IOQP - 61

Time: 9:00 AM to 10:00 AM
Question Paper Code: 61

Student's Roll No:														

Write the question paper code mentioned above on YOUR OMR Answer Sheet (in the space provided), otherwise your Answer Sheet will NOT be evaluated. Note that the same Question Paper Code appears on each page of the question paper.

Instructions to Candidates:

1. Use of mobile phone, smart watch, and iPad during examination is STRICTLY PROHIBITED.
2. In addition to this question paper, you are given OMR Answer Sheet along with candidate's copy.
3. On the OMR sheet, make all the entries carefully in the space provided **ONLY** in **BLOCK CAPITALS** as well as by properly darkening the appropriate bubbles.

   Incomplete/ incorrect/ carelessly filled information may disqualify your candidature.
4. On the OMR Answer Sheet, use only **BLUE** or **BLACK BALL POINT PEN** for making entries and filling the bubbles.
5. Your **fourteen-digit roll number and date of birth** entered on the OMR Answer Sheet shall remain your login credentials means login id and password respectively for accessing your performance / result in Indian Olympiad Qualifier in Physics 2020-21 (Part I).
6. Question paper has two parts. In part A1 (Q. No.1 to 24) each question has four alternatives, out of which only one is correct. Choose the correct alternative and fill the appropriate bubble, as shown.

   Q.No. 12 (a) ● (c) (d)

   In part A2 (Q. No. 25 to 32) each question has four alternatives out of which any number of alternative(s) (1, 2, 3, or 4) may be correct. You have to choose **all** correct alternative(s) and fill the appropriate bubble(s), as shown

   Q.No. 30 (a) ● (c) ●
7. For **Part A1**, each correct answer carries 3 marks whereas 1 mark will be deducted for each wrong answer. In **Part A2**, you get 6 marks if all the correct alternatives are marked and no incorrect. No negative marks in this part.
8. Rough work should be done only in the space provided. There are **08** printed pages in this paper.
9. Use of **non- programmable scientific** calculator is allowed.
10. No candidate should leave the examination hall before the completion of the examination.
11. After submitting answer paper, take away the question paper and candidate's copy of OMR for your reference

    Please DO NOT make any mark other than filling the appropriate bubbles properly in the space provided on the OMR answer sheet.

    OMR answer sheets are evaluated using machine, hence CHANGE OF ENTRY IS NOT ALLOWED. Scratching or overwriting may result in a wrong score.

    DO NOT WRITE ON THE BACK SIDE OF THE OMR ANSWER SHEET.

Instructions to Candidates (Continued) :

You may read the following instructions after submitting the answer sheet.

12. Comments/Inquiries/Grievances regarding this question paper, if any, can be shared on the Inquiry/Grievance column on www.iaptexam.in on the specified format till February 12, 2021.

13. The answers/solutions to this question paper will be available on the website: www.iapt.org.in by February 13, 2021.

14. CERTIFICATES and AWARDS:

Following certificates are awarded by IAPT to students, successful in the Indian Olympiad Qualifier in Physics 2020-21 (Part I)

(i) "CENTRE TOP 10 %"

(ii) "STATE TOP 1 %"

(iii) "NATIONAL TOP 1 %"

(iv) "GOLD MEDAL & MERIT CERTIFICATE" to all students who attend OCSC-2021 at HBCSE Mumbai

15. All these certificates (except gold medal) will be downloadable from IAPT website : www.iapt.org.in after March 15, 2020-21.

16. List of students (with centre number and roll number only) having score above MAS will be displayed on the website: www.iapt.org.in by **February 25, 2021. See the Minimum Admissible score Clause** on the Student's brochure on the web.

17. List of Students eligible for evaluation of IOQP 2020-21 (Part II) shall be displayed on www.iapt.org.in by March 1, 2021.

Physical constants you may need….

Mass of electron $m_e = 9.10\times10^{-31}$ kg	Magnitude of charge on electron $e = 1.60\times10^{-19}$ C
Mass of proton $m_p = 1.67\times10^{-27}$ kg	Permittivity of free space $\varepsilon_0 = 8.85\times10^{-12}\ C^2N^{-1}m^{-2}$
Acceleration due to gravity $g = 9.8\ ms^{-2}$	Permeability of free space $\mu_0 = 4\pi \times 10^{-7}\ Hm^{-1}$
Universal gravitational constant $G = 6.67\times10^{-11}\ Nm^2 Kg^{-2}$	Planck's constant $h = 6.625 \times 10^{-34}$ Js
Universal gas constant $R = 8.31\ Jmol^{-1} K^{-1}$	Faraday constant = 96,500 $Cmol^{-1}$
Boltzmann constant $k = 1.38\times10^{-23}\ JK^{-1}$	Rydberg constant $R = 1.097\times10^{7}\ m^{-1}$
Stefan's constant $\sigma = 5.67\times10^{-8}\ Wm^{-2}K^{-4}$	Speed of light in free space $c = 3 \times 10^{8}\ ms^{-1}$
Avogadro's constant $N_A = 6.023 \times 10^{23}\ mol^{-1}$	

Question Paper Code: 61

Time: 60 Minute **Max. Marks: 120**

Attempt All Thirty Two Questions

A - 1

ONLY ONE OUT OF FOUR OPTIONS IS CORRECT. BUBBLE THE CORRECT OPTION.

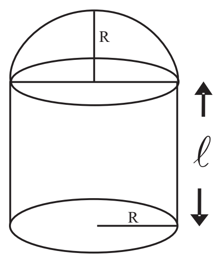
1. If speed of light c, Planck's constant h and gravitational constant G are chosen as fundamental quantities, dimensions of time in this system of units is

(a) $ch^{3/2}G^{-3/2}$ (b) $c^{-2}G^{1/2}h$ (c) $c^{2}G^{1/2}h^{5/2}$ (d) $c^{-5/2}G^{1/2}h^{1/2}$

2. A solid hemisphere is cemented on the flat surface of a solid cylinder of same radius R and same material. The composite body is rotating about the axis of the cylinder of length ℓ with angular speed ω. The radius of gyration K is

(a) $R\sqrt{\frac{2}{5}\left(\frac{15R+8\ell}{3R+2\ell}\right)}$ (b) $R\sqrt{\frac{1}{10}\left(\frac{15\ell+8R}{3\ell+2R}\right)}$

(c) $R\sqrt{\frac{3}{10}\left(\frac{15R+8\ell}{3R+2\ell}\right)}$ (d) $R\sqrt{\frac{1}{10}\left(\frac{3\ell+2R}{15\ell+8R}\right)}$



3. The shortest period of rotation of a planet (considered to be a sphere of uniform density ρ) about its own axis, such that any mass m kept on its equator is just to fly off the surface, is

(a) $T=\sqrt{\frac{5\pi}{\rho G}}$ (b) $T=\sqrt{\frac{\pi}{3\rho G}}$ (c) $T=\sqrt{\frac{3\pi}{\rho G}}$ (d) $T=\sqrt{\frac{5\pi}{3\rho G}}$

4. A body of mass 10 kg at rest explodes into two fragments of masses 3 kg and 7 kg. If the total kinetic energy of two pieces after explosion is 1680 J, the magnitude of their relative velocity in m/s after explosion is:

(a) 40 (b) 50 (c) 70 (d) 80

5. A shot is fired at an angle α to the horizontal up a hill (Considered to be a long straight incline plane) of inclination β to the horizontal. It will strike the hill horizontally if

(a) $\tan\alpha = 2\tan\beta$ (b) $\sin\alpha = \sin 2\beta$ (c) $\sin\alpha = 2\sin\beta$ (d) $\tan\alpha = 4\tan\beta$

6. A particle is executing Simple Harmonic Motion of time period $T = 4\pi^2$ in a straight line. Starting from rest, it travels a distance 'a' in the first second and distance 'b' in the next second travelling in the same direction. The amplitude of SHM is

(a) $\frac{2a^2}{3a-b}$ (b) $\frac{3a^2}{3a-2b}$ (c) $\frac{2a^2}{2a-b}$ (d) none of these

7. The kinetic energy of a particle moving along a circle of radius R depends upon the distance covered 's' as $KE = as^2$ where a is a constant. The magnitude of the force acting on the particle as a function of 's' is

(a) $\frac{2as^2}{R}$ (b) $\frac{2as^2}{m}$ (c) 2as (d) $2as\sqrt{1+\left(\frac{s}{R}\right)^2}$

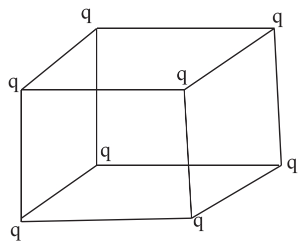
8. The flow of water in a horizontal pipe is stream line flow. Along the pipe, at a point, where cross - sectional area is 10 cm^2, the velocity of water flow is 1.00 ms^{-1} and the pressure is 2000 Pa. The pressure of water at another point where cross - sectional area is 5 cm^2 is

(a) 2000 Pa (b) 1500 Pa (c) 3500 Pa (d) 500 Pa

9. Three containers A, B and C are filled with water at different temperature. When 1 litre of water from A is mixed with 2 litre of water from B, the resulting temperature of mixture is 52^0 C. When 1 litre of water from B is mixed with 2 litre of water from C, the resulting temperature of mixture is 40^0 C. Similarly when 1 litre of water from C is mixed with 2 litre of water from A, the resulting temperature of mixture is 34^0 C. Temperature of mixture when one litre of water from each container is mixed (neglect the water equivalent of container) is

(a) 40^0C (b) 42^0C (c) 38^0C (d) 45^0C

10. Point charge q is kept at each corner of a cube of edge length ℓ. The resultant force of repulsion on any one of the charges due to all others is expressed as



(a) $\frac{\left(1+\frac{1}{2\sqrt{2}}+\frac{1}{3\sqrt{3}}\right)q^2}{\pi\varepsilon_0\ell^2}$ (b) $\frac{\left(\frac{1}{2\sqrt{2}}-1+\frac{1}{3\sqrt{3}}\right)q^2}{\pi\varepsilon_0\ell^2}$

(c) $\frac{(1-0.1775)q^2}{\pi\varepsilon_0\ell^2}$ (d) none of these

11. In an experiment with potentiometer, the balancing length is 250 cm for a cell. When the cell is shunted by a resistance of 7.5 Ω, balancing point is shifted by 25 cm. If the cell is shunted by a resistance of 20 Ω, the balancing length will be nearly

(a) 240 cm (b) 236 cm (c) 232 cm (d) 230 cm

12. One mole of a gas with $\gamma = \frac{5}{3}$ is mixed with two moles of another non-interacting gas with $\gamma = \frac{7}{5}$ The ratio of specific heats $\gamma = \frac{C_P}{C_V}$ of mixture is approximately

(a) 1.50 (b) 1.46 (c) 1.49 (d) 1.53

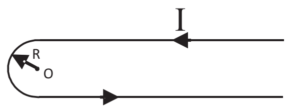
13. An ideal gas is expanding such that PT^3 = constant. The coefficient of volume expansion of the gas is

(a) $\frac{1}{T}$ (b) $\frac{2}{T}$ (c) $\frac{3}{T}$ (d) $\frac{4}{T}$

14. What is the magnetic induction B at the centre O of the semicircular arc if a current carrying wire has shape of an hair pin as shown in figure? The radius of the curved part of the wire is R, the linear parts are assumed to be very long.

(a) $B = \frac{\mu_0 I}{4\pi R}(2+\pi)$ (b) $B = \frac{\mu_0 I}{4R}(2+\pi)$

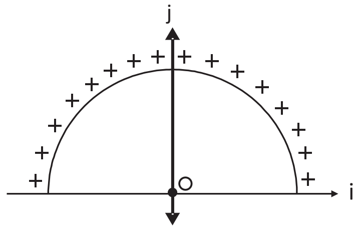
(c) $B = \frac{3\mu_0 I}{4R}(2+\pi)$ (d) $B = \frac{\mu_0}{4\pi}\frac{2I}{R}$



15. A thin semi-circular metal ring of radius R has a positive charge q distributed uniformly over its curved length. The resultant electric field $\vec{E}$ at the center O is

(a) $-\hat{j}\frac{q}{2\pi^2\varepsilon_0 R^2}$ (b) $+\hat{j}\frac{q}{2\pi^2\varepsilon_0 R^2}$

(c) $+\hat{j}\frac{q}{4\pi^2\varepsilon_0 R^2}$ (d) $-\hat{j}\frac{q}{4\pi^2\varepsilon_0 R^2}$



16. An Alternating Current is expressed as $i = i_1 \cos\omega t + i_2 \sin\omega t$. The RMS value of current is

(a) $\sqrt{\frac{(i_1+i_2)^2}{2}}$ (b) $\sqrt{\frac{i_1 i_2}{2}}$ (c) $\sqrt{\frac{(i_1^2+i_2^2)}{2}}$ (d) $\sqrt{\frac{(i_1-i_2)^2}{2}}$

17. A charge + q is placed at each of the points $x = x_0, x = 3x_0, x = 5x_0, x = 7x_0$ ....∞ on the x-axis and a charge -q is placed at each of the points $x = 2x_0, x = 4x_0, x = 6x_0, x = 8x_0$ ....∞ here x_0 is a positive constant. Take the electric potential at a point due to a charge q at a distance r from it to be $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$. The electric potential at the origin due to the above system of charges is

(a) zero (b) $\frac{1}{4\pi\varepsilon_0}\frac{q}{x_0}\ln 2$ (c) $\frac{1}{4\pi\varepsilon_0}\frac{q}{x_0 2\ln 2}$ (d) infinite

18. The Nucleus $^{23}_{10}\text{Ne}$ decays by $\beta -$ emission through the reaction
$^{23}_{10}\text{Ne} \rightarrow ^{23}_{11}\text{Na} + ^{0}_{-1}\beta + \bar{\upsilon} + \text{energy}$ The atomic masses are $^{23}_{10}\text{Ne} = 22.994466\text{u}$ and $^{23}_{11}Na = 22.989770\text{u}$, $^{0}_{-1}\beta = 0.000549$ u. The maximum kinetic energy that the emitted electron can ever have is

(a) 4.374 MeV (b) 3.862 MeV (c) 2.187 MeV (d) 1.931 MeV

19. The distance between two slits in Young's double slits experiment is $d = 2.5$ mm and the distance of the screen from the plane of slits is $D = 120$ cm. The slits are illuminated with coherent beam of light of wavelength $\lambda = 600$ nm. The minimum distance (from the central maximum) of a point where the intensity reduces to 25% of maximum intensity is

(a) 24 μm (b) 48 μm (c) 96 μm (d) 120 μm

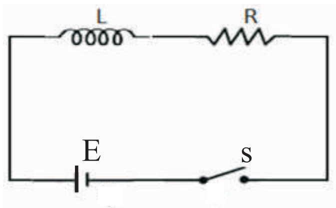
20. What amount of heat will be generated in a coil of resistance R (ohm) due to a total charge Q (coulomb) passing through it if the current in the coil decreases down to zero halving its value every Δt second?

(a) $\frac{1}{2}\frac{Q^2R}{\Delta t}$ (b) $\frac{Q^2R}{\Delta t}\ln 2$ (c) $\frac{1}{2}\frac{Q^2R}{\Delta t}\ln 2$ (d) $\frac{1}{4}\frac{Q^2R}{\Delta t}$

21. In the L R circuit shown in figure, switch S is closed at time $t = 0$, the charge that passes through the battery of emf E in one time constant is (e being the base of natural logarithm).

(a) $\frac{EL}{eR^2}$ (b) $\frac{EL}{eR}$

(c) $\frac{eER^2}{L}$ (d) $\frac{EL}{R}$



22. Natural Uranium is a mixture of $^{238}_{92}\text{U}$ and $^{235}_{92}\text{U}$ with a relative mass abundance of 140 : 1. The ratio of radioactivity contributed by the two isotopes of natural uranium, if their half-lives are 4.5×10^9 years and 7.0×10^8 years respectively is

(a) 99.3 : 0.7 (b) 50.3 : 49.7 (c) 95.6 : 04.4 (d) cannot be estimated

23. A cylinder of length $l > 1$m filled with water ($\mu = \frac{4}{3}$) up to the brim, kept on a horizontal table is covered at its top by an equiconvex glass ($\mu = 1.5$) lens of focal length 25 cm when in air. At mid day, 12.00 noon, Sun is just overhead and light rays comes parallel to the principal axis of the lens. The sun rays will be focused

(a) 25 cm behind the lens in the water (b) 37.5 cm behind the lens in the water
(c) 50 cm behind the lens in the water (d) 100 cm behind the lens in the water

24. Even the radiation of highest wave length in the ultraviolet region of hydrogen spectrum is just able to eject photoelectrons from a metal. The value of threshold frequency for the given metal is

(a) 3.83×10^{15} Hz (b) 4.33×10^{14} Hz (c) 2.46×10^{15} Hz (d) 7.83×10^{14} Hz

A - 2

ANY NUMBER OF OPTIONS 4, 3, 2 or 1 MAY BE CORRECT

MARKS WILL BE AWARDED ONLY IF ALL CORRECT OPTIONS ARE BUBBLED AND NO WRONG OPTION

25. A parallel plate capacitor of plate area A and plate separation d is charged to potential V. Then the battery is disconnected. A slab of dielectric constant k is then inserted between the plates of the capacitor so as to fill the space between the plates completely. If Q, E and W denote respectively, the magnitude of charge on each plate, the electric field between the plates (after the slab is inserted) and work done on the system, in question, in the process of inserting the slab, then

(a) $Q = k\varepsilon_0 AE$ (b) $Q = \frac{\varepsilon_0 kAV}{d}$ (c) $E = \frac{V}{kd}$ (d) $W = \frac{\varepsilon_0 AV^2}{2d}(1-\frac{1}{k})$

26. The magnitudes of the gravitational field at distances r_1 and r_2 from the centre of a uniform solid sphere of radius R and mass M are $F(r_1)$ and $F(r_2)$ respectively. Such that

(a) $\frac{F(r_1)}{F(r_2)} = \frac{r_1}{r_2}$ if $r_1 \le R$ and $r_2 \le R$

(b) $\frac{F(r_1)}{F(r_2)} = \frac{r_2^2}{r_1^2}$ if $r_1 \ge R$ and $r_2 \ge R$

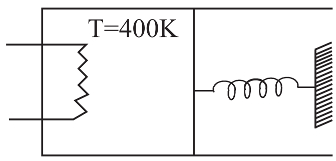
(c) $\frac{F(r_1)}{F(r_2)} = \frac{r_1}{r_2}$ if $r_1 \ge R$ and $r_2 \ge R$

(d) $\frac{F(r_1)}{F(r_2)} = \frac{r_1^2}{r_2^2}$ if $r_1 \le R$ and $r_2 \le R$

27. The intensity of sound at a point P is I_0, when the sounds reach this point directly and in same phase from two identical sources S_1 and S_2. The power of S_1 is now reduced by 64 % and the phase difference (ϕ) between S_1 and S_2 is varied continuously. The maximum and minimum intensities recorded at P are now I_{max} and I_{min} such that

(a) $I_{max} = 0.64\, I_0$ (b) $I_{min} = 0.36\, I_0$ (c) $\frac{I_{max}}{I_{min}} = 16$ (d) $\frac{I_{max}}{I_{min}} = \frac{16}{9}$

28. An ideal monatomic gas is confined within a cylinder by a spring loaded piston of cross-sectional area 4×10^{-3} m^2. Initially the gas is at 400 K and occupies a volume 2×10^{-3} m^3 and the spring is in its relaxed position. The gas is heated by an electric heater for some time. During this time the gas expands and the piston moves out by a distance 0.1 m. The spring connected to the rigid wall is massless and frictionless. The force constant of the spring is 2000 Nm^{-1} and atmospheric pressure is 10^5 Nm^{-2} then



(a) The final temperature of the gas is 720 K.
(b) The work done by gas in expanding is 50 J
(c) The heat supplied by heater is 190 J
(d) The heat supplied by heater is 290 J

29. A particle of mass m is located in a one dimensional potential field U (x) = U_0 (1 - cos ax); U_0 and a are constants. Which of the following statement/s is/are correct?

(a) The particle will execute Simple Harmonic Motion for small displacements.

(b) The stable equilibrium condition is x = 0

(c) The time period of small oscillations is $\frac{2\pi}{a}\sqrt{\frac{m}{U_0}}$

(d) The angular frequency for small oscillations is $\omega = a\sqrt{\frac{U_0}{m}}$

30. A ray of light is incident on an equilateral prism made of flint glass (refractive index 1.6) placed in air.

(a) The ray suffers a minimum deviation if it is incident at angle 53^0.

(b) The minimum angle of deviation suffered by the ray is 46^0.

(c) If prism is immersed in water ($\mu = \frac{4}{3}$) the minimum deviation produced by the prism is 14^0.

(d) The minimum deviation produced by the prism is 23.6^0 if it is immersed in a liquid of refractive index μ = 1.2

31. In a p-n junction diode, the current (i) varies with applied biasing voltage (V) and can be expressed as $i = i_0\left(e^{qV/kT} - 1\right)$ where $i_0 = 5 \times 10^{-12}$ A is reverse saturation current, k is Boltzmann constant and q is the charge on the electron

At Absolute Temperature T = 300K

(a) The forward current is approximately 59.5 mA for a forward bias of 0.6 volt

(b) The current increases approximately by 2.75A if the biasing voltage changes from 0.6 V to 0.7 V

(c) The dynamic resistance of p-n junction is approximately 435 mΩ at the biasing voltage of 0.6 V

(d) The change in reverse bias current when biasing voltage change from -1 volt to -2 volt happens to be practically zero.

32. A charged oil (density 880 kg m^{-3}) drop is held stationary between two parallel horizontal metal plates 6.0 mm apart when a potential difference of V = 103 volt is applied between the two plates. When the electric field is switched off, the drop falls. At a certain time the drop is seen to fall a distance of 2.0 mm in 35.7 s and next 1.2 mm in 21.4 s. (The upper plate in the experiment is at higher potential).

Given that the viscosity of air = 1.80×10^{-5} Nsm^{-2} and density of air = 1.29 kg m^{-3}

(a) The radius of the drop is a = 7.25×10^{-7}m

(b) The charge on the drop is q = 8.0×10^{-19}C

(c) The terminal velocity of the oil drop, under its free fall, is 5.6×10^{-5} ms^{-1}

(d) The oil drop carries 5 excess electrons

Final Answer Key IOQP 2020-21 Part I (NSEP) held on 7.2.2021

Question no.	**Set 61**	**Set 62**	**Set 63**	**Set 64**
1	d	b	a	a
2	b	d	d	c
3	c	a	d	c
4	a	a	b	a
5	a	c	c	c
6	a	b	d	c
7	d	a	b	c
8	d	c	c	b
9	b	c	a	d
10	c	a	a	a
11	a	c	a	a
12	b	c	a	c
13	d	c	c	b
14	a	d	c	a
15	a	b	a	d
16	c	c	c	d
17	b	a	c	b
18	a	a	c	c
19	c	a	b	a
20	c	d	d	d
21	a	d	a	b
22	c	b	a	c
23	c	c	c	a
24	c	a	b	a
25	a,c	a,c	a,b,c,d	a,c
26	a,b	a,b	a,b,c,d	a,b
27	a,c	a,c	a,b,c,d	a,c
28	a,b,d	a,b,d	a,c,d	a,b,d
29	a,b,c,d	a,b,c,d	a,c	a,b,c,d
30	a,b,c,d	a,b,c,d	a,b	a,b,c,d
31	a,b,c,d	a,b,c,d	a,c	a,b,c,d
32	a,c,d	a,c,d	a,b,d	a,c,d

INTERNATIONAL OLYMPIAD QUALIFIER IN PHYSICS 2020-21
Paper code 61 Solutions: (1.3.2021)

1. Let time t depend on c, h and G such that
$t = c^x h^y G^z$ Taking dimensions on both sides
$M^0 L^0 T^1 = \left(LT^{-1}\right)^x \left(ML^2T^{-1}\right)^y \left(M^{-1}L^3T^{-2}\right)^z$
or $M^0 L^0 T^1 = L^{x+2y+3z} M^{y-z} T^{-x-y-2z}$
Giving $y - z = 0$ (1) $x + 2y + 3z = 0$ (2) $-x - y - 2z = 0$ (3)
Or $y = z$ Putting in (2) we get $x = -5y$ then from (3) $5y - y - 2y = 1$
$\Rightarrow 2y = 1 \quad \Rightarrow y = \frac{1}{2}, \quad x = -\frac{5}{2}$ and $z = \frac{1}{2}$ So we get $t = c^{-\frac{5}{2}} h^{\frac{1}{2}} G^{\frac{1}{2}} \Rightarrow \sqrt{\frac{hG}{c^5}}$

Ans: d

2. The mass of the composite system is $M = \frac{2}{3}\pi R^3\rho + \pi R^2 \ell \rho = \frac{2}{3}\pi R^3 \rho\left(1 + \frac{3\ell}{2R}\right)$

The moment of Inertia is $I = \frac{2}{5} \times \frac{2}{3}\pi R^3 \rho R^2 + \frac{1}{2}\pi R^2 \ell \rho R^2 = \frac{4}{15}\pi R^5 \rho \left(1 + \frac{15\ell}{8R}\right)$ using now

$I = MK^2$ we get $K = \sqrt{\dfrac{\frac{4}{15}\pi R^5 \rho\left(1 + \frac{15\ell}{8R}\right)}{\frac{2}{3}\pi R^3 \rho\left(1 + \frac{3\ell}{2R}\right)}} = R\sqrt{\frac{1}{10}\frac{(8R + 15\ell)}{(2R + 3\ell)}}$

Ans: b

3. $g' = g - \omega^2 R$ where g' is apparent acceleration due to gravity and $\omega = \frac{2\pi}{T}$ is the angular velocity at the verge of fly off means $g' = 0$ or $g = \omega^2 R = \left(\frac{2\pi}{T}\right)^2 R$ Thereby

$\frac{G}{R^2}\frac{4}{3}\pi R^3 \rho = \left(\frac{2\pi}{T}\right)^2 R \Rightarrow T = \sqrt{\frac{3\pi}{\rho G}}$

Ans: c

4. Let the stationary mass m explodes in to m_1 and m_2
By conservation of momentum $m_1 v_1 + m_2 v_2 = 0$ (1) and Energy is
$\frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2 = 1680 \Rightarrow \frac{1}{2}m_1 v_1^2\left(1 + \frac{m_1}{m_2}\right) = 1680$
$\Rightarrow v_1 = 12\ ms^{-1}$ and $\Rightarrow v_2 = -28\ ms^{-1}$ Thereby $v_1 - v_2 = \left[12 - (-28)\right]\ ms^{-1} = 40\ ms^{-1}$
Thus we get $v_{rel} = 40\ ms^{-1}$
Ans: a

5. For a projectile the maximum height is $H=\dfrac{u^2\sin^2\alpha}{2g}$ and the range is $R=\dfrac{u^2\sin 2\alpha}{g}$

For the given problem $\dfrac{H}{R/2}=\tan\beta \Rightarrow \dfrac{\sin^2\alpha}{\sin 2\alpha}=\tan\beta \Rightarrow \tan\alpha = 2\tan\beta$

Ans: a

6. As particle starts from rest, it must have started from extreme position. So equation of SHM is $x=A\cos\omega t$, where A is amplitude and x displacement from Centre.

Given that at $t=1,\ x=A-a \ \Rightarrow A-a=A\cos(\omega\times 1)$.............(1) and

at $t=2,\ \ x=A-a-b \Rightarrow A-a-b=A\cos(\omega\times 2)$...............(2)

Using $\cos 2\omega = 2cos^2\omega - 1$ one obtains $A=\dfrac{2a^2}{3a-b}$

Ans: a

7. The velocity is changing on circular path so centripital acceleration and tangential acceleration both Further Given is that $\dfrac{1}{2}mv^2=as^2 \Rightarrow \dfrac{mv^2}{R}=\dfrac{2as^2}{R}$ centripetal force

Also $mv^2=2as^2 \Rightarrow v=\sqrt{\dfrac{2a}{m}}\ s \Rightarrow \dfrac{dv}{dt}=\sqrt{\dfrac{2a}{m}}\ \dfrac{ds}{dt}=\sqrt{\dfrac{2a}{m}}\sqrt{\dfrac{2a}{m}}\ s$

$\Rightarrow \dfrac{dv}{dt}=\dfrac{2a}{m}s \Rightarrow m\dfrac{dv}{dt}=2as=$ tangential force

Net force as a function of s is $F=\sqrt{F_T^2+F_R^2} \Rightarrow 2as\sqrt{1+\left(\dfrac{s}{R}\right)^2}$

Ans: d

8. From eq. of continuity $A_1v_1 = A_2\ v_2$. ------(1)

Given that A_1 =10 cm^2 and A_2 = 5 cm^2 and v_1 = 1 m/sPutting in (1) gives v_2 = 2m/s

For horizontal tube from Bernoulli eq.

$P_1 + \frac{1}{2}\rho v_1^2 = P_2 + \frac{1}{2}\rho v_2^2$.----------(2)

Now put in eq (2)P_1= 2000 Pa, $\rho = 10^3$ kg/m^3. Also v_1 = 1 m/s and v_2 = 2m/s

And get P_2 = 500 Pa.

Ans: d

9. Let $\theta_1,\ \theta_2\ and\ \theta_3$ be the temperature of water in the three containers.

When one litre from A and two litre from B is mixed, we get

$(\theta_1-52)=2(52-\theta_2)\Rightarrow \theta_1+2\theta_2=3\times 52$

When one litre from B and two litre from C is mixed, we get

$(\theta_2-40)=2(40-\theta_3)\Rightarrow \theta_2+2\theta_3=3\times 40$

When one litre from C and two litre from A is mixed, we get

$(\theta_3 - 34) = 2(34 - \theta_1) \Rightarrow \theta_3 + 2\theta_1 = 3\times 34$

Adding the three, we get $3(\theta_1+\theta_2+\theta_3) = 3\times(52+40+34) \Rightarrow \theta_1+\theta_2+\theta_3 = 126$ If θ_0 is the temperature when one litre from each A, B and C is mixed then

$(\theta_1-\theta_0) = (\theta_0-\theta_2)+(\theta_0-\theta_3) \Rightarrow \theta_1+\theta_2+\theta_3 = 3\theta_0 \Rightarrow \theta_0 = 42^\circ$

Ans: b

10. The force along x axis is

$$F_x = \frac{1}{4\pi\varepsilon_0}\left[\frac{q^2}{\ell^2} + 2\frac{q^2}{\left(\ell\sqrt{2}\right)^2}\frac{1}{\sqrt{2}} + \frac{q^2}{\left(\ell\sqrt{3}\right)^2}\frac{1}{\sqrt{3}}\right] = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{\ell^2}\left[1+\frac{1}{\sqrt{2}}+\frac{1}{3\sqrt{3}}\right]$$ Similar

expressions are held along y and z axes. Hence the resultant force is

$F = \sqrt{F_x^2 + F_y^2 + F_z^2} \Rightarrow$

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{\ell^2}\left[1+\frac{1}{\sqrt{2}}+\frac{1}{3\sqrt{3}}\right]\sqrt{\{1+1+1\}} = \frac{1}{4\pi\varepsilon_0}\frac{q^2}{\ell^2}\left[\sqrt{3}+\sqrt{\frac{3}{2}}+\frac{1}{3}\right] = \frac{0.8225\; q^2}{\pi\varepsilon_0\ell^2}$$

Or $F = \dfrac{(1-0.1775)\; q^2}{\pi\varepsilon_0\ell^2}$

Ans: c

11. The internal resistance 'r' of a cell is measured by a potentiometer as

r = $\left(\frac{L}{L_1}-1\right)R_1 = \left(\frac{L}{L_2}-1\right)R_2$ **where** L is the balancing length when cell is in open circuit and L_1 when the cell is shunted by resistance R_1 and L_2 when cell is shunted by resistance R_2. Given that L=250cm, R_1= 7.5 Ω, L_1= 250 – 25 = 225cm, R_2= 20Ω, This gives L_2= 240 cm

Ans: a

12. Knowing that $C_V = \dfrac{R}{(\gamma-1)}$, $C_P = \dfrac{\gamma R}{(\gamma-1)}$ *and* $\gamma_{mix} = \dfrac{n_1C_{P1}+n_2C_{P2}}{n_1C_{V1}+n_2C_{V2}}$ with

$\gamma_1 = \frac{5}{3}$ *and* $\gamma_2 = \frac{7}{5}$ *and* $n_1 = 1$, & $n_2 = 2$, we get

$C_{V1} = \frac{3}{2}R,\ C_{P1} = \frac{5}{2}R$ *and* $C_{V2} = \frac{5}{2}R,\ C_{P2} = \frac{7}{2}R$ and obtain

$$\gamma_{mix} = \frac{n_1C_{P1}+n_2C_{P2}}{n_1C_{V1}+n_2C_{V2}} = \frac{19}{13} = 1.46$$

Ans: b

13. Given that $PT^3 = K$, using $PV = \mu RT$ or $P = \dfrac{\mu RT}{V}$ we get

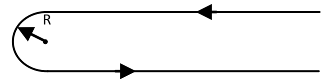
$\dfrac{\mu RT}{V} T^3 = K \ or \ T^4 = \dfrac{KV}{\mu R}$ differentiating we get $4T^3 \, dT = \dfrac{KdV}{\mu R}$ Thereby

$\dfrac{dV}{dT} = \dfrac{4\mu RT.T^2}{K} = \dfrac{4V}{T}$ *so coefficient of volume* expension $\dfrac{1}{V}\dfrac{dV}{dT} = \dfrac{4}{T}$

Ans: d

14. Magnetic field at the centre of arc O is due to semi-circular part and to two semi infinite straight lines.

So $B = \dfrac{\mu_0 I}{4R} + 2\left[\dfrac{\mu_0}{4\pi}\dfrac{I}{R}\left(\sin 0 + \sin 90\right)\right] = \dfrac{\mu_0 I}{4R}\left(1 + \dfrac{2}{\pi}\right)$



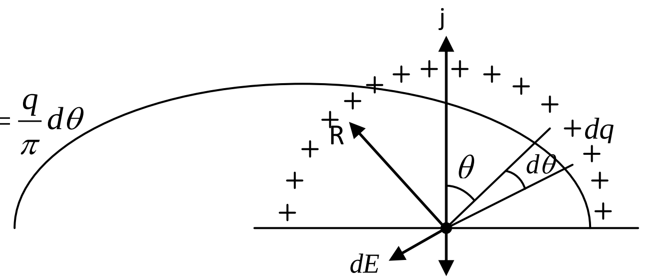
$B = \dfrac{\mu_0}{4\pi}\dfrac{I}{R}\left(\pi + 2\right)$

Ans: a

15. By symmetry net electric field along X-axis at the centre O is zero and the electric field along y axis will be added up

$dE_y = \left(-\hat{j}\right)\dfrac{1}{4\pi\varepsilon_0}\dfrac{dq}{R^2}\cos\theta$

where $dq = \lambda\left(Rd\theta\right) = \dfrac{q}{\pi R}\left(Rd\theta\right) = \dfrac{q}{\pi}d\theta$



$E_y = \left(-\hat{j}\right)2 \times \dfrac{1}{4\pi\varepsilon_0}\displaystyle\int_0^{\frac{\pi}{2}} \dfrac{\left(\dfrac{q}{\pi}\cos\theta d\theta\right)}{R^2}$

$E_y = \left(-\hat{j}\right)\dfrac{q}{2\pi^2\varepsilon_0 R^2}$

Ans: a

16. The current is $i = i_1 \cos\omega t + i_2 \sin\omega t = i_1\left(\cos\omega t + \dfrac{i_2}{i_1}\sin\omega t\right)$ let us put

$\dfrac{i_2}{i_1} = \cot\theta = \dfrac{\cos\theta}{\sin\theta}$ then $i = \dfrac{i_1}{\sin\theta}\left(\cos\omega t \sin\theta + \sin\omega t \cos\theta\right)$ or

$i = \dfrac{i_1}{\dfrac{i_1}{\sqrt{i_1^2 + i_2^2}}}\sin\left(\omega t + \theta\right)$ or $i = \sqrt{\left(i_1^2 + i_2^2\right)}\sin\left(\omega t + \theta\right)$ Thereby rms current is

$i_{rms} = \sqrt{\dfrac{\left(i_1^2 + i_2^2\right)}{2}}$

Ans: c

17. The potential at the origin may be expressed as

$$V_0 = \frac{1}{4\pi\varepsilon_0}\left(\frac{q}{x_0} - \frac{q}{2x_0} + \frac{q}{3x_0} - \frac{q}{4x_0} + \frac{q}{5x_0}............\right)$$

$$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{x_0}\left(1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} - \frac{1}{6} + ...\right)$$ using now

$$\log_e(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} + \frac{x^4}{4} + \frac{x^5}{5} - \frac{x^6}{6}......... \quad for\ -1 < x \le 1$$

$$\ln 2 = 1 - \frac{1}{2} + \frac{1}{3} - \frac{1}{4} + \frac{1}{5} - \frac{1}{6}........$$

One obtains $V = \frac{1}{4\pi\varepsilon_0}\frac{q}{x_0}\ln 2$

Ans: b

18. The mass defect $\Delta m =$(mass of ${}^{23}_{10}Ne$ - mass of 10 electrons) - (mass of ${}^{23}_{11}Na$ - mass of 11 electrons) – mass of one electron

Or $\Delta m =$(mass of ${}^{23}_{10}Ne$) - (mass of ${}^{23}_{11}Na$) = (22.994466) - (22.989770)=0.004696 amu

Thereby $\Delta E = 0.004696 \times 931.5 = 4.374\ MeV$ This energy is shared between the electron and the neutrino. In an extreeme situation the electron can take the wholeof this energy so the maximum energy the electron can have is 4.374 MeV

Ans:a

19. The resultant intensity on the screen is given by $I = I_m \cos^2\left(\frac{\pi}{\lambda} d \frac{y}{D}\right) = \frac{1}{4} I_m$

Thereby $\cos^2\left(\frac{\pi}{\lambda} d \frac{y}{D}\right) = \frac{1}{4} \Rightarrow \frac{\pi}{\lambda} d \frac{y}{D} = \frac{\pi}{3} \Rightarrow y = \frac{D\lambda}{3d}$

$$y = \frac{1.20 \times 600 \times 10^{-9}}{3 \times 2.5 \times 10^{-3}} = 96 \times 10^{-6} m = 96 \mu m$$

Ans: c

20. Let the initial current through the coil be I_0 at $t = 0$. The current decrease down to zero halving after each Δt second This means that the current at any time t is expressed as $i = I_0 e^{-\frac{\ln 2}{\Delta t}t}$. The heat produced in time dt in the coil is $dH = i^2 R dt$. The total heat produced will be $H = \int_0^\infty i^2 R dt$ Substituting the values

$$H = \int_0^\infty I_0^2 e^{-2\frac{\ln 2}{\Delta t}t} R dt = I_0^2 R \int_0^\infty e^{-2\frac{\ln 2}{\Delta t}t} dt = \frac{I_0^2 R \Delta t}{-2\ln 2}\left\{ e^{-2\frac{\ln 2}{\Delta t}t}\Big|_0^\infty \right\} = \frac{I_0^2 R \Delta t}{2\ln 2} \quad ....(1)$$ Also we know

$i=\frac{dQ}{dt}$ or $dQ = idt$ or $Q=\int_0^q dQ=\int_0^\infty idt=\int_0^\infty I_0 e^{-\frac{\ln 2}{\Delta t}t}dt=\left\{-\frac{I_0\Delta t}{\ln 2}e^{-\frac{\ln 2}{\Delta t}t}\Big|_0^\infty\right\}=\frac{I_0\Delta t}{\ln 2}$ or

$I_0=\frac{Q\ln 2}{\Delta t}$ Substituting in (1) $H=\frac{\left(\frac{Q\ln 2}{\Delta t}\right)^2 R\Delta t}{2\ln 2}=\frac{1}{2}\frac{Q^2R}{\Delta t}\ln 2$ Ans

Ans: c

21. When switch S is closed, current starts flowing and is given by

$$I=I_0(1-e^{\frac{-t}{\tau}}) \quad =\frac{E}{R}\left(1-e^{\frac{-t}{\tau}}\right)=\frac{dq}{dt} \text{ Therefore } \quad q=\int_0^\tau I\,dt \;=\; q=\frac{E}{R}\int_0^\tau\left(1-e^{\frac{-t}{\tau}}\right)dt$$

Where charge q flows in time τ ($\because \tau=\frac{L}{R}$ = time constant)

$$q=\frac{E}{R}\tau-\frac{E}{R}\int_0^\tau e^{\frac{-t}{\tau}}dt=\frac{E}{R}\tau-\frac{E}{R}\left[\frac{e^{\frac{-t}{\tau}}}{\left(\frac{-1}{\tau}\right)}\right]_0^\tau \quad =\frac{E}{R}\tau+\frac{E}{R}\tau\left[e^{\frac{-t}{\tau}}\right]_0^\tau$$

$$q=\frac{E}{R}\tau+\left(\frac{E}{R}\tau e^{-1}-\frac{E}{R}\tau e^{0}\right)=\frac{E\tau}{eR}=\frac{E\left(\frac{L}{R}\right)}{eR}=\frac{EL}{eR^2}$$

Ans: a

22. In a sample of uranium of mass M, the masses of the two isotopes are

$M_1=\frac{140}{141}M$ *and* $M_2=\frac{1}{141}M$ The number of atoms of the two isotopes are

$N_1=\frac{140}{141}M\frac{N_A}{238}$ *and* $N_2=\frac{1}{141}M\frac{N_A}{235}$ Knowing further that $N=N_0e^{-\lambda t}$ gives the Activity as $A_1=-\frac{dN_1}{dt}=\lambda N_1=\frac{\ln 2}{T_1}\frac{140}{141}M\frac{N_A}{238}$ and $A_2=-\frac{dN_2}{dt}=\lambda N_2=\frac{\ln 2}{T_2}\frac{1}{141}M\frac{N_A}{235}$ The relative contribution of Activity thus turns out to be $\frac{A_1}{A_1+A_2}:\frac{A_2}{A_1+A_2}\Rightarrow$

$$\frac{1}{4.5}\times\frac{140}{238}:\frac{1}{0.7}\times\frac{1}{235}$$

$$\Rightarrow 0.1307:0.0060::\frac{0.1307}{0.1367}\times 100:\frac{0.0061}{0,1367}\times 100\Rightarrow 95.6\% \text{ and } 4.4\%$$

Ans: c

23. The focal length of a lens is obtained by $\frac{\mu_2}{f_2} = \frac{\mu - \mu_1}{R_1} - \frac{\mu - \mu_2}{R_2}$ …..(1) where μ, μ_1 & μ_2 are the refractive indices of the material of lens, the object space and the image space respectively. R_1 & R_2 are the two radii of the lens. f_2 is the second focal length. When the lens is placed in air $\mu = 1.5, \mu_1 = 1$ & $\mu_2 = 1$ and then $\frac{1}{25} = \frac{1}{f} = \frac{1.5-1}{R} - \frac{1.5-1}{-R} \Rightarrow R = 25$

In the present case $\mu = 1.5, \mu_1 = 1$ & $\mu_2 = \frac{4}{3}$ Then equation (1) yields $\frac{4}{3f_2} = \frac{\frac{3}{2}-1}{25} - \frac{\frac{3}{2}-\frac{4}{3}}{-25}$

$\Rightarrow f_2 = 50\ cm$ Hence the sun will be focused 50 below the lens.

Ans: c

24.Lymen series of hydrogen spectrum falls in ultra violet region. Minimum energy photon of Lymen series is emitted for transition from n=2 to n=1 and has an energy $13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$ eV = 10.2 eV. All other spectral lines will be of higher energies and so the frequencies. Therefore if this 10.2 eV photon can eject photo electron then other will definitely. So required threshold frequency ν is

$$\nu = \frac{10.2 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}}\ Hz = 2.46 \times 10^{15}\ Hz$$

Ans : c

Multiple choice questions (Any number of options may be correct)

25. When battery has been disconnected, the charge Q remains unchanged

$$Q = C_{air}V = \left(\frac{\varepsilon_0 A}{d}\right)V = k\varepsilon_0 AE$$

Electric field in dielectric between plates of capacitor $E = \frac{\sigma}{K\varepsilon_0} = \frac{E_{air}}{K} = \frac{V}{Kd}$

Work done on the system = $\frac{Q^2}{2C_{air}} - \frac{Q^2}{2C_{dielectric}} = \frac{Q^2}{2}\left[\frac{1}{C_{air}} - \frac{1}{C_{dielectric}}\right]$

$$W = \frac{1}{2}\left(\frac{\varepsilon_0 AV}{d}\right)^2 \left(\frac{d}{\varepsilon_0 A} - \frac{d}{k\varepsilon_0 A}\right) = \frac{\varepsilon_0 AV^2}{2d}\left[1 - \frac{1}{k}\right]$$

Ans: a, & c

26. The gravitational field due to a uniform solid sphere of mass M and radius R at a distance r from its centre is

$F(r) = \left(\frac{GM}{R^3}\right)r \quad if\ r < R$ and $F(R) = \frac{GM}{r^2} \quad if\ r > R$ Thereby

$\frac{F(r_1)}{F(r_2)} = \frac{r_1}{r_2}\ for\ r_1 \le R\ and\ r_2 \le R$ and $\frac{F(r_1)}{F(r_2)} = \frac{r_2^2}{r_1^2}\ for\ r_1 \ge R\ and\ r_2 \ge R$

Ans: a & b

27.The resultant intensity is $I_0 = I + I + 2\sqrt{I \times I}\cos 0 = 4I$ when the intensity of one source is reduced by 64 % it becomes $I - 0.64I = 0.36I$ Then the resultant intensity becomes $I_{Result} = 0.36I + I + 2\sqrt{0.36I \times I}\cos\phi = I_0\left(0.34 + 0.30\cos\phi\right)$ where phase ϕ is now varied.

When $\phi = 0$, The intensity at P is $I_{Result} = 0.64I_0 = I_{\max}$ Ans a

When $\phi = \frac{\pi}{2}$. The intensity at P is $I_{Result} = 0.34I_0$

When $\phi = \pi$ The intensity at P is $I_{Result} = 0.04I_0 = I_{\min}$

This shows that $\frac{I_{\max}}{I_{\min}} = \frac{0.64}{0.04} = 16$ Ans c

Ans: a & c

28. The given parameters are $P_i = 1\times10^5\ \mathrm{N/m^2}, V_i = 2\times10^{-3}\ \mathrm{m^3}$,

$P_f = P_o + \frac{kx}{A} = 1.5\times10^5 N/m^2$ and $V_f = V_0 + Ax = 2.4\times10^{-3} m^3$ Now $T_f = \frac{P_F \times V_f}{P_i V_i} T_i = 720K$

And $\Delta U = nC_V dT = \frac{nR}{\gamma - 1} dT = \frac{P_i V_i}{\gamma - 1}\frac{dT}{T} = 240J$ $\Delta W = P_0 Ax + \frac{1}{2}kx^2 = 50J$ Then $\Delta Q = \Delta U + \Delta W = 290J$

Ans: a, b & d

29. Given that $U_x = U_0(1 - \cos ax)$ The force $F = -\frac{dU_x}{dx} = -aU_0 \sin \mathrm{ax}$ For small displacement x it turns out to $F = -\frac{dU_x}{dx} = -a^2 U_0\ \mathrm{x}$ Obviously the force is zero at x = 0showing that x = o is the equilibrium position. The equilibrium is stable as the second derivative of potential function is negative. Once again $m\frac{d^2x}{dt^2} = -a^2 U_0\ \mathrm{x}$ is the equation of SHM whose time period is $T = 2\pi\sqrt{\frac{m}{a^2 U_0}}$ and its angular frequency is $\omega = \sqrt{\frac{a^2 U_0}{m}} = a\sqrt{\frac{U_0}{m}}$

Ans: a, b, c & d

30. The refractive index of the prismis $\mu = 1.6 = \frac{\sin\left(\frac{A + \partial_m}{2}\right)}{\sin\frac{A}{2}}$ where ∂_m is the angle of minimum deviation. Using $\mu = 1.6$ and $A = 60^0$ One gets,

$\sin\frac{A+\partial_m}{2}=0.8\Rightarrow\frac{A+\partial_m}{2}=53^\circ\Rightarrow\partial_m=46^\circ$ **Ansb**Also the angle of incidence here is

$i=\left(\frac{A+\partial_m}{2}\right)=\frac{60+46}{2}=53^\circ$ Ans a

Nowthe prism is immersed in water of refractive index ${}_a\mu_w=\frac{4}{3}$, the angle of minimum deviation may now be obtained from ${}_w\mu_g=\frac{{}_a\mu_g}{{}_a\mu_w}=\frac{1.6}{4/3}=1.2=\frac{\sin\left(\frac{A+\partial_m}{2}\right)}{\sin\frac{A}{2}}\Rightarrow\left(\frac{A+\partial_m}{2}\right)=37^\circ\Rightarrow\partial_m=14^\circ$ A

When immersed in a liquid of refractive index ${}_a\mu_l=1.2$, The deviation may be obtained from ${}_l\mu_g\sin\frac{A}{2}=\sin\left(\frac{A+\partial_m}{2}\right)$ or $\frac{1.6}{1.2}\sin\frac{60}{2}=\sin\left(\frac{60+\partial_m}{2}\right)\Rightarrow\partial_m=23.6^\circ$

Ans: a, b, c & d

31.The current in a p – n junction diode is expressed as

$i=i_0\left(e^{eV/kT}-1\right)$ At 300 K, the value of $\frac{qV}{kT}=\frac{1.6\times10^{-19}\times0.6}{1.38\times10^{-23}\times300}=23.2$ Therefore the current $i=5\times10^{-12}\left(e^{23.2}-1\right)=5.0\times10^{-12}\times1.190\times10^{10}\ or\ i=0.0595A\cong59.5\ mA$ Now when $V=0.7$ V The value of $\frac{qV}{kT}=\frac{1.6\times10^{-19}\times0.7}{1.38\times10^{-23}\times300}=27.053$ and the current $i=i_0\left(e^{27.053}-1\right)$

$i=5.0\times10^{-12}\times5.610\times10^{11}\Rightarrow i=2.805A$

Thereby the change in current when voltage is changed from 0.6 V to 0.7 V is

$\Delta i=2.805-0.0595A\cong2.75\ A$

For dynamic resistance, using now $i=i_0\left(e^{qV/kT}-1\right)$ we get $\left.\frac{di}{dV}\right|_T=\frac{qi_0}{kT}\left(e^{qV/kT}\right)$.

At V = 0.6 volt, $\left.\frac{di}{dV}\right|_{T=300K}=\frac{qi_0}{kT}\left(e^{23.2}\right)=\frac{1.6\times5}{1.38\times3}10^{-10}\times1.19\times10^{10}\cong2.3\mho$

Therefore the dynamic resistance of the diode at a biasing voltage of 0.6 volt is

$R_d=\left.\frac{dV}{di}\right|_{V=0.6V,T=300K}=\frac{1}{2.3}=0.435=435\ m\Omega$

In the reverse bias the current practically remains constant up to a large value known as break down voltage so no change in reverse bias current occurs when voltage changes from -1V to -2V

Ans: a, b, c & d

average

32.In the absence of electric field, when the drop falls under gravity alone, its speed is $v = \frac{distance\ covered}{time} \Rightarrow v = \frac{2.0\times10^{-3} m}{35.7\, s} = 0.056\ \frac{mm}{s}$ Also the next $v = \frac{1.2\times10^{-3} m}{21,4\, s} = 0.056\ \frac{mm}{s}$ This shows that this is the terminal velocity.

Therefore the apparent weight of the drop of radius r and density ρ equals the viscous force, that is, $\frac{4}{3}\pi r^3 (\rho-\sigma) g = 6\pi\eta r v$ Where σ is the density and η the viscosity of air.

Thus, $r = \sqrt{\frac{9\eta v}{2(\rho-\sigma) g}}$ or $r = \sqrt{\frac{9\times(1.80\times10^{-5})\times(0.056\times10^{-3})}{2\times(880-1.29)\times9.81}} \Rightarrow r = 7.26\times10^{-7} m$

When the drop is held stationary in the electric field, the upward electric force on the drop equals the apparent weight of the drop. That is,

$qE = \frac{4}{3}\pi r^3 (\rho-\sigma) g$ or $q = \frac{4\pi r^3 (\rho-\sigma) g}{3E}$ Here $E = \frac{V}{d} = \frac{103}{6.0\times10^{-3}}\ Vm^{-1}$

$$\therefore\ q = \frac{4\times3.14\times(7.26\times10^{-7})^3\times(880-1.29)\times9.81}{3\times103/6.0\times10^{-3}}$$

$or\ \ q = \frac{4\times3.14\times(7.26)^3\times878.71\times9.81\times6.0}{3\times103}\times10^{-24} = 8.045\times10^{-19} C$ to achieve equilibrium this chage must be negative

Now q = ne, where n is the number of excess electrons on the drop. Therefore,

$n = \frac{q}{e} = \frac{8.045\times10^{-19}}{1.6\times10^{-19}} = 5$ Thus the drop carries 5 excess electrons.

Ans: a,c &d