (b)	117 (a)	118 (a)	119 (a)
120 (c)									

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Hints & Explanations

3 (*d*) When a horizontal force is applied on uniform bar to pull it, then an acceleration is produced in the each cross-section of rod. Hence, each section of rod experiences a tension which is zero at other end. Therefore, stress in the rod developed gradually reduces to zero at the end of the bar where no force is applied.

4 (*b*) If radius for wires A and B are r_A and r_B, then

$$r_A = 2r_B \quad \text{(given)}$$

Now, $$\text{Stress} = \frac{\text{Force}}{\text{Area}} = \frac{F}{\pi r^2}$$

$\therefore$ $$\text{Stress} \propto \frac{1}{r^2}$$

Then, ratio of stress for wire A and B is

$$\frac{(\text{Stress})_B}{(\text{Stress})_A} = \left(\frac{r_A}{r_B}\right)^2 = (2)^2$$

$\Rightarrow$ $$(\text{Stress})_B = 4 \times (\text{Stress})_A \quad (\text{as, } F = \text{constant})$$

Thus, stress in B is four times that on stress in A.

5 (*c*) Given, radius of wire, $r = 2\text{ mm} = 2 \times 10^{-3}$ m, weight of load, $m = 4$ kg and $g = 3.1\,\pi\text{ ms}^{-2}$

$$\therefore \quad \text{Tensile stress} = \frac{\text{Force }(F)}{\text{Area }(A)} = \frac{mg}{\pi r^2}$$

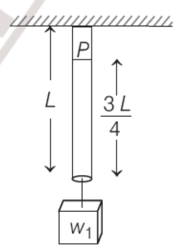
$$= \frac{4 \times 3.1 \times \pi}{\pi \times (2 \times 10^{-3})^2}$$

$$= 3.1 \times 10^6\text{ Nm}^{-2}$$

6 (*c*) When the length of wire becomes doubled, its area of cross-section will become half because volume of wire is constant ($V = AL$).

So, the instantaneous stress $= \dfrac{\text{force}}{\text{area}} = \dfrac{Mg}{A/2} = \dfrac{2Mg}{A}$

7 (*c*) Let P be the point at a height $\dfrac{3L}{4}$ from its lower end of wire. As, the wire is uniform, so the weight of wire below point P is $\dfrac{3w}{4}$.



$\therefore$ Total force at point $P = w_1 + \dfrac{3w}{4}$ and area of cross-section $= S$

$$\text{Stress at point } P = \frac{\text{Force}}{\text{Area}} = \frac{w_1 + \frac{3w}{4}}{S}$$

8 (*d*) Given, cross-sectional area of steel, $A_1 = 0.1\text{ cm}^2$,

Cross-sectional area of brass, $A_2 = 0.2\text{ cm}^2$

Now, according to the question, stress produced in both the wire is same, hence stress will be constant, i.e.

$$\text{Stress} = \frac{\text{Tension}}{\text{Area of cross-section}} = \text{constant}$$

$$\therefore \quad \frac{T_1}{A_1} = \frac{T_2}{A_2} \Rightarrow \frac{T_1}{T_2} = \frac{A_1}{A_2} = \frac{0.1}{0.2} = \frac{1}{2} = 0.5$$

9 (*b*) If a wire is stretched to double its length, then

$$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{2L - L}{L} = 1$$

10 (*c*) $$\text{Strain} = \frac{\text{Change in length}}{\text{Original length}} = \frac{1\% \text{ of } L}{L} = \frac{L/100}{L} = 0.01$$

11 (*d*) Given, length of cube, $L = 0.1$ m,

Shearing force, $F = 100$ N

and displaced distance, $x = 0.02\text{ cm} = 0.02 \times 10^{-2}$ m

$$\text{Shearing strain, } \phi = \frac{x}{L} = \frac{0.02 \times 10^{-2}}{0.1\text{ m}} = 0.002$$

12 (*d*) Volume of cube, $V = L^3$

$\therefore$ Percentage change in $V = 3 \times$ (percentage change in L)

$= 3(1\%) = 3\%$

$\therefore$ $\Delta V = 3\%$ of V

$\Rightarrow$ $$\text{Volumetric strain} = \frac{\Delta V}{V} = \frac{3}{100} = 0.03$$

15 (*d*) The ratio of stress to strain is equal to the modulus of elasticity, which is the characteristic property of the body and depends on nature of material. So, the ratio will remain same, as for an increased stress an equivalent strain will compensate it.

16 (*c*) According to Hooke's law,

within the limit of elasticity, stress is directly proportional to strain.

i.e. $\quad$ Stress $\propto$ Strain

or $$\frac{\text{Load}}{\text{Area}} \propto \frac{\text{Extension}}{\text{Original dimension}}$$

or $\quad$ Load $\propto$ Extension

Hence, graph given in option (c) obeys Hooke's law.

17 (*b*) $$\text{Stress} = \frac{\text{Force}}{\text{Area}}$$

Since each wire is of same diameter, hence the area of cross-section is same for both the wires. As both the wires have the same deforming force F and same area of cross-section A, therefore stress is same for both the wires.

But Young's modulus, $Y = \dfrac{\text{Stress}}{\text{Strain}}$ or $\text{Strain} = \dfrac{\text{Stress}}{Y}$

Since Y is different for both the wires, therefore strain is different for both the wires.

18 (*b*) Given, stress $F = 20 \times 10^8\text{ Nm}^{-2}$

$$\text{Young's modulus} = \frac{\text{Stress}}{\text{Strain}}$$

As the length of wire gets doubled, therefore strain = 1

$$\left[\because \text{ strain } = \frac{\text{change in length}}{\text{original length}} = \frac{2L - L}{L} = 1\right]$$

$$\therefore \quad Y = \text{stress} = 20 \times 10^8\text{ Nm}^{-2}$$

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19 (*d*) Given, change in length of wire, $l_1 = 2\,\text{mm}$, $l_2 = ?$, length of wire, $L_1 = 2\,\text{m}$ and length of another wire, $L_2 = 8\,\text{m}$

Change in length, $l = \dfrac{FL}{AY} = \dfrac{FL^2}{VY}$

where, Y is Young's modulus.

$$\therefore \quad l \propto L^2$$

(as V, Y and F are constants)

$$\frac{l_2}{l_1} = \left[\frac{L_2}{L_1}\right]^2 = \left(\frac{8}{2}\right)^2 = 16$$

$$\Rightarrow \quad l_2 = 16 l_1 = 16 \times 2\ \text{mm}$$

$$= 32\,\text{mm} = 3.2\,\text{cm}$$

20 (*a*) Given, diameter of a brass rod, $d = 4$ mm, then radius, $r = 2 \times 10^{-3}$ m,

Young's modulus, $Y = 9 \times 10^{10}\ \text{Nm}^{-2}$,

Change in length, $l = 0.1\%\, L$

$$\Rightarrow \quad \frac{l}{L} = 0.001$$

Young's modulus, $Y = \dfrac{F}{A} \cdot \dfrac{L}{l}$

$$\therefore \quad F = YA\,\frac{l}{L}$$

$$= 9 \times 10^{10} \times \pi \times (2 \times 10^{-3})^2 \times 0.001$$

$$= 360\,\pi\text{N}$$

21 (*c*) Young's modulus, $Y = \dfrac{FL}{A\Delta L} = \dfrac{TL}{\pi r^2 \Delta L}$

$$\Rightarrow \quad \Delta L = \frac{TL}{\pi r^2 Y}$$

As wires are of same material, so Y is same for all. Also T is same, so $\Delta L \propto \dfrac{L}{r^2}$.

Thus, $\dfrac{L}{r^2}$ is maximum for length, $L = 250\,\text{cm}$ and radius, $r = 0.1\,\text{mm}$, i.e. 25×10^7 m, so its extension is largest.

22 (*b*) Young's modulus of a wire is

$$Y = \frac{F/A}{l/L} \Rightarrow F = \frac{YAl}{L}$$

Force constant, $k = \dfrac{F}{l} = \dfrac{YA}{L}$

23 (*a*) Given, length of nylon rope, $l = 4.5\,\text{m}$,

Radius, $r = \dfrac{6}{2}\ \text{mm} = 3 \times 10^{-3}$ m.

According to the question, $F = w = 100\,\text{N}$

and Young's modulus, $Y = 4.8 \times 10^{11}\ \text{Nm}^{-2}$

As, $\quad Y = \dfrac{Fl}{A\Delta l}$

$$\Rightarrow \quad \Delta l = \frac{Fl}{AY} = \frac{Fl}{\pi r^2 Y} = \frac{100 \times 4.5}{3.14 (3 \times 10^{-3})^2 \times 4.8 \times 10^{11}}$$

$$= 3.32 \times 10^{-5}\ \text{m} = 0.332\,\mu\text{m}$$

24 (*d*) Given, ratio of radius of two wires, $r_1 : r_2 = 2 : 1$

$$\Rightarrow \quad \frac{r_1}{r_2} = \frac{2}{1}$$

and ratio in their lengths, $l_1 : l_2 = 1 : 2$

$$\Rightarrow \quad \frac{l_1}{l_2} = \frac{1}{2}$$

When same force is applied on them, then ratio of change in their length $\dfrac{\Delta l_1}{\Delta l_2} = ?$

We know that, Young's modulus, $Y = \dfrac{Fl}{A\Delta l}$

$$\Rightarrow \quad \Delta l = \frac{Fl}{AY}$$

$$\Delta l \propto \frac{l}{A}$$

$$\therefore \quad \frac{\Delta l_1}{\Delta l_2} = \frac{l_1 A_2}{l_2 A_1}$$

$$\Rightarrow \quad \frac{\Delta l_1}{\Delta l_2} = \frac{l_1}{l_2} \cdot \frac{r_2^2}{r_1^2}$$

$$= \frac{1}{2} \cdot \left(\frac{1}{2}\right)^2 = \frac{1}{8} \qquad [\because A = \pi r^2]$$

25 (*c*) According to the question,

For wire 1

From the relation of Young's modulus of elasticity,

$$Y_1 = \frac{F_1 l_1}{A_1 \Delta l} \qquad \text{...(i)}$$

For wire 2

$$Y_2 = \frac{F_2 l_2}{A_2 \Delta l} \qquad \text{...(ii)}$$

$\because \quad$ Volume, $V = Al$ or $l = \dfrac{V}{A}$

Substituting the value of l in Eqs. (i) and (ii), we get

$$Y_1 = \frac{F_1 V}{A_1^2 \Delta l} \text{ and } Y_2 = \frac{F_2 V}{A_2^2 \Delta l}$$

As it is given that the wires are made up of same material, i.e. $\quad Y_1 = Y_2$

$$\Rightarrow \quad \frac{F_1 V}{A_1^2 \Delta l} = \frac{F_2 V}{A_2^2 \Delta l}$$

$$\Rightarrow \quad \frac{F_1}{F_2} = \frac{A_1^2}{A_2^2} = \frac{A^2}{9A^2} = \frac{1}{9}$$

$(\because A_1 = A$ and $A_2 = 3A)$

or $\quad F_2 = 9F_1 = 9F \qquad$ (given, $F_1 = F$)

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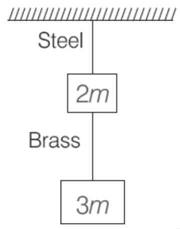
26 (*b*)



As, Young's modulus, $Y = \dfrac{FL}{A\Delta L} = \dfrac{4FL}{\pi D^2 \Delta L}$

$\left(\because A = \dfrac{\pi D^2}{4}\right)$

where, the symbols have their usual meanings.

$$\therefore \quad \Delta L = \frac{4FL}{\pi D^2 Y}$$

$$\therefore \quad \frac{\Delta L_s}{\Delta L_b} = \frac{F_s}{F_b}\frac{L_s}{L_b}\frac{D_b^2}{D_s^2}\frac{Y_b}{Y_s} \quad \text{...(i)}$$

where, subscripts s and b refer to steel and brass respectively.

Here, according to the question,

$$F_s = (2m + 3m)\,g = 5mg$$

$$F_b = 3mg$$

$$\because \quad \frac{D_s}{D_b} = p, \frac{L_s}{L_b} = q, \frac{Y_s}{Y_b} = r \quad \text{(given)}$$

From Eq. (i), we get

$$\therefore \quad \frac{\Delta L_s}{\Delta L_b} = \left(\frac{5\,mg}{3\,mg}\right)(q)\left(\frac{1}{p}\right)^2\left(\frac{1}{r}\right) = \frac{5q}{3p^2 r}$$

27 (*b*) Given, relation between Young's modulus, $Y_s = 2Y_b$, between lengths, $L_s = L_b$ and between areas, $A_s = A_b$

where, subscripts s and b refer to steel and brass, respectively.

As we know that, $\Delta L = \dfrac{wL}{AY}$ [where, force $F = w$]

As $\Delta L_s = \Delta L_b \Rightarrow \dfrac{w_s L_s}{A_s Y_s} = \dfrac{w_b L_b}{A_b Y_b}$

$$\frac{w_s}{w_b} = \frac{Y_s}{Y_b} = \frac{2Y_b}{Y_b} = \frac{2}{1}$$

Thus, weight added to the steel and brass wires must be in the ratio of $2:1$.

28 (*d*) When a wire is stretched, then change in length of wire is

$\Delta l = \dfrac{Fl}{\pi r^2 Y}$, where Y is its Young's modulus.

Here, for wires A and B,

$l_A = 2\text{ m}, l_B = 1.5\text{ m},$

$\dfrac{Y_A}{Y_B} = \dfrac{7}{4}, r_B = 2\text{ mm} = 2 \times 10^{-3}\text{ m}$ and $\dfrac{F_A}{F_B} = 1$

As, it is given that $\Delta l_A = \Delta l_B$

$$\Rightarrow \quad \frac{F_A l_A}{\pi r_A^2 Y_A} = \frac{F_B l_B}{\pi r_B^2 Y_B}$$

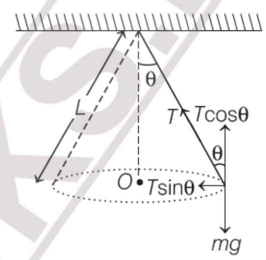
$$\Rightarrow \quad r_A^2 = \frac{F_A}{F_B}\cdot\frac{l_A}{l_B}\cdot\frac{Y_B}{Y_A}\cdot r_B^2$$

$$= 1 \times \frac{2}{1.5} \times \frac{4}{7} \times 4 \times 10^{-6}\text{ m} = 3.04 \times 10^{-6}\text{ m}$$

or $\quad r_A = 1.7 \times 10^{-3}$ m

or $\quad r_A = 1.7$ mm

29 (*c*) The situation is as shown in the figure



For vertical equilibrium of stone,

$$T\cos\theta = mg \text{ or } T = \frac{mg}{\cos\theta} \quad \text{...(i)}$$

where, T is tension in the wire.

As, $\quad Y = \dfrac{TL}{A\Delta L}$

$\Rightarrow \quad \Delta L = \dfrac{TL}{AY}$

[using Eq. (i)]

$$= \frac{mgL}{\cos\theta(\pi D^2/4)Y} = \frac{4mgL}{\pi D^2 Y \cos\theta}$$

30 (*c*) The length and radius of thick copper and thin copper wires are $2L$ & L and $2R$ & R respectively.

$\because$ Elongation in the wire, $\Delta l = \dfrac{FL}{AY} = \dfrac{FL}{(\pi r^2)Y}$

$$\therefore \quad \Delta l \propto \frac{L}{r^2}$$

Ratio of elongation in the thin wire to that in the thick wire.

$$\frac{\Delta l_1}{\Delta l_2} = \frac{L/R^2}{2L/(2R)^2} = 2$$

31 (*a*) Given, $T_1 = 40^\circ$ C and $T_2 = 20^\circ$ C

$$\Rightarrow \quad \Delta T = T_1 - T_2 = 40 - 20 = 20^\circ\text{ C}$$

Also, Young's modulus,

$$Y = 10^{11}\text{ N/m}^2$$

Coefficient of linear expansion,

$$\alpha = 10^{-5}/^\circ\text{C}$$

Area of the brass wire, $A = \pi \times (10^{-3})^2\text{ m}^2$

Now, expansion in the wire due to rise in temperature is

$$\Delta l = l\,\alpha\Delta T \Rightarrow \frac{\Delta l}{l} = \alpha\Delta T \quad \text{...(i)}$$

We know that, Young's modulus is defined as

$$Y = \frac{Mgl}{A\Delta l} \Rightarrow M = \frac{YA\Delta l}{gl} \quad \text{...(ii)}$$

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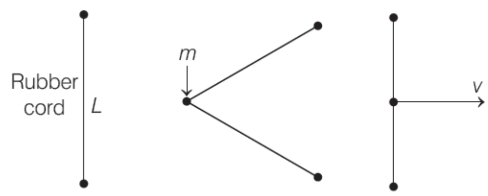
Using Eq. (i), we get

$$M = \frac{YA}{g} \times \alpha \Delta T = \frac{10^{11} \times 22 \times 10^{-6} \times 10^{-5} \times 20}{7 \times 10}$$

$$\Rightarrow M = \frac{22 \times 20}{7 \times 10} = \frac{44}{7} = 6.28 \text{ kg}$$

which is closest to 9, so option (a) is nearly correct.

32 (*a*) When rubber cord is stretched, then it stores potential energy and when released, this potential energy is given to the stone as kinetic energy.



So, potential energy of stretched cord = kinetic energy of stone

$$\Rightarrow \frac{1}{2} Y \left(\frac{\Delta L}{L}\right)^2 A \cdot L = \frac{1}{2} mv^2$$

Here, $\Delta L = 20 \text{ cm} = 0.2 \text{ m}$, $L = 42 \text{ cm} = 0.42 \text{ m}$, $v = 20 \text{ ms}^{-1}$, $m = 0.02 \text{ kg}$, $d = 6 \text{ mm} = 6 \times 10^{-3} \text{ m}$

$$\therefore \quad A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \pi \left(\frac{6 \times 10^{-3}}{2}\right)^2$$

$$= \pi (3 \times 10^{-3})^2 = 9\pi \times 10^{-6} \text{ m}^2$$

On substituting values, we get

$$Y = \frac{mv^2 L}{A (\Delta L)^2} = \frac{0.02 \times (20)^2 \times 0.42}{9\pi \times 10^{-6} \times (0.2)^2} \approx 3.0 \times 10^6 \text{Nm}^{-2}$$

So, the closest value of Young's modulus is 10^6 Nm^{-2}.

33 (*b*) Given, radius of wire, $r = 4 \text{ mm} = 4 \times 10^{-3} \text{m}$, twisted angle, $\theta = 30°$ and length of wire, $L = 100 \text{ cm} = 1 \text{m}$

$$L\phi = r\theta$$

$$\therefore \quad \phi = \frac{r\theta}{L} = \frac{4 \times 10^{-3} \times 30°}{1} = 0.12°$$

35 (*c*) We know that, $1 \text{ atm} = 10^5 \text{ Nm}^{-2}$

$\therefore$ $100 \text{ atm} = 10^7 \text{ Nm}^{-2}$ and $\Delta V = 0.01\% V$

$$\therefore \quad \frac{\Delta V}{V} = 0.0001$$

$$|B| = \frac{p}{\Delta V / V} = \frac{10^7}{0.0001}$$

$$= 1 \times 10^{11} \text{ Nm}^{-2}$$

$$= 1 \times 10^{12} \text{ dyne cm}^{-2} \qquad [\because 1 \text{ N} = 10^5 \text{ dyne}]$$

36 (*c*) We know that, $B = \dfrac{Mg / A}{\delta V / V}$

$$\Rightarrow \quad \frac{\delta V}{V} = \frac{Mg}{BA} \qquad \ldots\text{(i)}$$

Now, $$V = \frac{4}{3} \pi R^3 \qquad \ldots\text{(ii)}$$

$\therefore$ On differentiating,

$$\delta V = 4\pi R^2 \delta R \qquad \ldots\text{(iii)}$$

On dividing Eq. (iii) by Eq. (ii). we get

$$\therefore \quad \frac{\delta V}{V} = \frac{3\delta R}{R}$$

$$\therefore \quad \frac{\delta R}{R} = \frac{Mg}{3BA} \qquad \text{[using Eq. (i)]}$$

37 (*a*) $\because$ Compressibility, $|K| = \dfrac{1}{|\text{Bulk modulus of elasticity}|}$

Bulk modulus, $|B| = \dfrac{pV}{\Delta V} \Rightarrow K = \dfrac{1}{\left(\dfrac{pV}{\Delta V}\right)} = \dfrac{\Delta V}{pV}$

Given, compressibility of material, $K = 4 \times 10^{-5}$ per atm, pressure, $p = 100$ atm and volume, $V = 100 \text{ cm}^3$.

$$\therefore \Delta V = K(p \cdot V) = 4 \times 10^{-5} (100 \times 10^{-6} \times 100)$$

$$= 0.4 \times 10^{-6} \text{ m}^3 = 0.4 \text{ cm}^3$$

38 (*c*) Given, depth of ocean, $d = 2700 \text{ m}$,

Density of water, $\rho = 10^3 \text{ kg/m}^3$

and compressibility $= 45.4 \times 10^{-11} \text{ Pa}^{-1}$.

The pressure at the bottom of ocean is given by

$$p = \rho g d = 10^3 \times 10 \times 2700 = 27 \times 10^6 \text{ Pa}$$

So, fractional compression = compressibility $\times$ pressure

$$= 45.4 \times 10^{-11} \times 27 \times 10^6 = 1.2 \times 10^{-2}$$

39 (*d*) Let L be the length and r be the radius of the wire, then volume of the wire, $V = \pi r^2 L$.

Differentiating on both sides, we get

$$\Delta V = \pi (2r\Delta r) L + \pi r^2 \Delta L$$

As the volume of the wire remains unchanged when it gets stretched, so $\Delta V = 0$.

Hence, $0 = 2\pi r L \Delta r + \pi r^2 \Delta L$

$$\therefore \quad \frac{\Delta r / r}{\Delta L / L} = -\frac{1}{2}$$

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = \frac{\Delta r / r}{\Delta L / L} = \frac{1}{2} = 0.5$$

[neglecting negative sign]

40 (*d*) As, on stretching volume remains constant, so there is no change in volume. Thus, percentage change in volume is zero.

41 (*b*) Poisson's ratio, $\sigma = 0.4 = \dfrac{(\Delta d / d)}{(\Delta l / l)}$

$$\text{Area, } A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4} \qquad \ldots\text{(i)}$$

or $$d^2 = \frac{4A}{\pi}$$

On differentiating both sides, we get

$$2d \cdot \Delta d = \frac{4}{\pi} \cdot \Delta A$$

So, $$\Delta A = \frac{2\pi d \cdot \Delta d}{4} = \frac{\pi d \cdot \Delta d}{2} \qquad \ldots\text{(ii)}$$

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On dividing Eq. (ii) by Eq. (i), we get

$$\frac{\Delta A}{A}=\frac{\pi\cdot\frac{d}{2}\cdot\Delta d}{\pi\cdot d^2/4}=2\cdot\frac{\Delta d}{d} \quad \ldots\text{(iii)}$$

Given, $\frac{\Delta A}{A}\times 100\% = 2\%$ ...(iv)

From Eqs. (iii) and (iv),

$\Rightarrow$ $2\% = 2\cdot\frac{\Delta d}{d}$ or $\frac{\Delta d}{d}=1\%$

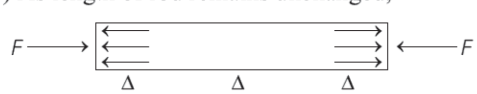
Given, Poisson's ratio, $\sigma=\frac{\Delta d/d}{\Delta l/l}=0.4$

or $\frac{\Delta d}{d}=0.4\left(\frac{\Delta l}{l}\right) \Rightarrow \frac{1}{0.4}\cdot\frac{\Delta d}{d}=\frac{\Delta l}{l}$

Percentage increase in its length,

i.e. $\left(\frac{\Delta l}{l}\right)\times 100\% = 2.5\times 1\% = 2.5\%$

42 (*c*) As length of rod remains unchanged,



Strain caused by compressive forces is equal and opposite to the thermal strain.

Now, compressive strain is obtained by using formula for Young's modulus,

$$Y=\frac{\frac{F}{A}}{\frac{\Delta l}{l}}$$

Compressive strain,

$\Rightarrow$ $\frac{\Delta l}{l}=\frac{F}{AY}=\frac{F}{\pi Y r^2}$ ...(i)

Also, thermal strain in rod is obtained by using formula for expansion in rod,

$$\Delta l = l\,\alpha\,\Delta T$$

$\Rightarrow$ Thermal strain, $\frac{\Delta l}{l}=\alpha\,\Delta T$ ...(ii)

From Eqs. (i) and (ii), we get

$$\frac{F}{\pi r^2 Y}=\alpha\,T \quad [\because \Delta T = T]$$

$\Rightarrow$ $\alpha=\frac{F}{\pi r^2 YT}$

Hence, coefficient of volumetric expansion of rod is

$$\gamma = 3\alpha = \frac{3F}{\pi r^2 YT}$$

43 (*b*) Work done, $W=\frac{1}{2}\times F\times\Delta L$

For a given F, $W\propto\Delta L$ ...(i)

and $\Delta L=\frac{FL}{AY}$

As force F, area A and length L are constants, so

$\therefore$ $\Delta L\propto\frac{1}{Y}$ ...(ii)

From Eqs. (i) and (ii), we get

$$W\propto\frac{1}{Y} \Rightarrow \frac{W_{\text{steel}}}{W_{\text{copper}}}=\frac{Y_{\text{copper}}}{Y_{\text{steel}}}$$

As, $Y_{\text{copper}}<Y_{\text{steel}} \Rightarrow W_{\text{steel}}<W_{\text{copper}}$

So, less work is done on steel spring.

44 (*a*) Work done in stretching the wire through 0.61 mm under the load of 3 kg-wt,

$$W_1=\frac{1}{2}\times\text{stretching force}\times\text{extension}$$

$$=\frac{1}{2}\times 3\times 9.8\times 0.61\times 10^{-3}=8.967\times 10^{-3}\text{ J}$$

Work done in stretching the wire through 1.02 mm under the load of 5 kg-wt.

$$W_2=\frac{1}{2}\times 5\times 9.8\times 1.02\times 10^{-3}=24.99\times 10^{-3}\text{ J}$$

Hence, the work done in stretching the wire from 0.61 mm to 1.02 mm is

$$\Delta W = W_2 - W_1 = (24.99-8.961)\times 10^{-3}$$

$$\simeq 16\times 10^{-3}\text{ J}$$

45 (*a*) Stretching force, $F=\frac{Y\pi r^2\Delta L}{L}$

Both the wires are of same material, so Y will be equal and extension in both the wires is same, so ΔL will be equal.

$\therefore$ $F\propto\frac{r^2}{L}$

If F' is the force on another wire of radius $2r$ and length $\frac{L}{2}$. Then,

$\therefore$ $\frac{F'}{F}=\frac{(2r)^2}{(L/2)}\times\frac{L}{r^2}=8$ or $F'=8F$ ...(i)

Work done in stretching a wire,

$$W=\frac{1}{2}\times F\times\Delta L$$

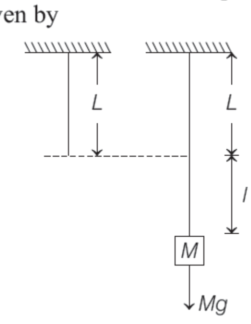
For same extension,

$$W\propto F$$

$\therefore$ $\frac{W'}{W}=\frac{F'}{F}=8$ [using Eq. (i)]

$$W'=8W=8\times 2\text{ J}=16\text{ J}$$

46 (*b*) In stretching a wire, the work done against internal restoring force is stored as elastic potential energy in wire and given by



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$$U = W = \frac{1}{2} \times \text{Force }(F) \times \text{ Elongation }(l)$$
$$= \frac{1}{2}Fl = \frac{1}{2} \times Mg \times l = \frac{1}{2}Mgl$$

47 (*d*) Elastic potential energy per unit volume is

$$u = \frac{1}{2}\frac{(\text{stress})^2}{Y} \Rightarrow u \propto (\text{stress})^2$$

$$\therefore \quad \frac{u_1}{u_2} = \frac{(\text{stress})_1^2}{(\text{stress})_2^2} = \frac{(F_1/A_1)^2}{(F_2/A_2)^2} \quad \left[\because \frac{F}{A} = \text{stress}\right]$$

As both the wires are stretched by the same load, therefore

$$F_1 = F_2$$

$$\therefore \quad \frac{u_1}{u_2} = \left(\frac{A_2}{A_1}\right)^2 = \left(\frac{D_2^2}{D_1^2}\right)^2 = \left(\frac{D_2}{D_1}\right)^4 = \left(\frac{2}{1}\right)^4 = \frac{16}{1}$$

50 (*a*) From O to A, Hooke's law is obeyed, i.e. the body regains its original dimensions when the applied force is removed. So, the solid body behaves as an elastic body.

51 (*b*) From the given figure, we can say that, the slope of the linear portion of the stress-strain curve is greater for material B. Hence, Young's modulus of B is greater than that of material A. Material B can withstand more load without breaking. So, it is stronger than material A and its ulimate stress is higher.

52 (*a*) A bridge has to be designed such that it can withstand the load of flowing traffic, the force of winds and its own weight. Since, steel is more elastic than aluminium. So, it can withstand the load of traffic. Thus, over bridges are constructed with steel but not with aluminium.

53 (*a*) Elastic potential energy stored in a loaded wire,

$$U = \frac{1}{2}(\text{Stress} \times \text{Strain} \times \text{Volume})$$

$\therefore$ Energy stored per unit volume,

$$u = \frac{U}{\text{Volume}} = \frac{1}{2} \times \text{Stress} \times \text{Strain} = \frac{1}{2}\left(\frac{F}{A}\right)^2 \times \frac{1}{Y}$$

Here, both wires are of same material and under same load, so the ratio of stored energies per unit volume, for both the wires will be

$$\frac{u_A}{u_B} = \frac{\frac{1}{2Y}\cdot\frac{F^2}{A_A^2}}{\frac{1}{2Y}\cdot\frac{F^2}{A_B^2}} = \frac{A_B^2}{A_A^2}$$

$$\Rightarrow \quad \frac{u_A}{u_B} = \frac{d_B^4}{d_A^4} \qquad \left(\because A = \pi\frac{d^2}{4}\right)$$

Here, $\quad \frac{u_A}{u_B} = \frac{1}{4}$

So, $\quad \frac{d_B^4}{d_A^4} = \frac{1}{4}$ or $\frac{d_B}{d_A} = \frac{1}{\sqrt{2}}$

$$\Rightarrow \quad \frac{d_A}{d_B} = \sqrt{2}:1$$

54 (*d*) Given, $d_1 = 1\,\text{mm}$, $d_2 = 2\,\text{mm}$ and $F = 1000\text{ N}$

Breaking force or tension $\propto$ area of cross-section

$$\frac{F_2}{F_1} = \left(\frac{d_2}{d_1}\right)^2$$

$$\left[\begin{array}{l}\because F \propto r^2, \text{ where } r \text{ is radius}\\ \therefore F \propto d^2, \text{ where } d \text{ is diameter}\end{array}\right]$$

$$\Rightarrow \quad \frac{F_2}{1000} = \left(\frac{2}{1}\right)^2$$

$$\Rightarrow \quad F_2 = 1000 \times 4 = 4000\text{ N}$$

55 (*d*) Given, Young's modulus $= 2 \times 10^{11}\text{ Nm}^{-2}$,

Strain $= 0.15$

$$\because \quad Y = \frac{\text{Stress}}{\text{Strain}}$$

$$\therefore \quad \text{Stress} = Y \times \text{Strain} = 2 \times 10^{11} \times 0.15 = 0.3 \times 10^{11}$$
$$= 3 \times 10^{10}\text{ Nm}^{-2}$$

56 (*b*) Given, length of rod = L, density of rod = ρ

and horizontal acceleration = α

The force at the transverse cross-section through the mid-point of the rod is

$$\text{Force, } F = \text{mass} \times \text{acceleration}$$

$$= \rho V\alpha \qquad \left[\begin{array}{l}\because \text{ density}, \rho = \frac{m}{V}\\ \therefore \text{ mass}, \quad m = \rho V\end{array}\right]$$

$$\because \quad \text{Volume }(V) = \text{Area}(A) \times \text{Length}(L)$$

$$\therefore \quad F = \rho A\frac{L}{2}\alpha \qquad \left[\begin{array}{l}\because \text{ For mid point of}\\ \text{the rod, length } = \frac{L}{2}\end{array}\right]$$

$$F = \frac{L}{2}A\rho\alpha$$

$$\therefore \quad \text{Stress} = \frac{F}{A} = \frac{1}{2}L\rho\alpha$$

57 (*c*) Let d_{min} = minimum diameter of brass.

Then, stress in brass rod is given by

$$\sigma = \frac{F}{A} = \frac{4F}{\pi d_{\text{min}}^2} \qquad \left[\because A = \frac{\pi d^2}{4}\right]$$

For stress not to exceed elastic limit, we have

$\sigma \le 379\text{ MPa}$

$$\Rightarrow \quad \frac{4F}{\pi d_{\text{min}}^2} \le 379 \times 10^6$$

Here, $F = 400\text{ N}$

$$\therefore \quad d_{\text{min}}^2 = \frac{1600}{\pi \times 379 \times 10^6}$$

$$\Rightarrow \quad d_{\text{min}} = 1.16 \times 10^{-3}\text{ m} = 1.16\text{ mm}$$

59 (*b*) A beam of length l, breadth b and depth d when loaded at the centre by a load w depresses by an amount given by

$$\delta = \frac{wl^3}{4bd^3Y}; \text{ i.e. } \delta \propto \frac{1}{Y}$$

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60 (*c*) Since, depression δ in the bar at centre is directly proportional to load.

i.e. $\delta \propto w$

$$\frac{\delta_2}{\delta_1} = \frac{w_2}{w_1} = \frac{2w_1}{w_1} = 2$$

$\therefore$ $\delta_2 = 2\delta_1$

Hence, depression in the bar at the centre is increased to double.

61 (*a*) The elasticity of a material is the ratio of stress and strain. In given case, the strain produced in the rubber is more than that in steel.

As, rubber is less elastic than steel.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

62 (*c*) When a spring is loaded, then shearing stress is produced, which changes the shape of spring.

Therefore, Assertion is correct but Reason is incorrect.

63 (*a*) Spring balance shows incorrect reading after using it for a long time as with time the spring in it loses its elastic strength.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

64 (*a*) If a solid sphere placed in the fluid under high pressure, then it is compressed uniformly on all sides.

The force applied by the fluids acts in perpendicular direction at each point of the surface and the body is said to be under hydraulic compression.

This leads to decrease in its volume without any change of its geometrical shape.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

65 (*b*) The strain produced by a hydraulic pressure is called volumetric strain as pressure creates a normal force on every point and is defined as the ratio of change in volume ΔV to the original volume V.

i.e. $$\text{volume strain} = \frac{\Delta V}{V}$$

Therefore, Assertion and Reason are correct but Reason is not the correct explanation of Assertion.

66 (*c*) According to Hooke's law, within the elastic limit, stress is directly proportional to the strain.

i.e. Stress $\propto$ Strain

$$\Rightarrow \frac{F}{A} \propto \frac{\Delta l}{l} \Rightarrow F \propto \Delta l$$

Hence, elongation produced in a body is directly proportional to the applied force.

Therefore, Assertion is correct but Reason is incorrect.

67 (*a*) Young's modulus of a material, $Y = \dfrac{\text{Stress}}{\text{Strain}}$

$$\therefore \quad \text{Stress} = \frac{\text{Restoring force } F}{\text{Area } A}$$

As, restoring force is zero for a plastic body.

$\therefore$ $Y = 0$

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

68 (*a*) Molecules in gases are very poorly coupled to their neighbours molecules.

Since, compressibility is defined as the fractional change in volume per unit increase or decrease in pressure.

$$K = 1/B = -(1/\Delta p) \times (\Delta V/V)$$

where, B is bulk modulus and Δp change in pressure.

So, in gases, fractional change in volume with per unit increase or decrease in pressure is not very prominent.

Thus, they have large compressibility.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

69 (*a*) A single wire of a radius would practically be a rigid rod. So, the ropes are always made of a number of thin wires braided together, like in pigtails, for ease in manufacturing flexibility and strength.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

70 (*a*) The maximum height of a mountain on earth is ~ 10 km.

As a mountain base is not under uniform compression and this provides some shearing stress to the rocks under which they can flow.

Thus, mathematically, it has been calculated that under the elastic limit, maximum height of a mountain is ~ 10 km.

Therefore, Assertion and Reason are correct and Reason is the correct explanation of Assertion.

71 (*b*) When we apply a force to a plastic substance, then they have no gross tendency to regain their original shape and they get permanently deformed, this property of plastic substance is called plasticity.

So, statements I and II are correct but III and IV are incorrect.

72 (*a*) Elastomers are those materials which can be elastically stretched to a large value of strain. Elastic region for them is very large but they do not obey Hooke's law.

Thus, Young's modulus of elastomers is very small.

So, statements I and II are correct but III is incorrect.

73 (*d*) Given, cross-section area of wires A and $B = x$

Young's modulus of wires $= Y$

$$\text{Tension in wire } B = \frac{m \cdot (m+m)}{m+(m+m)} \cdot g = \frac{2}{3} mg \quad \ldots\text{(i)}$$

where, g is gravitational acceleration

[$\because$ tension = force = mass $\times$ acceleration]

$$\because \quad \text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\text{Stress in } B = \frac{\text{Force (tension)}}{\text{Cross-section area of wire } B} = \frac{2mg}{3x} \quad \ldots\text{(ii)}$$

[using Eq. (i)]

$$\text{Young's modulus, } Y = \frac{\text{Stress}}{\text{Strain}}$$

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$\therefore$ Strain in wire $B = \dfrac{\text{Stress}}{Y} = \dfrac{2mg}{3xY}$ [using Eq. (ii)]

Tension in wire $A = \dfrac{m \cdot m}{m+(m+m)} g = \dfrac{mg}{3}$

Similarly, stress in wire $A = \dfrac{mg}{3x}$

So, statements II and IV are correct but I and III are incorrect.

74 (*c*) The weights placed in the pan exert a downward force and stretch the experimental wire under a tensile stress. So, the elongation of the wire (increase in length) is measured by the vernier arrangement.

The reference wire is used to compensate for any change in length that may occur due to change in room temperature, since any change in length of the reference wire due to temperature change will be compensate by an equal change in experimental wire.

So, both statements are correct.

75 (*b*) In strain-stress curve, slope of curve $= \dfrac{1}{Y}$

From the given diagram we can write, $\dfrac{1}{Y_P} > \dfrac{1}{Y_Q} > \dfrac{1}{Y_R}$

Therefore, elasticity of P or Y_P is minimum and that of R is maximum.

Elasticity of Q lies between them (between P and R).

As elasticity of R is maximum, which means it can bear maximum stress, so its tensile strength is maximum.

So, statements I and III are correct but II is incorrect.

76 (*c*) The point D on the graph is the ultimate tensile strength σ_u of the material. Beyond this point, additional strain is produced even by a reduced applied force and fracture occurs at point E.

If the ultimate strength and fracture points D and E are close to yield point B, the material is said to be brittle and if points D and E are far apart, the material is said to be ductile.

So, statements II and III are correct but I is incorrect.

77 (*d*) Use of pillars or columns is very common in buildings and bridges. A pillar with rounded ends as shown in Fig. (i) supports less load than that with a distributed shape at ends [Fig. (ii)].

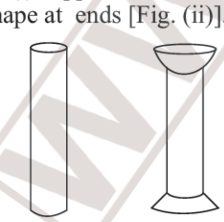

Fig. (i) Fig. (ii)

The precise design of a bridge or a building has to take into account to the conditions under which it will function, the cost and long period, reliability of usable materials, etc.

So, all statements are correct.

78 (*d*) Statement given in option (d) is incorrect and it can be corrected as,

Metals have larger values of Young's modulus than alloy and elastomers.

Rest statements are correct.

79 (*b*) Statement given in option (b) is incorrect and it can be corrected as,

Gases are about a million times compressible than solids. So, solids are least compressible.

Rest statements are correct.

80 (*c*) Statement given in option (c) is correct, rest are incorrect and these can be corrected as

The ratio of the lateral strain to the longitudinal strain is called Poisson's ratio σ.

Its value depends only on the nature of the material.

It is the ratio of two similar quantities, so it is unitless and dimensionless quantity.

The practical value of Poisson's ratio lies between 0 and 0.5.

81 (*b*) From given graph, P has more strain for same stress as on Q, so P is more ductile than Q.

Thus, the statement given in option (b) is correct, rest are incorrect.

82 (*a*) If A and B are prepared for identical wires of two different materials, then

Young's modulus,

$$Y = \frac{Fl}{A\Delta l} \Rightarrow F = \frac{YA}{l} \cdot \Delta l \Rightarrow \frac{F}{\Delta l} = \frac{YA}{l}$$

So, slope of load-extension graph $= \dfrac{F}{\Delta l} = \dfrac{YA}{l}$

As wires are identical,

$$\frac{(\text{Slope})_A}{(\text{Slope})_B} = \frac{\tan\theta_A}{\tan\theta_B} = \frac{\tan 60^\circ}{\tan 30^\circ} = \frac{Y_A}{Y_B}$$

$[\theta_A = 60^\circ \text{ and } \theta_B = 30^\circ]$

$\Rightarrow \quad Y_A : Y_B = 3:1$

As, extension, $\Delta l = \dfrac{Fl}{AY} \Rightarrow \Delta l \propto \dfrac{1}{Y}$

then for wire A and B

$$\frac{\Delta l_B}{\Delta l_A} = \frac{Y_A}{Y_B} = \frac{3}{1} \quad \therefore \quad \Delta l_B > \Delta l_A$$

As extension for wire A is less than that of B,

so A is more thicker than B.

Thus, the statements given in option (a) is incorrect, rest are correct.

83 (*a*) Given, mass of blocks, $m_1 = 1\,\text{kg}$ and $m_2 = 4\,\text{kg}$

$\because$ Tension, $T = \dfrac{2m_1 m_2}{m_1 + m_2} \times g = \dfrac{2 \times 1 \times 4}{1+4} \times 10 = 16\,\text{N}$

$(\because\ g = 10\,\text{ms}^{-2})$

If breaking stress is $3.18 \times 10^9\ \text{Nm}^{-2}$, then

Breaking force = Breaking stress × Area

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$$\Rightarrow \quad 16 = 3.18 \times 10^9 \times \pi r^2$$

$$\Rightarrow \quad r = \sqrt{\frac{16}{3.18 \times 10^9 \times 3.14}} = 4 \times 10^{-5} \text{ m}$$

Thus, the statement given in option (a) is incorrect, rest are correct.

84 (*a*) Given, radii of wires A and B are r_A and r_B, respectively.

$$\text{Force, } F = \frac{mg}{3}$$

$$\because \quad \text{Stress} = \frac{\text{Force}}{\text{Area}}$$

$$\therefore \quad \text{Stress in } B = \frac{mg}{3\pi r_B^2} \quad [\because \text{ Area of wire } B = \pi r_B^2]$$

$$\text{Similarly, stress in } A = \frac{F + mg}{\pi r_A^2} = \frac{\frac{mg}{3} + mg}{\pi r_A^2}$$

When $r_A = r_B$,

$$\text{Stress in } B = \frac{mg}{3\pi r_B^2} \text{ and stress in } A = \frac{4}{3}\frac{mg}{\pi r_A^2}$$

$\therefore$ Stress in $A >$ Stress in B

So, wire A will break earlier.

If $r_A = 2r_B$, then stress in A = stress in B, it means either A or B may breaks.

If $r_A < 2r_B$, then stress in A is more than that of B.

$\therefore$ A may break earlier.

Thus, the statement given in option (a) is correct, rest are incorrect.

85 (*b*) Loss in gravitational potential energy of mass $m = mgl$

Elastic potential energy stored in wire = Work done

$$= \frac{1}{2} \times \text{Stretching force} \times \text{Extension} = \frac{1}{2} mgl$$

$$\therefore \text{ Heat produced} = \frac{1}{2} mgl$$

Thus, the statement given in option (b) is incorrect, rest are correct.

86 (*c*)

A. Longitudinal stress can be a tensile or compressive. During tensile stress, length of wire increases and during compressive stress, length of wire decreases.

B. When deforming force is applied tangentially to a surface of the body, then tangential or shear stress is produced and shape of the body changes.

C. Breaking stress is independent of area of cross-section of wire.

D. Bulk stress is equal to change in pressure.

Hence, A $\rightarrow$ 3, B $\rightarrow$ 4, C $\rightarrow$ 1 and D $\rightarrow$ 2.

87 (*a*)

A. $\text{Stress} \times \text{Strain} = \text{N m}^{-2} = (\text{Nm})\text{m}^{-3} = \text{Jm}^{-3}$

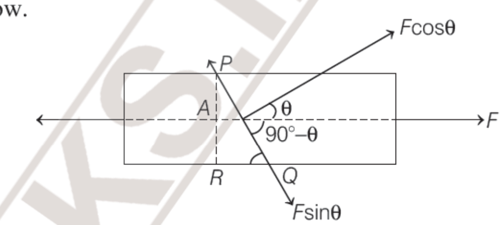
B. $\dfrac{YA}{l} = \dfrac{\text{Nm}^{-2} \times \text{m}^2}{\text{m}} = \text{Nm}^{-1}$

C. $Yl^3 = \text{Nm}^{-2} \times \text{m}^3 = \text{Nm} = \text{J}$

D. $Fl/AY = \dfrac{\text{N} \times \text{m}}{\text{m}^2 \times \text{Nm}^{-2}} = \text{m}$

Hence, A $\rightarrow$ 3, B $\rightarrow$ 2, C $\rightarrow$ 1 and D $\rightarrow$ 4.

88 (*b*) The resolved part of F along the normal is the tensile stress on this plane and the resolved part parallel to the plane is the shearing stress on the plane as shown below.



Given, cross-section area of bar = A

Let cross-section area of plane = A'

then, from ΔPQR

$$\because \quad \frac{A}{A'} = \sin(90° - \theta) = \cos\theta$$

$$\therefore \text{ Area, } A' = \frac{A}{\cos\theta} = A\sec$$

A. $\text{Tensile stress} = \dfrac{\text{Force}}{\text{Area}} = \dfrac{F\cos\theta}{A\sec\theta} = \dfrac{F}{A}\cos^2\theta$

(area of plane section = $A\sec\theta$)

B. $\text{Shearing stress} = \dfrac{\text{Force}}{\text{Area}} = \dfrac{F\sin\theta}{A\sec\theta}$

$$= \frac{F}{A}\sin\theta\cos\theta = \frac{F}{2A}\sin 2\theta$$

C. Tensile stress or strength will be maximum when $\cos^2\theta$ is maximum, i.e. $\cos\theta = 1$ or $\theta = 0°$.

D. Shearing stress will be maximum when $\sin 2\theta$ is maximum, i.e. or $2\theta = 90°$, i.e. $\theta = 45°$.

Hence, A $\rightarrow$ 2, B $\rightarrow$ 3, C $\rightarrow$ 1 and D $\rightarrow$ 4.

90 (*c*) The slope of straight line portion of strain-stress curve for a given material represents its Young's modulus.

(i) Young's modulus of the given material (Y)

= Slope of strain-stress curve

$$Y = \frac{150 \times 10^6}{0.002} = 75 \times 10^9$$

$$= 7.5 \times 10^{10} \text{ Nm}^{-2}$$

(ii) Yield strength of the given material

= Maximum stress that material can sustain

$= 300 \times 10^6 = 3 \times 10^8 \text{ Nm}^{-2}$

91 (*c*) Given, side of an aluminium cube,

$$l = 10 \text{ cm} = 0.1 \text{ m}$$

Area of its each face,

$$A = l^2 = (0.1)^2 = 0.01 \text{ m}^2$$

Load, $m = 100$ kg

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Tangential force acting on one face of the cube,

$$F = mg = 100 \times 9.8 = 980 \text{ N}$$

Shearing stress acting on this face =

$$\frac{F}{A} = \frac{980}{0.01} = 9.8 \times 10^4 \text{ Nm}^{-2}$$

Shear modulus of aluminium, $\eta = 25$ GPa

$$= 25 \times 10^9 \text{ Nm}^{-2}$$

Shear modulus, $\eta = \dfrac{\text{Shearing stress}}{\text{Shearing strain}}$

Shearing strain $\left(\dfrac{\Delta x}{l}\right) = \dfrac{\text{Shearing stress}}{\text{Shearing modulus}}$

$$\Rightarrow \quad \Delta x = \frac{9.8 \times 10^4}{25 \times 10^9} \times 0.1 = 3.92 \times 10^{-7} \text{ m}$$

92 (*a*) Given, Young's modulus of copper,

$$Y_1 = 110 \times 10^9 \text{ Nm}^{-2}$$

Young's modulus of steel, $Y_2 = 190 \times 10^9 \text{ Nm}^{-2}$

As tension in each wire is same, hence each wire has same strain.

Young's modulus, $Y = \dfrac{\text{Stress}}{\text{Strain}} = \dfrac{F/A}{\text{Strain}}$

$$Y = \frac{F}{\left(\frac{\pi d^2}{4}\right)\text{strain}} = \frac{4F}{\pi d^2 \times \text{strain}}$$

where, d is diameter of the wire.

$$\Rightarrow \quad Y \propto \frac{1}{d^2} \quad \text{or} \quad d^2 \propto \frac{1}{Y}$$

Then ratio of diameter of copper wire with steel wire is

$$\therefore \quad \frac{d_1^2}{d_2^2} = \frac{Y_2}{Y_1} \Rightarrow \sqrt{\frac{Y_2}{Y_1}}$$

$$\frac{d_1}{d_2} = \sqrt{\frac{190 \times 10^9}{110 \times 10^9}} = \sqrt{\frac{19}{11}}$$

$$= \sqrt{1.73} = 1.31$$

$$d_1 : d_2 = 1.31 : 1$$

93 (*b*) Diameter of wires $(2r) = 0.25$ cm

$$\therefore \quad r = 0.125 \text{ cm} = 1.25 \times 10^{-3} \text{ m}$$

For steel wire (from given figure)

Load, $F_1 = (4 + 6)$ kgf $= 10 \times 9.8$ N $= 98$ N

Length of steel wire, $l_1 = 1.5$ m

Young's modulus, $Y_1 = 2.0 \times 10^{11}$ Pa

$\because$ Young's modulus, $Y_1 = \dfrac{F_1 \times l_1}{A_1 \times \Delta l_1}$

$\therefore$ Change in length, $\Delta l_1 = \dfrac{F_1 \times l_1}{A_1 \times Y_1}$

$$= \frac{98 \times 1.5}{3.14 \times (1.25 \times 10^{-3})^2 \times 2.0 \times 10^{11}} = 1.5 \times 10^{-4} \text{ m}$$

For brass wire

Load, $F_2 = 6$ kgf $= 6 \times 9.8$ N $= 58.8$ N

Length of brass wire, $l_2 = 1.0$ m

Young's modulus, $Y_2 = 0.91 \times 10^{11}$ Pa

$\therefore$ Change in length, $\Delta l_2 = \dfrac{F_2 \times l_2}{A_2 \times Y_1}$

$$= \frac{58.8 \times 1.0}{3.14 \times (1.25 \times 10^{-3})^2 \times 0.91 \times 10^{11}}$$

$$= 1.3 \times 10^{-4} \text{ m}$$

94 (*a*) Depth of pacific ocean, $h = 11$ km $= 11 \times 10^3$ m

Pressure at the bottom of the trench, $p = 1.1 \times 10^8$ Pa

Initial volume of the ball, $V = 0.32 \text{ m}^3$

$\because$ Bulk modulus for steel, $B = 1.6 \times 10^{11} \text{ Nm}^{-2}$

Bulk modulus of steel, $|B| = \dfrac{p}{(\Delta V/V)} = \dfrac{pV}{\Delta V}$

Change in the volume of the ball when it reaches to the bottom,

$$\Delta V = \frac{pV}{B} = \frac{1.1 \times 10^8 \times 0.32}{1.6 \times 10^{11}} = 2.2 \times 10^{-4} \text{ m}^3$$

95 (*c*) Let length of each wire be L and their area of cross-section be A_1 and A_2, respectively.

Given, $A_1 = 1 \text{ mm}^2 = 1 \times 10^{-6} \text{ m}^2$

$$A_2 = 2 \text{ mm}^2 = 2 \times 10^{-6} \text{ m}^2$$

$$Y_{\text{steel}} = 2 \times 10^{11} \text{ Nm}^{-2}$$

$$\Rightarrow \quad Y_{\text{Al}} = 7.0 \times 10^{10} \text{ Nm}^{-2}$$

Let F_1 and F_2 be the tensions in the two wires, respectively. When equal stresses are produced, then

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$\text{or} \quad \frac{F_1}{F_2} = \frac{A_1}{A_2} = \frac{1 \times 10^{-6}}{2 \times 10^{-6}}$$

$$\text{or} \quad \frac{F_1}{F_2} = \frac{1}{2} \quad \ldots\text{(i)}$$

Let mass m be suspended at a distance x from steel wire A.

Taking moment of forces about the point of suspension of mass from the rod, we get

$$F_1 \times x = F_2 \times (1.05 - x)$$

$$\Rightarrow \quad \frac{F_1}{F_2} = \frac{(1.05 - x)}{x} \quad \ldots\text{(ii)}$$

From Eqs. (i) and (ii), we get

$$\frac{1}{2} = \frac{(1.05 - x)}{x} \Rightarrow x = 2.10 - 2x$$

$$\Rightarrow \quad 3x = 2.10 \quad \Rightarrow x = 0.70 \text{ m}$$

So, the mass m must be suspended at a distance 0.70 m from steel wire A.

96 (*c*) Given, compressional force, $F = 50000$ N

Diameter, $D = 0.5$ mm $= 5 \times 10^{-4}$ m

$\therefore$ Radius, $r = \dfrac{D}{2} = 2.5 \times 10^{-4}$ m

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