JEE MAIN 2024
Paper with Solution

PHYSICS | 29th January 2024 _ Shift-1

SECTION – A

31. The de-Broglie wavelength of an electron is the same as that of a photon. If velocity of electron is 25% of the velocity of light, then the ratio of K.E. of electron and K.E. of photon will be:

(1) $\frac{1}{4}$ (2) $\frac{1}{1}$ (3) $\frac{8}{1}$ (4) $\frac{1}{8}$

Sol. **4**

For photon, $E = \frac{hC}{\lambda_p}$

$\lambda_p = \frac{hC}{E_p}$

for electron, $\lambda_e = \frac{h}{m_e v_e \times \frac{2}{2} \times \frac{v_e}{v_c}}$

$= \frac{h}{\frac{1}{2} m_e v_e^2 \times \frac{2}{v_e}}$

$= \frac{h \times v_e}{2k_E}$

$= \frac{h\frac{c}{4}}{2kE_e}$

$\lambda_e = \frac{hC}{8kE_e}$

given :- $\lambda_e = \lambda_p$

$\frac{hC}{8kE_e} = \frac{hC}{E_p}$

$\boxed{\frac{1}{8} = \frac{kE_e}{E_p}}$

32. If the radius of curvature of the path of two particles of same mass are in the ratio 3: 4, then in order to have constant centripetal force, their velocities will be in the ratio of:

(1) $1:\sqrt{3}$ (2) $\sqrt{3}:1$ (3) $\sqrt{3}:2$ (4) $2:\sqrt{3}$

Sol. **3**

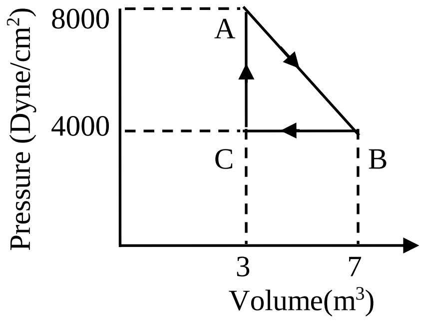
$F_1 = F_2$

$\frac{\cancel{m} v_1^2}{R_1} = \frac{\cancel{m} v_2^2}{R_2}$

$\left(\frac{v_1}{v_2}\right)^2 = \frac{R_1}{R_2}$

$\frac{v_1}{v_2} = \left(\frac{3}{4}\right)^{\frac{1}{2}} = \frac{\sqrt{3}}{2}$

33. A thermodynamic system is taken from an original state A to an intermediate state B by a linear process as shown in the figure. It's volume is then reduced to the original value from B to C by an isobaric process. The total work done by the gas from A to B and B to C would be :



(1) 2200 J (2) 1200 J (3) 33800 J (4) 600 J

Sol. **Bonus**

Work done from A to B

= area under line AB

= area of trapezium

$= \frac{1}{2} \times (8000 + 4000)(\text{dyne/cm}^2) \times 4\ \text{m}^3$

$= 12000 \times \frac{10^{-5}\,\text{N}}{10^{-4}\,\text{m}^2} \times \text{m}^3 \times 2$

= 2400 J

Work done from B to C

= area under line BC

$= 4000(\text{dyne/cm}^2) \times 4\text{m}^3$

$= 4000 \times \frac{10^{-5}}{10^{-4}} \times 4$

= 1600 J (–ve work)

total = 2400 – 1600 = 800 J

34. A body starts moving from rest with constant acceleration covers displacement S_1 in first (p-1) seconds and S_2 in first p seconds. The displacement $S_1 + S_2$ will be made in time:

(1) $\sqrt{(2p^2 - 2p + 1)}$s (2) $(2p^2 - 2p + 1)$s (3) $(2p + 1)$s (4) $(2p - 1)$s

Sol. **1**

$$S_1 = \frac{1}{2}a(p-1)^2 = \frac{1}{2}a(p^2 + 1 - 2p)$$

$$S_2 = \frac{1}{2}ap^2$$

$$S_1 + S_2 = \frac{1}{2}ap^2 + \frac{1}{2}ap^2 + \frac{a}{2} - ap$$

$$\frac{1}{2}at^2 = ap^2 - ap + \frac{a}{2}$$

$$t^2 = \frac{2\not{a}}{\not{a}}\left(p^2 - p + \frac{1}{2}\right)$$

$$t = \sqrt{2\left(p^2 - p + \frac{1}{2}\right)}$$

$$= \sqrt{2p^2 - 2p + 1}$$

35. Given below are two statements:

Statement I : If a capillary tube is immersed first in cold water and then in hot water, the height of capillary rise will be smaller in hot water.

Statement II : If a capillary tube is immersed first in cold water and then in hot water, the height of capillary rise will be smaller in cold water.

In the light of the above statements, choose the most appropriate from the options given below

(1) **Statement I** is false but **Statement II** is true

(2) Both **Statement I** and **Statement II** are false

(3) **Statement I** is true but **Statement II** is false

(4) Both **Statement I** and **Statement II** are true

Sol. **3**

$$h = \frac{2T\cos\theta}{\rho g r}$$

as temperature increases surface tension decreases so h decreases.

36. Match List I with List II

LIST I		**LIST II**	
A.	$\oint \vec{B}.\vec{dl} = \mu_0 i_c + \mu_0 \varepsilon_0 \frac{d\phi_E}{dt}$	I.	Gauss law for electricity
B.	$\oint \vec{E}.\vec{dl} = \frac{d\phi_B}{dt}$	II.	Gauss law for magnetism
C.	$\oint \vec{E}.\vec{dA} = \frac{Q}{\varepsilon_0}$	III.	Faraday law
D.	$\oint \vec{B}.\vec{dA} = 0$	IV.	Ampere – Maxwell law

Choose the correct answer from the options given below :

(1) A-II, B=III, C-I, D-IV (2) A-IV, B=I, C-III, D-II

(3) A-IV, B=III, C-I, D-II (4) A-I, B=II, C-III, D-IV

Sol. **3**

37. The explosive in a Hydergine bomb is a mixture of ${}_1H^2$, ${}_1H^3$ and ${}_3Li^6$ in some condensed form. The chains reaction is given by

${}_3Li^6 + {}_0n1 \rightarrow {}_2He^4 + {}_1H^3$

${}_1H^2 + {}_1H^3 \rightarrow {}_2He^4 + {}_0n^1$

During the explosion the energy released is approximately

[Given ; M (Li) = 6.01690 amu, M(${}_1H^2$) = 2.01471 amu, M (${}_2He^4$) = 4.00388 amu, and 1 amu = 931.5 MeV]

(1) 28. 12 MeV (2) 16.48 MeV (3) 12.64 MeV (4) 22.22 MeV

Sol. **4**

${}_3L_i{}^6 + {}_0\cancel{n}^1 \rightarrow {}_2He^4 + \cancel{{}_1H^3}$

${}_1H^2 + \cancel{{}_1H^3} \rightarrow {}_2H_e{}^4 + {}_0\cancel{n}^1$

${}_3L_1{}^6 + {}_1H^2 \rightarrow 2\,{}_2H_e{}^4$

$\Delta m = [M(L_i) + M(H)] - [2M(He)]$

$= [6.01690 + 2.01471] - [2 \times 4.00388]$

$= 8.03161 - 8.00776$

$\Delta m = 0.02385$

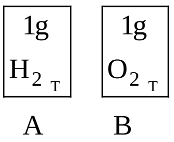
$E = \Delta m \times 931.5$ Mev

$= 22.22$ MeV

38. Two vessels A and B are of the same size and are at same temperature A contains 1g of hydrogen and B contains 1g of oxygen. P_A and P_B are the pressures of the gases in A and B respectively, then $\frac{P_A}{P_B}$ is :

(1) 8 (2) 16 (3) 32 (4) 4

Sol. **2**



$P = \frac{nRT}{V}$

as T & V are same so

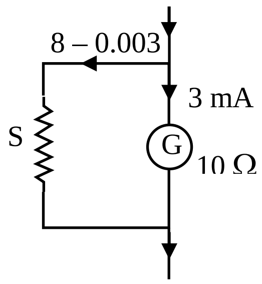
$P \propto n$

$\frac{P_A}{P_B} = \frac{n_A}{n_B} = \frac{1g \times 32}{2 \times 1g} = 16$

39. A galvanometer having coil resistance 10 Ω shows a full scale deflection for a current of 3 mA. For it to measure a current of 8 A, the value of the shunt should be:

(1) 4.85×10^{-3} Ω (2) 3×10^{-3} Ω (3) 3.75×10^{-3} Ω (4) 2.75×10^{-3} Ω

Sol. **1**



$S \times (8 - 0.003) = 0.003 \times 10$

$S = \frac{0.03}{7.997}$

$= 3.75 \times 10^{-3}$ Ω

40. A convex mirror of radius of curvature 30 cm forms an image that is half the size of the object. The object distance is :

(A) -15 cm (B) -45 cm (C) 45 cm (D) 15 cm

Sol. **1**

$$m = \frac{f}{f-u} \qquad \left(f = \frac{R}{2}\right)$$

$$+\frac{1}{2} = \frac{+15}{15-u}$$

15 – u = 30

15 – 30 = u

u = – 15 cm

41. A biconvex lens of refractive index 1.5 has a focal length of 20 cm in air. Its focal length when immersed in a liquid of refractive index 1.6 will be:

(1) –16 cm (2) + 16 cm (3) 160 cm (4) – 160 cm

Sol. **4**

$$f = \frac{R}{2\left(\frac{\mu_L}{\mu_S}-1\right)}$$

$$20 = \frac{R}{2(1.5-1)} \qquad ...(1)$$

$$f' = \frac{R}{2\left(\frac{1.5}{1.6}-1\right)} \qquad ...(2)$$

$$\frac{20}{f'} = \frac{(1.5-1.6)/1.6}{1.5-1}$$

$$\frac{20}{f'} = \frac{-0.1}{1.6} \times \frac{1}{0.5} \Rightarrow f' = -160\text{cm}$$

42. The electric current through a wire varies with time as $I = I_0 + \beta t$, where $I_0 = 20$ A and $\beta = 3$ A/s. The amount of electric charge crossed through a section of the wire in 20 s is :

(1) 1600 C (2) 800 C (3) 80 C (4) 1000 C

Sol. **4**

$$i = \frac{dq}{dt}$$

$$\int_0^Q dq = \int_0^{20} i\,dt$$

$$= \int_0^{20} (i_0 + \beta t)dt$$

$$= \int_0^{20} (20 + 3t)dt$$

$$= 20[t]_0^{20} + 3\left[\frac{t^2}{2}\right]_0^{20}$$

$$= 400 + \frac{3}{2}\left[20^2 - 0\right]$$

= 400 + 600 = 1000 C

43. The deflection in moving coil galvanometer falls from 25 divisions to 5 division when a shunt of 24Ω is applied. The resistance of galvanometer coil will be :

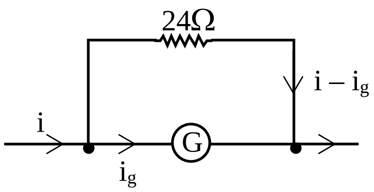
(1) 100 Ω (2) 48 Ω (3) 12 Ω (4) 96 Ω

Sol. **4**

$i \propto \theta$

$\frac{i_g}{i} = \frac{5}{25}$

$\boxed{5i_g = i}$



Potential is same across galvanometer shunt

$Si_5 = i_g G$

$S(i - i_g) = i_g G$

$24\,(5i_g - i_g) = i_g G$

$24 \times 4\ i_g = i_g G$

$G = 24 \times 4 = 96$

44. A block of mass 100 kg slides over a distance of 10 m on a horizontal surface. If the co-efficient of friction between the surfaces is 0.4 , then the work done against friction (in J) is :

(1) 4000 (2) 3900 (3) 4200 (4) 4500

Sol. **1**

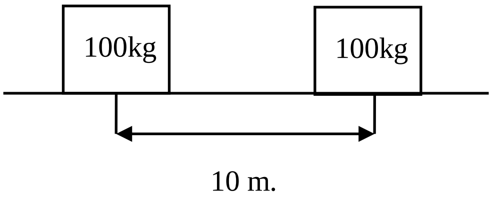
$W.D = f_s.\ s$

$W.D = \mu mg(10)$

$= (0.4)\,(100)(10)(10)$

$W.D = 4000\ J$

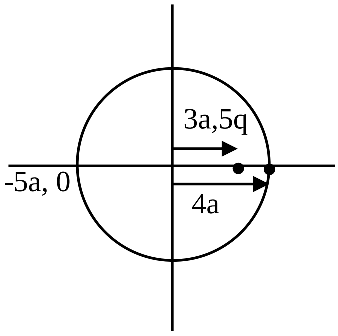
W.D Against friction = 4000 J



45. Two charges of 5Q and –2Q are situated at the points (3a, 0) and (-5a, 0) respectively. The electric flux through a sphere of radius '4a' having center at origin is :

(1) $\frac{3Q}{\varepsilon_0}$ (2) $\frac{5Q}{\varepsilon_0}$ (3) $\frac{7Q}{\varepsilon_0}$ (4) $\frac{2Q}{\varepsilon_0}$

Sol. **2**



gauss law,

$\phi = \frac{q_{in}}{\epsilon_0} = \frac{5q}{\epsilon_0}$

46. A capacitor of capacitance 100 μF is charged to a potential of 12 V and connected to a 6.4 mH inductor to produce oscillations. The maximum current in the circuit would be :

(1) 1.2 A (2) 1.5 A (3) 3.2 A (4) 2.0 A

Sol. **2**

$$\frac{Q_{max}}{2C} = \frac{1}{2}Li^2$$

C = 100μf, V = 12 V.

$L = 6.4 \times 10^{-3}$,

Q_{max} = CV

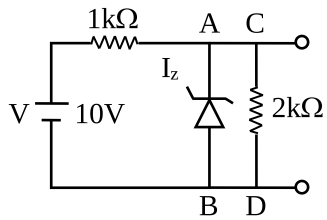
$$= \frac{\left(100\times10^{-6}\times12\right)^2}{\cancel{2}\times100\times10^{-6}} = \frac{1}{\cancel{2}}\times6.4\times10^{-3}\times i^2$$

$$\frac{12^2\times10^{-\cancel{8}-3}}{10^{-4}} = 6.4\times10^{\cancel{-3}}\times i^2$$

$$\sqrt{\frac{12^2\times10^{-1}}{6.4}} = i\sqrt{2.25}$$

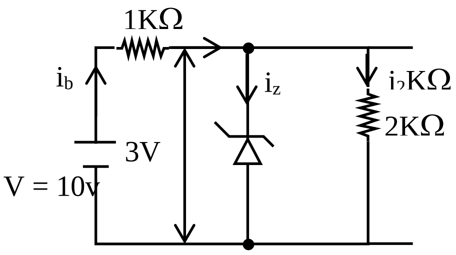
$$\boxed{i = 1.25}$$

47. In the given circuit, the breakdown voltage of the Zener diode is 3.0 V. What is the value of I_z ?



(1) 7 mA (2) 5.5 mA (3) 10 mA (4) 3.3 mA

Sol. **4**



$$i_{battery} = \frac{10-3}{1000}$$

$i_{battery}$ = 7 mA

$$i\Omega = \frac{V}{R} = \frac{3}{2000}$$

$i_{2K\Omega}$ = 1.5 mA

$i_z = i_b - i_{2K\Omega}$

$$\boxed{i_z = (7-1.5) = 5.5mA}$$

48. At what distance above and below the surface of the earth a body will have same weight. (take radius of earth as R.)

(1) $\frac{R}{2}$ (2) $\sqrt{5}R - R$ (3) $\frac{\sqrt{3}R - R}{2}$ (4) $\frac{\sqrt{5}R - R}{2}$

Sol. **4**

$$\frac{GMm}{(R+x)^2} = \frac{GMm(R-x)}{R^3}$$

$R^3 = (R + x)^2 (R - x)$

$R^3 = (R^2 - x^2)(R + x)$

$x^2 + Rx - R^2 = 0$

$$x = \frac{-R \pm \sqrt{R + 4R^2}}{2}$$

$$\boxed{x = \frac{\sqrt{5}R - R}{2}}$$

49. The resistance $R = \frac{V}{I}$ where V = (200 ± 5) V and I = (20 ± 0.2)A, the percentage error in the measurement of R is :

(1) 3.5% (2) 5.5% (3) 7% (4) 3%

Sol. **1**

V = (200 ± 5) vol. I = (20 ± 0.2)A

$\% \text{ error} = \frac{dV}{V} + \frac{dI}{I}$ $R = \frac{V}{I}$

$= \left(\frac{5}{200} + \frac{0.2}{20}\right) \times 100$

= 3.5%

50. The potential energy function (in J) of a particle in a region of space is given as $U = (2x^2 + 3y^3 + 2z)$. Here x, y and z are in meter. The magnitude of x-component of force (in N) acting on the particle at point P(1,2,3) m is :

(1) 6 (2) 2 (3) 8 (4) 4

Sol. **4**

$u = 2x^2 + 3y^3 + 2z,$

$$F = -\left[\frac{\partial}{\partial x}(2x^2)\hat{i} + \frac{\partial}{\partial y}(3y^3)\hat{j} + \frac{\partial}{\partial z}(2z)\hat{k}\right]$$

sss

$$\vec{F}(1,2,3) = -4(1)\hat{i} - 9(2)^2\hat{j} - 2\hat{k}$$

$$\vec{F}_{net} = -4\hat{i} - 36\hat{j} - 2\hat{k}$$

$$\boxed{|\vec{F}_x| = 4}$$

SECTION – B

51. When the displacement of a simple harmonic oscillator is one third of its amplitude, the ratio of total energy to the kinetic energy is $\frac{x}{8}$, where x = _______.

Sol. **9**

Total energy = $\frac{1}{2}kA^2$

$$u = \frac{1}{2}K\left(\frac{A}{3}\right)^2 = \frac{KA^2}{2\times 9} = \frac{E}{9}$$

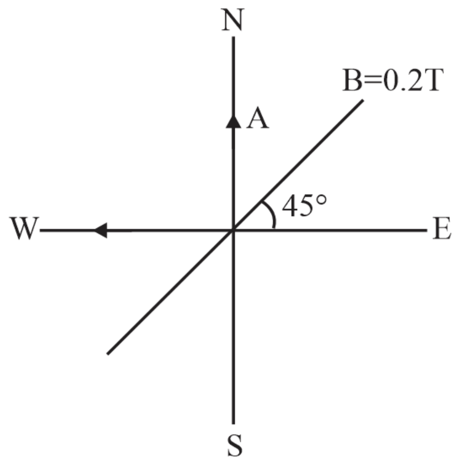
$$KE = E - \frac{E}{9} = \frac{8E}{9}$$

$$\text{Ratio, } \frac{\text{total}}{KE} = \frac{E}{\frac{8E}{9}} = \frac{9}{8}$$

x = 9

52. A square loop of side 10 cm and resistance 0.7 Ω is placed vertically in east-west plane. A uniform magnetic field of 0.20 T is set up across the plane in north east direction. The magnetic field is decreased to zero in 1 s at a steady rate. Then, magnitude of induced emf is $\sqrt{x}\times 10^{-3}$ V . The value of x is ______.

Sol. **2**



$$\vec{A} = (0.1)^2\hat{j}$$

$$\vec{B} = \frac{0.2}{\sqrt{2}}\hat{i} + \frac{0.2}{\sqrt{2}}\hat{j}$$

Mag. of Emf,

$$e = \frac{\Delta\phi}{\Delta t} = \frac{\vec{B}.\vec{A} - 0}{1} = \sqrt{2}\times 10^{-3}\,V$$

x = 2

53. In a test experiment on a model aeroplane in wind tunnel, the flow speeds on the upper and lower surfaces of the wings are 70 ms^{-1} and 65 ms^{-1} respectively. If the wing area is 2 m^2 , the lift of the wing is ______N. (Given density of air = 1.2 kg m^{-3})

Sol. **810**

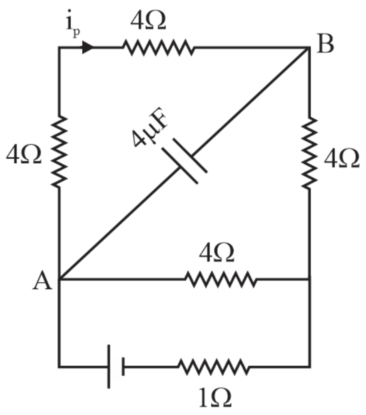
$F = \frac{1}{2}\rho\left(v_1^2 - V_2^2\right)A$

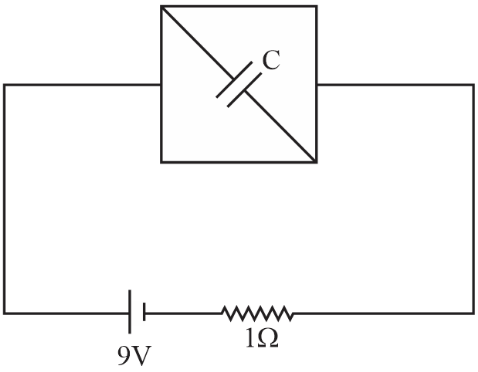
$= = \frac{1}{2}\times 1.2\times\left[70^2 - 65^2\right]\times 2$

$\vec{F} - = 810N$

54. A 16Ω wire is bend to form a square loop. A 9V battery with internal resistance 1Ω is connected across one of its sides. If a 4μF capacitor is connected across one of its diagonals, the energy stored by the capacitor will be $\frac{x}{2}\mu J$, where x = ______.

Sol. **81**





$i = \frac{V}{R_{eq}} = \frac{9}{1+\frac{12\times 4}{12+4}} = \frac{9}{4}$

$i_1 = \frac{9}{4}\times\frac{4}{16} = \frac{9}{16}$

$V_A - V_B = i_1 \times 8 = \frac{9}{16}\times 8 = \frac{9}{2}V$

$u = \frac{1}{2}\times 4\times\frac{81}{4} = \frac{81}{2}uJ$

x = 81

55. The magnetic potential due to a magnetic dipole at a point on its axis situated at a distance of 20 cm from its center is 1.5 × 10^{-5} Tm. The magnetic moment of the dipole is ______ Am^2. (Given : $\frac{\mu_0}{4\pi} = 10^{-7}TmA^{-1}$)

Sol. **6**

$V = \frac{\mu_0}{4\pi}\frac{M}{r^2}$

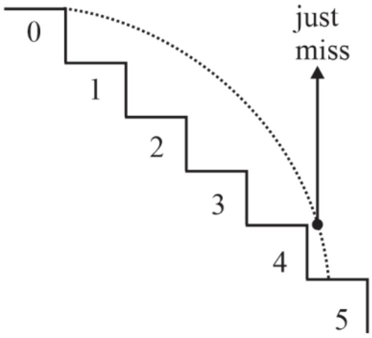
$\Rightarrow 1.5\times 10^{-5} = 10^{-7}\times\frac{M}{\left(20\times 10^{-2}\right)^2}$

$m = \frac{1.5\times 10^{-5}\times 20\times 20\times 10^{-4}}{10^{-7}}$

M = 1.5 × 4 = 6

56. A ball rolls off the top of a stairway with horizontal velocity u. The steps are 0.1 m high and 0.1 m wide. The minimum velocity u with which that ball just hits the step 5 of the stairway will be $\sqrt{x}\,ms^{-1}$ where x = _______ [use g = 10 m/s^2].

Sol. **2**



the ball needs to just cross 4 steps to just hit 5th step

$\therefore$ horizontal range (R) = 0.4 m

R = u.t

Similarly in vertical direction

$h = \frac{1}{2}gt^2$

$0.4 = \frac{1}{2}gt^2$

$0.4 = \frac{1}{2}g\left(\frac{0.4}{4}\right)^2$

$u^2 = 2$

$u = \sqrt{2} m/s$, x = 2

57. An electron is moving under the influence of the electric field of a uniformly charged infinite plane sheet S having surface charge density + σ. The electron at t = 0 is at a distance of 1 m from S and has a speed of 1 m/s. The maximum value of σ if the electron strikes S at t = 1 s is $\alpha\left[\frac{m \in_0}{e}\right]\frac{C}{m^2}$, the value of α is ______.

Sol. **8**

u = 1 m/s, $a = -\frac{\sigma e}{2\varepsilon_0 m}$

t = 1 sec

s = –1 m

using $S = ut + \frac{1}{2}at^2$

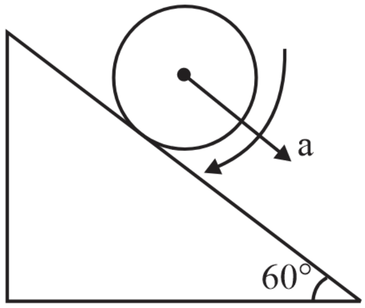
$-1 = 1 \times 1 + \left(-\frac{1}{2}\left(\frac{\sigma e}{2\varepsilon_0 m}\right)\right)(1)^2$

$\alpha = \frac{8\varepsilon.m}{e}$

$\alpha = 8$

58. A cylinder is rolling down on an inclined plane inclination 60°. It's acceleration during rolling down will be $\frac{x}{\sqrt{3}} m/s^2$, where x = ______ (use g = 10 m/s^2). Given -

Sol. **10**



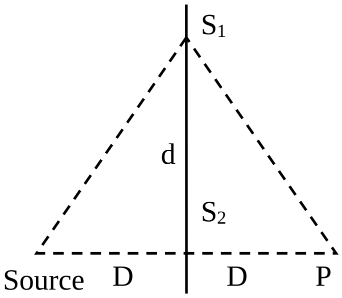
for rolling motion

$$a = \frac{g\sin\theta}{1+\frac{I_{COM}}{MR^2}}$$

$$a = \frac{g\sin\theta}{1+\frac{1}{2}} = \frac{2\times10\times\frac{\sqrt{3}}{2}}{3}$$

$$= \frac{10}{\sqrt{3}} = x = 10$$

59. In a double slit experiment shown in figure, when light of wavelength 400 nm is used, dark fringe is observed at P. If D = 0.2 m, the minimum distance between the slits S_1 and S_2 is _______ mm.



Sol. **0.20**

Path diff. for minima at P

$$2\sqrt{D^2+d^2} - 2D = \frac{\lambda}{2}$$

$$\therefore \sqrt{D^2+d^2} - D = \frac{\lambda}{4}$$

$$\sqrt{D^2+d^2} = \frac{\lambda}{4} + D$$

$$D^2 + d^2 = D^2 + \frac{\lambda^2}{16} + \frac{\lambda D}{2}$$

$d^2 = \frac{D\lambda}{2} + \frac{\lambda^2}{16}$

$d^2 = \frac{0.2 \times 400 \times 10^{-9}}{2} + \frac{4 \times 10^{-14}}{4}$

$d^2 \approx 400 \times 10^{-10}$ $\therefore$ $d = 20 \times 10^{-5}$

d = 0.20 mm

60. When a hydrogen atom going n = 2 to n = 1 emits a photon, its recoil speed is $\frac{x}{5}$ m / s . Where x = _____.

(Use, mass of hydrogen atom = 1.6×10^{-27} kg) Given -

Sol. **17**

Recoil speed

$V = \frac{\Delta E}{mC}$

$= \frac{10.2 eV}{1.6 \times 10^{-27} \times 3 \times 10^8}$

$= \frac{10.2 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-27} \times 3 \times 10^8}$

= V = 3.4 m/s = $\frac{17}{5}$ m/s

x = 17

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of **imparting education** for the **last 17 Years**

65136+ SELECTIONS SINCE 2007

JEE (Advanced)	JEE (Main)	NEET/AIIMS	NTSE/OLYMPIADS
12142	32584	17875 (Under 50000 Rank)	2535 (6th to 10th class)

Most Promising RANKS
Produced by MOTION Faculties

NEET / AIIMS

- **AIR-1 to 10** 25 Times
- **AIR-11 to 50** 84 Times
- **AIR-51 to 100** 84 Times

JEE MAIN+ADVANCED

- **AIR-1 to 10** 8 Times
- **AIR-11 to 50** 37 Times
- **AIR-51 to 100** 41 Times

Nation's Best SELECTION
Percentage (%) Ratio

Student Qualified in NEET

(2023)
6492/7084 = **91.64%**
(2022)
4837/5356 = **90.31%**

Student Qualified in JEE ADVANCED

(2023)
2747/5182 = **53.01%**
(2022)
1756/4818 = **36.45%**

Student Qualified in JEE MAIN

(2023)
5993/8497 = **70.53%**
(2022)
4818/6653 = **72.41%**

NITIN VIIJAY (NV Sir)
Founder & CEO

MOTION