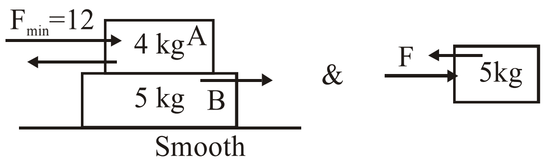
1. A block A of mass 4 kg is placed on another block B of mass 5 kg, and the block B rests on a smooth horizontal table. If the minimum force that can be applied on A so that both the blocks move together is 12 N, the maximum force that can be applied on B for the blocks to move together will be :

(1) 48 N (2) 27 N (3) 30 N (4) 25 N

Ans. (Bonus)

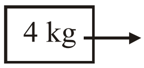
Sol.



12 = 9a

a = 4/3

$f = 5(4/3) = 20/3$



$f = 2/3 = 4a$

$a = 5/3$

$$F - f = 5 \times \frac{4}{3}$$

$$F - \frac{20}{3} = \frac{20}{3}$$

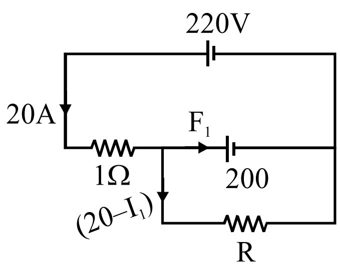
$$f = \frac{40}{3}$$

2. A d.c. main supply of e.m.f. 220 V is connected across a storage battery of e.m.f. 200 V through a resistance of 1Ω. The battery terminals are connected to an external resistance 'R'. The minimum value of 'R', so that a current passes through the battery to charge it is :

(1) Zero (2) 11 Ω (3) 9 Ω (4) 7 Ω

Ans. (2)

Sol.



$(20 - I_1)$ R = 200

$$R = \frac{200}{(20 - I_1)}$$

R ⟶ Minimum

when $20 - I_1$ ⟶ maximum

& I_1 cannot be zero

so $R \approx 11\Omega$

3. A transverse wave is represented by :

$$y = \frac{10}{\pi}\sin\left(\frac{2\pi}{T}t - \frac{2\pi}{\lambda}x\right)$$

For what value of the wavelength the wave velocity is twice the maximum particle velocity?

(1) 40 cm (2) 10 cm

(3) 60 cm (4) 20 cm

Ans. **(1)**

Sol. $V = 2(V_p)_{max}$

$\because V = f\lambda$

$f\lambda = 2\omega A$

$\lambda = 4\pi A$

$$= 4\pi \times \frac{10}{\pi}$$

= 40 cm

4. The equation of state for a gas is given by $PV = nRT + \alpha V$, where n is the number of moles and α is a positive constant. The initial temperature and pressure of one mole of the gas contained in a cylinder are T_0 and P_0 respectively. The work done by the gas when its temperature doubles isobarically will be :

(1) $\frac{P_0T_0R}{P_0 - \alpha}$ (2) $\frac{P_0T_0R}{P_0 + \alpha}$

(3) $P_0\ T_0\ R$ (4) $P_0\ T_0\ R\ \ell n\ 2$

Ans. (1)

Sol. $P_0V_0 = nRT_0$

$P_0V = nRT$

$T_f = 2T_0$

$W = \int PdV$

$$= \int\left(\frac{nRT}{V} + \alpha\right)dv$$

$PV = nRT + \alpha V$

$$\int pdV = \int_{T_0}^{2T_0} nRdT + \int_{V_i}^{V_f} \alpha dV$$

$= nRT_0 + \alpha\ V_i$

$= nRT_0 + \alpha\left(\frac{nRT_0}{P_0}\right)$

$= nRT_0\left(1+\frac{\alpha}{P_0}\right)$

$PV = nRT + \alpha V$

$\int pdV = \int nRdT + \int \alpha dV$

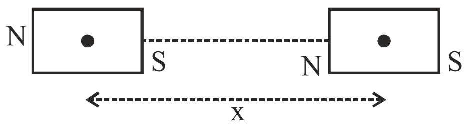
$W = nRT_0 + \alpha\left[\frac{nRT_0}{P_0-\alpha}\right]$

$W = nRT_0\left[1+\frac{\alpha}{p_0-\alpha}\right]$

$= nR_0T_0\left[\frac{P_0}{P_0-\alpha}\right]$

$= \frac{nRT_0\ P_0}{P_0-\alpha}$

5. The mid points of two small magnetic dipoles of length d in end-on positions, are separated by a distance x, (x >> d). The force between them is proportional to x^{-n} where n is :

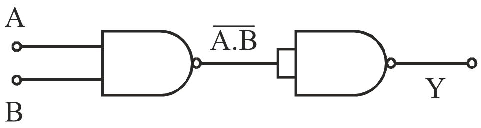


(1) 2 (2) 1 (3) 4 (4) 3

Ans. (3)

Sol. $F \propto \frac{1}{r^4}$

6. Identify the gate and match A, B, Y in bracket to check.



(1) XOR (A=0, B = 0. Y = 0)
(2) AND (A=l, B = l, Y= l)
(3) NOT (A=l, B = l, Y=l)
(4) OR (A = l, B=l, Y = 0)

Ans. (2)

7. When the rms voltages V_L, V_C and V_R are measured respectively across the inductor L, the capacitor C and the resistor R in a series LCR circuit connected to an AC source, it is found that the ratio$V_L : V_C : V_R = 1 : 2 : 3$. If the rms voltage of the AC source is 100 V, then V_R is close to:

(1) 50 V (2) 100 V (3) 70 V (4) 90 V

Ans. (4)

Sol. $I = \frac{V_{rms}}{Z} = \frac{V_{rms}}{\sqrt{R^2+(X_L-X_C)^2}} = \frac{100}{\sqrt{9x^2+x^2}} = \frac{100}{\sqrt{10x^2}}$

Since $V_L : V_C : V_R = 1 : 2 : 3$

$X_L = X_C : X_R = 1 : 2 : 3$

$= x : 2x : 3x$

now $V_R = I\ (3x)$

$= \frac{100}{\sqrt{10x^2}}\cdot 3x$

≈ 94.87 V

8. A capillary tube is immersed vertically in water and the height of the water column is x. When this arrangement is taken into a mine of depth d, the height of the water column is y. If R is the radius of earth, the ratio $\frac{x}{y}$ is :

(1) $\left(1-\frac{2d}{R}\right)$ (2) $\left(1-\frac{d}{R}\right)$

(3) $\left(\frac{R-d}{R+d}\right)$ (4) $\left(\frac{R+d}{R-d}\right)$

Ans. (2)

Sol. height talances additional presence hence

$\rho g_s x = \rho\ g_{depth}\ y$

$g_s\ x = g_s(1 - d/R)y$

$\frac{x}{y} = 1-\frac{d}{R}$

9. In materials like aluminium and copper, the correct order of magnitude of various elastic modulii is :

(1) Bulk modulii < shear modulii < Young's modulii.

(2) Young's modulii < shear modulii < bulk modulii.

(3) Bulk modulii < Young's modulii < shear modulii.

(4) Shear modulii < Young's modulii < bulk modulii.

Ans. (4)

10. Three capacitances, each of 3 μF, are provided. These cannot be combined to provide the resultant capacitance of :

(1) 4.5 μF (2) 1 μF (3) 2μF (4) 6μF

Ans. (4)

Sol. When all in series

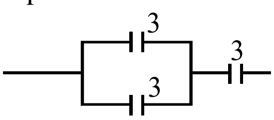
$$\frac{1}{C_{eq}} = \frac{3}{3}$$

C_{eq} = 1μF (2 not possible)

when 3 is parallel

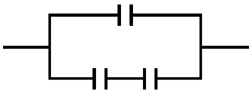
C_{eq} = 9μF

2 parallel 1 series



$C_{eq} = \frac{6\times3}{9}$ = 2μF (3 option not possible)

2 series 1 parallel



$\frac{3\times3}{6}+3$ = 4.5 μF

(1 option not possible)

Hence answer is (4)

11. The amplitude of a simple pendulum, oscillating in air with a small spherical bob, decreases from 10 cm to 8 cm in 40 seconds. Assuming that Stokes law is valid, and ratio of the coefficient of viscosity of air to that of carbon dioxide is 1.3, the time in which amplitude of this pendulum will reduce from 10 cm to 5 cm in carbondioxide will be close to (ℓn 5 = 1.601, ℓn 2 = 0.693).

(1) 161 s (2) 208 s (3) 231 s (4) 142 s

Ans. (1)

Sol. $8 = 10e^{-\lambda \times 40}$

$$5 = 10e^{-\frac{\lambda t}{1.3}}$$

$$\ln\frac{4}{5} = -\lambda\times40$$

$2 \times 0.693 - 1.601 = -\lambda \times 40$

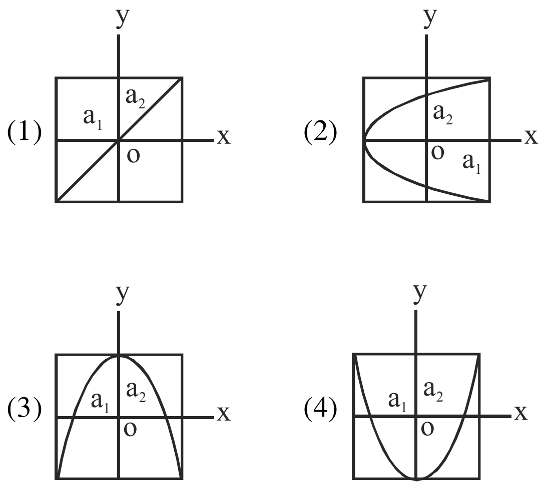
$\lambda = 0.005375$

$$\ln\frac{1}{2} = -\frac{\lambda t}{1.3}$$

$$-0.693 = -\frac{0.005375}{1.3}t$$

t = 167.6

12. A particle which is simultaneously subjected to two perpendicular simple harmonic motions represented by ; $x=a_1 \cos \omega t$ and $y = a_2 \cos 2\omega t$ traces a curve given by :



Ans. (4)

Sol. $y = a_2 [2 \cos^2\omega t - 1]$

$$= a_2\left[2\cdot\frac{x^2}{a_1^2}-1\right]$$

$$y = \frac{2a_2}{a_1^2}x^2 - a_2$$

at x = 0, y is negative and this is a equation parabola. Hence answer is 4.

13. Match **List I** (Wavelength range of electromagnetic spectrum) with **List II**. (Method of production of these waves) and select the **correct** option from the options given below the lists.

List I		**List II**	
(a)	700 nm to 1 mm	(i)	Vibration of atoms and molecules.
(b)	1 nm to 400 nm	(ii)	Inner shell electrons in atoms moving from one energy level to a lower level.
(c)	$< 10^{-3}$ nm	(iii)	Radioactive decay of the nucleus.
(d)	1 mm to 0.1 m	(iv)	Magnetron valve.

	(a)	(b)	(c)	(d)
(1)	(iii)	(iv)	(i)	(ii)
(2)	(i)	(ii)	(iii)	(iv)
(3)	(ii)	(iii)	(iv)	(i)
(4)	(iv)	(iii)	(ii)	(i)

Ans. (2)

Sol. 10^{19}

$E = \frac{hC}{\lambda} = hV$ $\quad \lambda = \frac{C}{V} = \frac{10^8}{10^{19}}$

$= 10^{-11}$ m $\quad = 10^{-2}$ nm

Magnetron valve generate microwaves.

14. The position of a projectile launched from the origin at t = 0 is given by $\vec{r} = \left(40\hat{i} + 50\hat{j}\right)$ m at t = 2s. If the projectile was launched at an angle θ from the horizontal, then θ is (take g =10 ms^{-2}).

(1) $\tan^{-1}\frac{4}{5}$ (2) $\tan^{-1}\frac{3}{2}$

(3) $\tan^{-1}\frac{2}{3}$ (4) $\tan^{-1}\frac{7}{4}$

Ans. (4)

Sol. $2u_x = 40 \Rightarrow 4x = 20$

$50 = 24y - \frac{1}{2} \times 10 \times 2^2 \Rightarrow 4y = 35$

$\tan\theta = \frac{u_y}{u_x} = \frac{35}{20} = \frac{7}{4}$

$\theta = \tan^{-1}\left(\frac{7}{4}\right)$

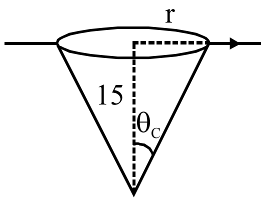
15. A diver looking up through the water sees the outside world contained in a circular horizon. The refractive index of water is $\frac{4}{3}$, and the diver's eyes are 15 cm below the surface of water. Then the radius of the circle is :

(1) $15 \times 3\sqrt{7}$ cm (2) $\frac{15 \times 3}{\sqrt{7}}$ cm

(3) $\frac{15 \times \sqrt{7}}{3}$ cm (4) $15 \times 3 \times \sqrt{5}$ cm

Ans. (2)

Sol. $\sin\theta_C = \frac{1}{4/3} = \frac{3}{4}$



$\tan\theta_C = \frac{3}{\sqrt{7}} = \frac{r}{h}$

$r = \frac{3}{\sqrt{7}} \times 15$

16. An experiment is performed to obtain the value of acceleration due to gravity g by using a simple pendulum of length L. In this experiment time for 100 oscillations is measured by using a watch of 1 second least count and the value is 90.0 seconds. The length L is measured by using a meter scale of least count 1 mm and the value is 20.0 cm. The error in the determination of g would be :

(1) 1.7% (2) 2.7% (3) 4.4% (4) 2.27%

Ans. (2)

Sol. $T^2 = \frac{4\pi^2\ell}{g}$

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

$\frac{\Delta g}{g} \times 100 = \left(\frac{\Delta\ell}{\ell} \times 100\right) + 2\left(\frac{\Delta T}{T} \times 100\right)$

$= \left(\frac{0.1}{20} \times 100\right) + 2\left(\frac{0.01}{.9} \times 100\right)$

$= 0.5 + 2 \times \frac{10}{9} = 0.5 + 2.2 = 2.7\%$

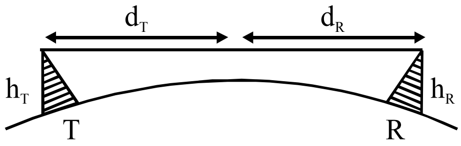
17. A transmitting antenna at the top of a tower has a height 32 m and the height of the receiving antenna is 50 m. What is the maximum distance between them for satisfactory communication in line of sight (LOS) mode ?

(1) 55.4 km (2) 54.5 km

(3) 455 km (4) 45.5 km

Ans. (4)

Sol.



$d_T = \sqrt{2Rh_T} = \sqrt{2\times6400\times10^3\times32}$

$= 202 \times 10^2$ m $= 20.20$ km

$d_R = \sqrt{2Rh_R} = \sqrt{2\times6400\times10^3\times50}$

$= 25.3$ km

$\therefore d = d_T + d_R = 20.2 + 25.3 = 45.5$ km

18. The magnitude of the average electric field normally present in the atmosphere just above the surface of the Earth is about 150 N/C, directed inward towards the center of the Earth. This gives the total net surface charge carried by the Earth to be :

[Given $\epsilon_0 = 8.85 \times 10^{-12}$ $C^2/N\text{–}m^2$, $R_E = 6.37 \times 10^6$ m]

(1) + 680 kC (2) – 680 kC

(3) – 670 kC (4) + 670 kC

Ans. (3)

Sol. $E = \frac{1}{4\pi\varepsilon_0}\frac{\theta}{R^2} = \frac{\sigma}{\varepsilon_0} \Rightarrow \sigma = \varepsilon_0 E$

$= 8.85 \times 10^{-12} \times 150$

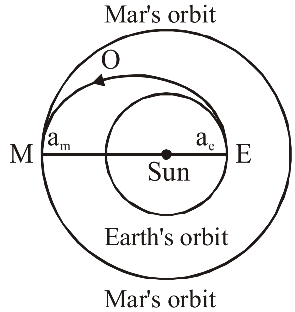
$Q = \varepsilon_0 E \times 4\pi R^2$

$= 6.76 \times 10^5 \times 10^{-12} \times 10^{+12}$

$= 680$ kC

for inward will be negative.

19. India's Mangalyan was sent to the Mars by launching it into a transfer orbit EOM around the sun. It leaves the earth at E and meets Mars at M. If the semi-major axis of Earth's orbit is $a_e = 1.5 \times 10^{11}$m, that of Mar's orbit $a_m = 2.28 \times 10^{11}$m, taken Kepler's laws give the estimate of time for Mangalyan to reach Mars from Earth to be close to :



(1) 500 days (2) 320 days

(3) 260 days (4) 220 days

Ans. (3)

Sol. $r = \frac{1.5+2.28}{2} = 1.89$

$\frac{T_m}{T_e} = \left(\frac{1.89}{1.5}\right)^{3/2}$

$t_m = \frac{T_m}{2} = \left(\frac{1.89}{1.5}\right)^{3/2}$

$= \frac{365}{2}\times1.41 = 257.3$ day

20. Water of volume 2 L in a closed container is heated with a coil of 1 kW. While water is heated, the container loses energy at a rate of 160 J/s. In how much time will the temperature of water rise from 27°C to 77°C ? (Specific heat of water is 4.2 kJ/kg and that of the container is negligible).

(1) 14 min (2) 8 min 20 s

(3) 7 min (4) 6 min 2s

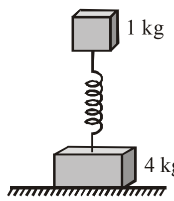
Ans. (2)

Sol. 1000 – 160 = 840 J/s

t-840 = $2 \times 4.2 \times 10^3 \times 50$

$t = \frac{500}{60}$ = 8 min 20 s.

21. Two bodies of masses 1 kg and 4 kg are connected to a vertical spring, as shown in the figure. The smaller mass executes simple harmonic motion of angular frequency 25 rad/s, and amplitude 1.6 cm while the bigger mass remains stationary on the ground. The maximum force exerted by the system on the floor is (take g = 10 ms^{-2}).



(1) 20 N (2) 10 N (3) 40 N (4) 60 N

Ans. (4)

Sol. T-mg = Mw^2A

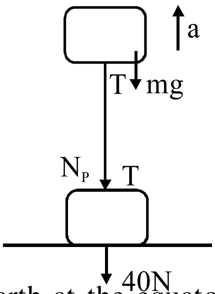
$= 1 \times 625 \times \frac{1.6}{100}$

= 10 N

T = 20 N

N = T + 40

= 60 N



22. The magnetic field of earth at the equator is approximately 4×10^{-5} T. The radius of earth is 6.4×10^6 m. Then the dipole moment of the earth will be nearly of the order of:

(1) 10^{20} A m^2 (2) 10^{23} A m^2

(3) 10^{10} A m^2 (4) 10^{16} A m^2

Ans. (2)

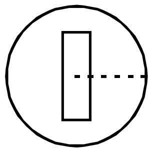
Sol. $B = 4 \times 10^{-5}$T

$B = \frac{\mu_0}{4\pi} \times \frac{M}{r^3} = 10^{-7} \times \frac{M}{(6.4 \times 10^6)^3} = 4 \times 10^{-5}$

$M = \frac{4 \times 10^{-5} \times 10^{18} \times 6.4^3}{10^{-7}}$

$= 1.048 \times 10^{3+18+7-5}$

$= 10^{23}$



23. The focal lengths of objective lens and eye lens of a Gallelian Telescope are respectively 30 cm and 3.0 cm. Telescope produces virtual, erect image of an object situated far away from it at least distance of distinct vision from the eye lens. In this condition, the Magnifying Power of the Gallelian Telescope should be :

(1) + 8.8 (2) – 11.2 (3) + 11.2 (4) – 8.8

Ans. (2)

Sol. f_0 = 30 cm f_e = 3cm

$M = \frac{f_0}{f_c}\left(1 - \frac{f_C}{D}\right)$

$= \frac{30}{3}\left(1 - \frac{3}{25}\right)$

$= \frac{22 \times 30}{3 \times 25} = \frac{44}{5} = +8.8$

24. Modern vacuum pumps can evacuate a vessel down to a pressure of 4.0×10^{-15} atm. at room temperature (300 K). Taking R= 8.3 JK^{-1} $mole^{-1}$, 1 atm=10^5 Pa and $N_{Avogadro} = 6 \times 10^{23}$ $mole^{-1}$, the mean distance between molecules of gas in an evacuated vessel will be of the order of :

(1) 0.2 nm (2) 0.2 cm

(3) 0.2 mm (4) 0.2μm

Ans. (3)

Sol. $\lambda = \frac{kT}{\sqrt{2}\pi d^2 P}$

$= \frac{1.38 \times 10^{-23} \times 300}{\sqrt{2}\pi \times 10^{-20} \times 4 \times 10^{-10}}$

$= \frac{1.38 \times 3}{\sqrt{2} \times 4\pi} \times 10^{-9}$

= 0.2 nm

25. An n-p-n transistor has three leads A, B and C. Connecting B and C by moist fingers, A to the positive lead of an ammeter, and C to the negative lead of the ammeter, one finds large deflection. Then, A, B and C refer respectively to :

(1) Emitter, base and collector

(2) Base, emitter and collector

(3) Base, collector and emitter

(4) Collector, emitter and base.

Ans. (1)

26. Water is flowing at a speed of 1.5 ms^{-1} through a horizontal tube of cross-sectional area 10^{-2} m^2 and you are trying to stop the flow by your palm. Assuming that the water stops immediately after hitting the palm, the minimum force that you must exert should be (density of water = 10^3 kgm^{-3}).

(1) 33.7N (2) 15N (3) 22.5N (4) 45N

Ans. (3)

Sol. $F = v\frac{dm}{dt}$

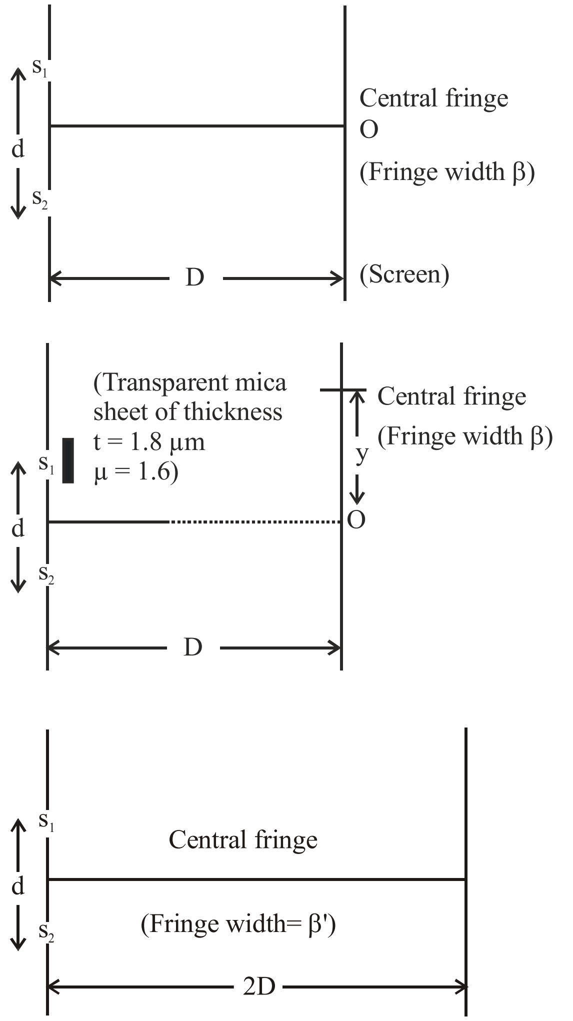
= v Apv

= v^2Ap

= $(1.5)^2 \times 10^{-2} \times 10^3$

= 2.25×10 = 22.5 N

27. Using monochromatic light of wavelength λ, an experimentalist sets up the Young's double slit experiment in three ways as shown. If she observes that $y=\beta'$, the wavelength of light used is



(1) 580 nm (2) 560 nm
(3) 520 nm (4) 540 nm

Ans. (4)

Sol. $B' = y$

$(\mu - 1)t = d\sin\theta$

$= d\theta = \dfrac{dy}{D}$

$$y = \frac{D(\mu-1)}{d}t$$

$$\frac{(2D)\lambda}{d} = \frac{D(\mu-1)t}{d}$$

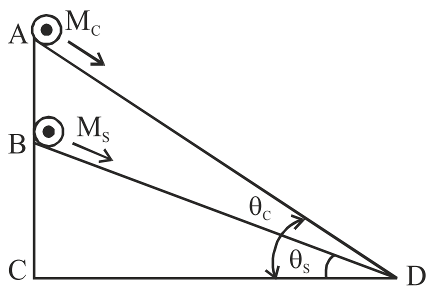
$$\lambda = \frac{(\mu-1)t}{2} = \frac{(1.6-1)\times 1.8\mu m}{2}$$

$= 0.6 \times 0.9\ \mu m$

$= .54\ \mu m$

$= 540$ nm

28. A cylinder of mass M_c and sphere of mass M_s are placed at points A and B of two inclines, respectively. (See Figure). If they roll on the incline without slipping such that their accelerations are the same, then ratio $\dfrac{\sin\theta_C}{\sin\theta_S}$ is:



(1) $\dfrac{15}{14}$ (2) $\dfrac{8}{7}$ (3) $\sqrt{\dfrac{15}{14}}$ (4) $\sqrt{\dfrac{8}{7}}$

Ans. (1)

Sol. $$\frac{g\sin\theta_c}{1+\frac{1}{2}} = \frac{g\sin\theta_s}{1+\frac{2}{5}}$$

$$\frac{\sin\theta_c}{\sin\theta_s} = \frac{3/2}{7/5} = \frac{15}{14}$$

29. For which of the following particles will it be most difficult to experimentally verify the de-Broglie relationship?

(1) a dust particle (2) an electron
(3) a proton (4) an α-particle

Ans. (1)

30. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is :

(1) 13.6 eV (2) 30.6 eV
(3) 122.4 eV (4) 3.4 eV

Ans. **(2)**

Sol. B.E. $= 3.4 \times 9 = 3.6$ eV