CBSE Class 12 Physics 2024 — Set 2 — Answer Key

English Medium

Time Allowed: 3 Hours

General Instructions:

1. This is an answer key — each question is shown with its correct answer and a step-by-step explanation.
2. Questions appear in the original paper order.

Q.1

Two charged particles P and Q, having the same charge but different masses mP and mQ, start from rest and travel equal distances in a uniform electric field E in time tP and tQ respectively. Neglecting the effect of gravity, the ratio tP/tQ is:

(a) mP/mQ

(b) mQ/mP

(c) √(mP/mQ) <<

(d) √(mQ/mP)

Explanation:

a = qE/m and s = ½at², so t = √(2sm/(qE)) ∝ √m.

Hence tP/tQ = √(mP/mQ), option (C).

Q.2

Electrons drift with speed vd in a conductor with potential difference V across its ends. If V is reduced to V/2, their drift speed will become:

(a) vd/2 <<

(b) vd

(c) 2vd

(d) 4vd

Explanation:

Drift speed vd = (eE/m)*tau = (eV)/(mL) * tau, so vd is proportional to V.

If V is halved, vd becomes vd/2.

Q.3

A wire of length 4·4 m is bent round in the shape of a circular loop and carries a current of 1·0 A. The magnetic moment of the loop will be:

(a) 0·7 Am2

(b) 1·54 Am2 <<

(c) 2·10 Am2

(d) 3·5 Am2

Explanation:

Circumference = 4.4 m => radius r = 4.4/(2*pi) = 4.4/6.2832 = 0.7 m.

Area A = pi*r^2 = pi*(0.7)^2 = 3.14159*0.49 = 1.539 m^2 ≈ 1.54 m^2.

Magnetic moment M = IA = 1.0 * 1.54 = 1.54 Am^2.

Q.4

A circular coil of radius 10 cm is placed in a magnetic field B = (1·0 i^ + 0·5 j^) mT such that the outward unit vector normal to the surface of the coil is (0·6 i^ + 0·8 j^). The magnetic flux linked with the coil is:

(a) 0·314 μWb

(b) 3·14 μWb

(c) 31·4 μWb <<

(d) 1·256 μWb

Explanation:

$B \cdot \hat{n} = (1{\cdot}0)(0{\cdot}6) + (0{\cdot}5)(0{\cdot}8) = 1{\cdot}0\ mT = 10^{-3}\ T.$

$A = \pi r^2 = \pi(0{\cdot}1)^2 = 3{\cdot}14\times10^{-2}\ m^2.$

$\Phi = 10^{-3} \times 3{\cdot}14\times10^{-2} = 3{\cdot}14\times10^{-5}\ Wb = 31{\cdot}4\ \mu Wb.$

Answer (C).

Q.5

Which of the following quantity/quantities remains same in primary and secondary coils of an ideal transformer? Current, Voltage, Power, Magnetic flux

(a) Current only

(b) Voltage only

(c) Power only

(d) Magnetic flux and Power both <<

Explanation:

In an ideal transformer, power is conserved (no energy loss), so power is the same in primary and secondary.

The magnetic flux through both coils is linked by the same core, so magnetic flux is the

same.
Current and voltage are transformed in ratio Ns/Np.
Hence both Magnetic flux and Power remain the same.

Q.6

A resistor and an ideal inductor are connected in series to a 100√2 V, 50 Hz ac source. When a voltmeter is connected across the resistor or the inductor, it shows the same reading. The reading of the voltmeter is:

(a) 100√2 V
(b) 100 V <<
(c) 50√2 V
(d) 50 V

Explanation:
VR = IR and VL = IXL.
Since VR = VL, we have R = XL.
The source emf = sqrt(VR^2 + VL^2) = sqrt(2)*VR = 100*sqrt(2) V.
So VR = 100 V.
The voltmeter reads 100 V.

Q.7

Electromagnetic waves with wavelength 10 nm are called:

(a) Infrared waves
(b) Ultraviolet rays
(c) Gamma rays
(d) X-rays <<

Explanation:
In the standard EM spectrum chart (NCERT) X-rays span about 10^{-8} m (10 nm) to 10^{-13} m, while gamma rays are far shorter and infrared far longer.
So 10 nm is the X-ray range: (D).

Q.8

The work function for a photosensitive surface is 3·315 eV. The cut-off

wavelength for photoemission of electrons from this surface is:

(a) 150 nm

(b) 200 nm

(c) 375 nm <<

(d) 500 nm

Explanation:

Cut-off wavelength: lambda_0 = hc/phi.

phi = 3.315 eV = 3.315 * 1.6e-19 J = 5.304e-19 J.

hc = 6.63e-34 * 3e8 = 1.989e-25 Jm.

lambda_0 = 1.989e-25 / 5.304e-19 = 3.75e-7 m = 375 nm.

Q.9

Energy levels A, B and C of an atom correspond to increasing values of energy i.e. EA < EB < EC. Let λ1, λ2 and λ3 be the wavelengths of radiation corresponding to the transitions C to B, B to A and C to A, respectively. The correct relation between λ1, λ2 and λ3 is:

(a) λ1^2 + λ2^2 = λ3^2

(b) 1/λ1 + 1/λ2 = 1/λ3 <<

(c) λ1 + λ2 + λ3 = 0

(d) λ1 + λ2 = λ3

Explanation:

E = hc/λ.

E_C − E_B = hc/λ1, E_B − E_A = hc/λ2, E_C − E_A = hc/λ3.

Adding the first two: hc/λ1 + hc/λ2 = hc/λ3 → 1/λ1 + 1/λ2 = 1/λ3.

Option (B).

Q.10

An alpha particle approaches a gold nucleus in Geiger-Marsden experiment with kinetic energy K. It momentarily stops at a distance d from the nucleus and reverses its direction. Then d is proportional to:

(a) 1/K <<

(b) K

(c) 1/sqrt(K)

(d) sqrt(K)

Explanation:

At closest approach, KE converts to PE: K = (1/4pi*epsilon0)*(2e*Ze)/d.

So d = (2Ze^2)/(4pi*epsilon0 * K).

Thus d is proportional to 1/K.

Q.11

An n-type semiconducting Si is obtained by doping intrinsic Si with:

(a) Al

(b) B

(c) P <<

(d) In

Explanation:

n-type semiconductor is obtained by doping with pentavalent (Group 15) impurities that donate extra electrons.

Phosphorus (P) is a pentavalent element.

Al, B, and In are trivalent (Group 13) and create p-type semiconductors.

Q.12

When a p-n junction diode is subjected to reverse biasing:

(a) the barrier height decreases and the depletion region widens.

(b) the barrier height increases and the depletion region widens. <<

(c) the barrier height decreases and the depletion region shrinks.

(d) the barrier height increases and the depletion region shrinks.

Explanation:

In reverse biasing, the external voltage adds to the built-in potential, increasing the barrier height.

This causes majority carriers to move away from the junction, widening the depletion region.

Q.13

Assertion (A): Photoelectric current increases with an increase in intensity of incident radiation, for a given frequency of incident radiation and the accelerating potential.

Reason (R): Increase in the intensity of incident radiation results in an increase in the number of photoelectrons emitted per second and hence an increase in the photocurrent.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A). <<

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

Explanation:

Both statements are correct.

Higher intensity means more photons per unit time, so more photoelectrons are emitted per second, increasing the photocurrent.

R correctly explains A.

Q.14

Assertion (A): Lenz's law is a consequence of the law of conservation of energy.

Reason (R): There is no power loss in an ideal inductor.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A). <<

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

Explanation:

Assertion A is true: Lenz's law states that induced current opposes the change causing it, which is a consequence of conservation of energy (energy cannot be created from nothing).

Reason R is also true (ideal inductor has no resistance, so no power loss), but R does not explain A.

Hence (B).

Q.15

Assertion (A): An electron and a proton enter with the same momentum p in a magnetic field B such that p $\perp$ B. Then both describe a circular path of the same radius.

Reason (R): The radius of the circular path described by the charged particle (charge q, mass m) moving in the magnetic field B is given by r = mv/(qB).

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A). <<

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false.

(d) Assertion (A) is false and Reason (R) is also false.

Explanation:

r = mv/(qB) = p/(qB).

Since the electron and proton have the same magnitude of charge e and same momentum p, they have the same radius r = p/(eB).

Assertion is true.

R gives the correct formula and explains A.

Hence (A).

Q.16

Assertion (A): The magnifying power of a compound microscope is negative.

Reason (R): The final image formed is erect with respect to the object.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the

correct explanation of the Assertion (A).

(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(c) Assertion (A) is true, but Reason (R) is false. <<

(d) Assertion (A) is false and Reason (R) is also false.

Explanation:

Assertion A is true: the magnifying power of a compound microscope is negative because the final image is inverted with respect to the object.

Reason R is false: the final image is actually inverted (not erect) with respect to the object.

Hence (C).

Q.17

Define resistivity of a conductor. How does the resistivity of a conductor depend upon the following:

(a) Number density of free electrons in the conductor (n)

(b) Their relaxation time (τ)

Answer: Resistivity (ρ) is defined as the resistance offered per unit length per unit cross-sectional area of the conductor; $\rho = RA/L$. From the relation $\rho = m/(ne^2\tau)$: (a) ρ is inversely proportional to number density n — greater n means lower resistivity. (b) ρ is inversely proportional to relaxation time τ — greater τ means lower resistivity.

Explanation:

Using the microscopic model: $J = nev_d$, $v_d = (eE/m)*\tau$, so $J = (ne^2\tau/m)E$.

By Ohm's law $J = \sigma E$, conductivity $\sigma = ne^2\tau/m$.

Resistivity $\rho = 1/\sigma = m/(ne^2\tau)$.

Thus $\rho \propto 1/n$ and $\rho \propto 1/\tau$.

Q.18

(a) Waves from two coherent sources of light superpose at a point. If the phase difference between the two waves is φ, obtain an expression for the

resultant intensity at that point.

Answer: $I = 4I_0 \cos^2(\varphi/2)$, where I_0 is the intensity due to each source. (Assuming equal amplitudes: $I = I_1 + I_2 + 2\sqrt{(I_1 \cdot I_2)} \cdot \cos(\varphi) = 2I_0(1 + \cos\varphi) = 4I_0 \cos^2(\varphi/2)$.)

Explanation:

Let the two waves be $E_1 = a \cdot \sin(\omega t)$ and $E_2 = a \cdot \sin(\omega t + \varphi)$.

Resultant amplitude: $A^2 = a^2 + a^2 + 2a^2\cos\varphi = 2a^2(1 + \cos\varphi) = 4a^2\cos^2(\varphi/2)$.

Intensity $\propto A^2$, so $I = 4I_0 \cdot \cos^2(\varphi/2)$ where $I_0 \propto a^2$.

OR

Q.18

(b) [OR] What is the effect on the interference pattern in Young's double-slit experiment when (i) the source slit is moved closer to the plane of the slits, and (ii) the separation between the two slits is increased? Justify your answers.

Answer: (i) The fringe width $\beta = \lambda D/d$ is unchanged, but the pattern becomes less sharp (fringes get blurred and may vanish) as the source slit is brought closer to the double slit. (ii) Fringe width $\beta = \lambda D/d$ decreases (fringes become narrower and closer).

Explanation:

(i) For sharp fringes the source width s and its distance S from the slits must satisfy $s/S \leq \lambda/d$.

Moving the source slit closer reduces S, so the condition fails: the fringes from different parts of the source overlap, the pattern becomes less sharp and may disappear.

$\beta = \lambda D/d$ does not depend on S.

(ii) $\beta = \lambda D/d \propto 1/d$, so increasing d makes the fringes narrower and more closely spaced.

Q.19

A convex lens (n = 1·52) has a focal length of 15·0 cm in air. Find its focal length when it is immersed in liquid of refractive index 1·65. What will be the

nature of the lens?

Answer: f = −99 cm (diverging/concave lens in the liquid)

Explanation:

In air: $1/15 = (1{\cdot}52 - 1)(1/R_1 - 1/R_2)$, so $(1/R_1 - 1/R_2) = 1/(0{\cdot}52 \times 15) = 1/7{\cdot}8$ cm^{-1}.

In the liquid: $1/f' = (1{\cdot}52/1{\cdot}65 - 1)(1/7{\cdot}8) = (-0{\cdot}13/1{\cdot}65)(1/7{\cdot}8) = -0{\cdot}13/12{\cdot}87 = -1/99$ cm^{-1}.

So $f' = -99$ cm.

Since n_liquid > n_lens, the convex lens behaves as a diverging (concave) lens.

Q.20

The carbon isotope 12/6 C has a nuclear mass of 12·000000 u. Calculate the binding energy of its nucleus. Given mp = 1·007825 u; mn = 1·008665 u.

Answer: Binding energy = 92.16 MeV

Explanation:

$_{6}^{12}C$ has 6 protons and 6 neutrons.

Mass of constituents = 6(1·007825) + 6(1·008665) = 6·04695 + 6·05199 = 12·09894 u.

Mass defect Δm = 12·09894 − 12·000000 = 0·09894 u.

BE = 0·09894 × 931·5 MeV = 92·16 MeV.

Q.21

How does the energy gap of an intrinsic semiconductor effectively change when doped with a (a) trivalent impurity, and (b) pentavalent impurity? Justify your answer in each case.

Answer: (a) Trivalent impurity (p-type): An acceptor energy level is created just above the valence band, effectively reducing the energy gap between the acceptor level and the conduction band. Electrons from the valence band can easily jump to the acceptor level. (b) Pentavalent impurity (n-type): A donor energy level is created just below the conduction band, reducing the effective energy gap. Donor electrons require much less energy to move to the conduction band.

Explanation:

(a) Trivalent dopants (like B, Al, In) create acceptor levels ~0.01–0.05 eV above the valence band, far smaller than the intrinsic gap (~1.1 eV for Si).

This effectively reduces the energy required for conduction.

(b) Pentavalent dopants (like P, As) create donor levels ~0.01–0.05 eV below the conduction band, dramatically reducing the energy needed to liberate electrons into the conduction band.

Q.22

The figure shows a circuit with three ideal batteries. Find the magnitude and direction of currents in the branches AG, BF and CD.

Answer: I_AG = 0·5 A (A to G, i.e. downward); I_BF = 0·25 A (F to B, upward); I_CD = 0·25 A (D to C, upward)

Explanation:

From the figure: 3 V battery in AG (+ at A);

4 Ω in series with a 6 V battery (+ towards B) in BF;

6 V battery (+ at C) in series with 2 Ω in CD;

2 Ω in AB, BC and GF;

F and D joined by a wire.

Take V_F = V_D = 0 and let V_B = b.

Current along G→A→B through the 3 V battery and the two 2 Ω resistors: $I_1 = (3 - b)/4$.

Current from B to F: $I_2 = (b - 6)/4$.

Current along B→C→D through the 6 V battery and the two 2 Ω resistors: $I_3 = (b - 6)/4$.

KCL at B: $I_1 = I_2 + I_3$, so $(3 - b)/4 = (b - 6)/2$, which gives b = 5 V.

Hence $I_1 = -0·5$ A, $I_2 = -0·25$ A and $I_3 = -0·25$ A.

So 0·5 A flows from A to G, 0·25 A from F to B, and 0·25 A from D to C.

Check at B: 0·25 (from F) + 0·25 (from C) = 0·5 A leaving towards A.

Q.23

(a) On what factors does the speed of an electromagnetic wave in a medium depend?

(b) How is an electromagnetic wave produced?

(c) Sketch a schematic diagram depicting the electric and magnetic fields for an electromagnetic wave propagating along z-axis.

Answer: (a) Speed of EM wave in a medium depends on the electric permittivity (ε) and magnetic permeability (μ) of the medium: v = 1/sqrt(με). In vacuum, v = c = 1/sqrt(μ0ε0). (b) An electromagnetic wave is produced by an accelerating (oscillating) electric charge. An oscillating electric charge produces an oscillating electric field, which in turn produces an oscillating magnetic field; together they propagate as an EM wave. (c) For a wave propagating along the z-axis: E is along x-axis (Ex = E0 sin(kz - ωt)) and B is along y-axis (By = B0 sin(kz - ωt)); E, B, and propagation direction (z) are mutually perpendicular.

Explanation:

(a) v = c/n = 1/sqrt(με) where n is refractive index.

(b) Maxwell showed that accelerating charges radiate EM waves.

(c) In a transverse EM wave along z: E ⊥ B ⊥ z, with E and B in phase.

Q.24

A 100-turn coil of radius 1·6 cm and resistance 5·0 Ω is co-axial with a solenoid of 250 turns/cm and radius 1·8 cm. The solenoid current drops from 1·5 A to zero in 25 ms. Calculate the current induced in the coil in this duration. (Take $\pi^2 = 10$)

Answer: Induced current ≈ 3.1×10^{-2} A (30.7 mA)

Explanation:

Coil (r = 1.6 cm) lies inside the solenoid, so flux through it = $\mu_0 n I \cdot \pi r^2$.

$M = \mu_0 n N \pi r^2 = 4\pi \times 10^{-7} \times 25000 \times 100 \times \pi \times (0.016)^2 = 4\pi^2 \times 10^{-7} \times 2.5 \times 10^6 \times 2.56 \times 10^{-4} = 40 \times 10^{-7} \times 2.5 \times 10^6 \times 2.56 \times 10^{-4} = 2.56 \times 10^{-3}$ H ($\pi^2 = 10$).

$|\varepsilon| = M(\Delta I/\Delta t) = 2.56 \times 10^{-3} \times (1.5/0.025) = 2.56 \times 10^{-3} \times 60 = 0.1536$ V.

$I = \varepsilon/R = 0.1536/5.0 \approx 3.07 \times 10^{-2}$ A.

Q.25

(a) Two long, straight, parallel conductors carry steady currents in opposite directions. Explain the nature of the force of interaction between them.

Obtain an expression for the magnitude of the force between the two conductors. Hence define one ampere.

Answer: The force between two parallel conductors carrying currents in opposite directions is repulsive. Force per unit length: $F/L = \mu_0 \cdot I1 \cdot I2/(2\pi d)$, where d is the separation. One ampere is defined as the current which, when flowing in each of two infinitely long, straight, parallel conductors of negligible cross-section placed 1 m apart in vacuum, produces a force of 2×10^{-7} N per metre of length between them.

Explanation:

Magnetic field due to conductor 1 at distance d: $B1 = \mu_0 \cdot I1/(2\pi d)$.

Force on conductor 2 of length L carrying I2: $F = I2 \cdot L \cdot B1 = \mu_0 \cdot I1 \cdot I2 \cdot L/(2\pi d)$.

$F/L = \mu_0 \cdot I1 \cdot I2/(2\pi d)$.

For opposite currents, by Fleming's left-hand rule or right-hand rule, the force is repulsive.

Definition of ampere follows from setting I1=I2=1A, d=1m: $F/L = 4\pi\times10^{-7}/(2\pi) = 2\times10^{-7}$ N/m.

OR

Q.25

(b) [OR] Obtain an expression for the torque τ acting on a current carrying loop in a uniform magnetic field B. Draw the necessary diagram.

Answer: Torque $\tau = nIAB\sin\theta = M \times B$ (in vector form), where $M = nIA$ is the magnetic moment of the loop, n = number of turns, I = current, A = area, θ = angle between M and B.

Explanation:

For a rectangular loop of sides a and b carrying current I in uniform field B: Forces on sides parallel to B are zero.

Forces on the other two sides are $F = IBa$ each, in opposite directions forming a couple.

Torque = $F \times b \sin\theta = IBa \times b \sin\theta = IB(ab)\sin\theta = IBA\sin\theta$.

For n turns: $\tau = nIBA\sin\theta = MB\sin\theta$, where $M = nIA$.

In vector form, $\tau = M \times B$.

Q.26

Using Bohr's postulates, derive the expression for the radius of the nth orbit of an electron in a hydrogen atom. Also find the numerical value of Bohr radius a0.

Answer: $r_n = n^2 a_0$, where $a_0 = \varepsilon_0 h^2/(\pi m e^2) = 0.529$ Å ≈ 0.53 Å

Explanation:

Bohr's postulates: (1) Electron moves in circular orbit;
centripetal force = Coulomb force: $mv^2/r = e^2/(4\pi\varepsilon_0 r^2)$.
(2) Angular momentum quantization: $mvr = nh/(2\pi)$.
From (2): $v = nh/(2\pi mr)$.
Substituting in (1): $m(n^2h^2/4\pi^2m^2r^2)/r = e^2/(4\pi\varepsilon_0 r^2)$.
=> $n^2h^2/(4\pi^2mr) = e^2/(4\pi\varepsilon_0)$.
=> $r = n^2h^2\varepsilon_0/(\pi me^2) = n^2a_0$.
$a_0 = \varepsilon_0h^2/(\pi me^2) = (8.854\times10^{-12}\times(6.626\times10^{-34})^2)/(\pi\times9.1\times10^{-31}\times(1.6\times10^{-19})^2) \approx 0.529\times10^{-10}$ m = 0.529 Å.

Q.27

de Broglie wavelength as a function of $1/\sqrt{K}$, for two particles of masses m1 and m2 are shown in the figure. Here, K is the energy of the moving particles.

(a) What does the slope of a line represent?

(b) Which of the two particles is heavier?

(c) Is this graph also valid for a photon? Justify your answer in each case.

Answer: (a) The slope is $h/\sqrt{(2m)}$. (b) m_1 is heavier: its line has the smaller slope (slope $\propto 1/\sqrt{m}$). (c) No: for a photon $\lambda = hc/E$, so $\lambda \propto 1/K$, not $1/\sqrt{K}$.

Explanation:

(a) $\lambda = h/\text{sqrt}(2mK) = [h/\text{sqrt}(2m)] * (1/\text{sqrt}(K))$.
Slope = $h/\text{sqrt}(2m)$.
(b) Slope $\propto 1/\text{sqrt}(m)$.

Larger slope => smaller m.

Particle with smaller slope is heavier.

(c) For photon: E = pc => p = E/c, so λ = h/p = hc/E = hc/K.

Thus λ ∝ 1/K, not 1/sqrt(K).

The graph is not valid for photons.

Q.28

With the help of a circuit diagram, explain the working of a p-n junction diode as a full wave rectifier. Draw its input and output waveforms.

Answer: A full wave rectifier uses two p-n junction diodes and a centre-tapped transformer. During the positive half cycle, diode D1 is forward biased and conducts, while D2 is reverse biased. During the negative half cycle, D2 conducts and D1 is reverse biased. In both half cycles, current flows in the same direction through the load resistance, producing a pulsating dc output. The output waveform shows both half cycles of the input appearing as positive pulses.

Explanation:

Circuit: Centre-tapped transformer with two diodes D1 and D2.

D1's anode connected to one end of secondary, D2's anode to other end;

both cathodes joined to one end of RL;

other end of RL to centre tap.

Positive half: Upper end positive => D1 forward biased, current through RL.

Negative half: Lower end positive => D2 forward biased, current through RL in same direction.

Output: full wave rectified signal (frequency doubled compared to input).

Q.29(i)

When the terminals of a cell are connected to a conductor of resistance R, an electric current flows through the circuit. The electrolyte of the cell also offers some resistance in the path of the current, like the conductor. This resistance offered by the electrolyte is called internal resistance of the cell (r). It depends upon the nature of the electrolyte, the area of the electrodes immersed in the electrolyte and the temperature. Due to internal resistance,

a part of the energy supplied by the cell is wasted in the form of heat.
When no current is drawn from the cell, the potential difference between the two electrodes in known as emf of the cell (ε). With a current drawn from the cell, the potential difference between the two electrodes is termed as terminal potential difference (V).

Choose the incorrect statement :

(a) The potential difference (V) between the two terminals of a cell in a closed circuit is always less than its emf (ε), during discharge of the cell.
(b) The internal resistance of a cell decreases with the decrease in temperature of the electrolyte. <<
(c) When current is drawn from the cell then $V = \varepsilon - Ir$.
(d) The graph between potential difference between the two terminals of the cell (V) and the current (I) through it is a straight line with a negative slope.

Explanation:

Statement (B) is incorrect.
The internal resistance of a cell increases (not decreases) with a decrease in temperature, because lower temperature reduces ionic mobility in the electrolyte, increasing resistance.

Q.0

Case Study Q29 (ii): Two cells of emfs 2·0 V and 6·0 V and internal resistances 0·1 Ω and 0·4 Ω respectively, are connected in parallel. The equivalent emf of the combination will be:

(a) 2·0 V
(b) 2·8 V <<
(c) 6·0 V
(d) 8·0 V

Explanation:

For cells in parallel: $\varepsilon_{eq} = (\varepsilon_1 r_2 + \varepsilon_2 r_1)/(r_1 + r_2) = (2.0 \times 0.4 + 6.0 \times 0.1)/(0.1 + 0.4) = (0.8 + 0.6)/0.5 = 2.8$ V.

Option (B).

Q.0

Case Study Q29 (iii): The electrode dipped in the solution exchanges charges with the electrolyte. The positive electrode develops a potential V+ (V+ > 0) and the negative electrode develops a potential V− (V− ≤ 0), relative to the electrolyte adjacent to it. When no current is drawn from the cell then:

(a) $\varepsilon = V+ + V- > 0$

(b) $\varepsilon = V+ - V- > 0$ <<

(c) $\varepsilon = V+ + V- < 0$

(d) $\varepsilon = V+ + V- = 0$

Explanation:

The emf is the potential difference between the two electrodes: $\varepsilon = V+ - V-$.

Since V+ > 0 and V− ≤ 0, we have $\varepsilon = V+ - V- > 0$ (positive − negative = positive + |negative| > 0).

Hence option (B).

Q.0

Case Study Q29 (iv)(a): Five identical cells, each of emf 2 V and internal resistance 0·1 Ω are connected in parallel. This combination in turn is connected to an external resistor of 9·98 Ω. The current flowing through the resistor is:

(a) 0·05 A

(b) 0·1 A

(c) 0·15 A

(d) 0·2 A <<

Explanation:

For n identical cells in parallel: ε_eq = ε = 2 V, r_eq = r/n = 0.1/5 = 0.02 Ω.

Total resistance = R + r_eq = 9.98 + 0.02 = 10 Ω.

Current I = ε_eq / (R + r_eq) = 2/10 = 0.2 A.

Q.0

Case Study Q29 (iv)(b) [OR]: Potential difference across a cell in the open circuit is 6 V. It becomes 4 V when a current of 2 A is drawn from it. The internal resistance of the cell is:

(a) 1·0 Ω <<

(b) 1·5 Ω

(c) 2·0 Ω

(d) 2·5 Ω

Explanation:

Open circuit voltage = ε = 6 V.

Terminal voltage V = 4 V when I = 2 A.

ε - V = Ir => 6 - 4 = 2r => r = 2/2 = 1 Ω.

Answer is (A) 1.0 Ω.

Q.30(i)

When a ray of light propagates from a denser medium to a rarer medium, it bends away from the normal. When the incident angle is increased, the refracted ray deviates more from the normal. For a particular angle of incidence in the denser medium, the refracted ray just grazes the interface of the two surfaces. This angle of incidence is called the critical angle for the pair of media involved.

For a ray incident at the critical angle, the angle of reflection is:

(a) 0°

(b) < 90° <<

(c) > 90°

(d) 90°

Explanation:

By the law of reflection, angle of reflection = angle of incidence.

At incidence equal to the critical angle (which is always less than 90°), the reflected ray makes the same angle, i.e.

< 90°.

(The 90° value belongs to the refracted ray, which grazes the interface.) Option (B).

Q.0

Case Study Q30 (ii): A ray of light of wavelength 600 nm is incident in water (n = 4/3) on the water-air interface at an angle less than the critical angle. The wavelength associated with the refracted ray is:

(a) 400 nm

(b) 450 nm

(c) 600 nm

(d) 800 nm <<

Explanation:

Frequency is unchanged on refraction, so $\lambda \propto 1/n$.

$\lambda_{air} = \lambda_{water} \times (n_{water}/n_{air}) = 600 \times (4/3) = 800$ nm.

Option (D).

Q.0

Case Study Q30 (iii)(a): The interface AB between the two media A and B is shown in the figure. In the denser medium A, the incident ray PQ makes an angle of 30° with the horizontal. The refracted ray is parallel to the interface. The refractive index of medium B w.r.t. medium A is:

(a) $\sqrt{3}/2$ <<

(b) $\sqrt{5}/2$

(c) $4/\sqrt{3}$

(d) $2/\sqrt{3}$

Explanation:

The incident ray makes 30° with the horizontal (interface), so angle of incidence with normal = 90° - 30° = 60°.

The refracted ray is parallel to the interface, meaning angle of refraction = 90°.

By Snell's law: $n_A \sin(60°) = n_B \sin(90°)$.

$n_B/n_A = \sin(60°)/\sin(90°) = (\sqrt{3}/2)/1 = \sqrt{3}/2$.

So refractive index of B w.r.t. A = $n_B/n_A = \sqrt{3}/2$.

Answer is (A) $\sqrt{3}/2$.

Q.0

Case Study Q30 (iii)(b) [OR]: Two media A and B are separated by a plane boundary. The speed of light in medium A and B is 2×10^8 ms^{-1} and $2{\cdot}5 \times 10^8$ ms^{-1} respectively. The critical angle for a ray of light going from medium A to medium B is:

(a) $\sin^{-1}(1/2)$

(b) $\sin^{-1}(4/5)$ <<

(c) $\sin^{-1}(3/5)$

(d) $\sin^{-1}(2/5)$

Explanation:

$n_A = c/v_A = 3e8/2e8 = 1.5$; $n_B = c/v_B = 3e8/2.5e8 = 1.2$.

Critical angle: $\sin(\theta_c) = n_B/n_A = 1.2/1.5 = 4/5$.

$\theta_c = \sin^{-1}(4/5)$.

Answer (B).

Q.0

Case Study Q30 (iv): The figure shows the path of a light ray through a triangular prism. In this phenomenon, the angle θ is given by:

(a) $\sin^{-1}(\sqrt{(n^2-1)})$ <<

(b) $\sin^{-1}(n^2-1)$

(c) $\sin^{-1}(1/\sqrt{(n^2-1)})$

(d) $\sin^{-1}(1/(n^2-1))$

Explanation:

The ray enters the left face at incidence θ and refracts through r, so sin θ = n sin r.

The prism angle is 90°, so at the second face the angle of incidence is 90° − r.

The ray just undergoes total internal reflection there: sin(90° − r) = 1/n, so cos r = 1/n and sin r = √(n²−1)/n.

Hence sin θ = n sin r = √(n²−1), θ = $\sin^{-1}(\sqrt{(n^2-1)})$.

Answer (A).

Q.31(a)

(a)(i) Obtain an expression for the electric potential due to a small electric dipole of dipole moment $\vec{p}$, at a point r from its centre, for much larger distances compared to the size of the dipole.

(ii) Three point charges q, 2q and nq are placed at the vertices of an equilateral triangle. If the potential energy of the system is zero, find the value of n.

Answer: (i) $V = (1/4\pi\varepsilon_0)(p\cos\theta/r^2)$, θ = angle between $\vec{p}$ and $\vec{r}$. (ii) n = −2/3

Explanation:

(i) Charges −q at A and +q at B, separation 2a, p = 2qa.

At P (distance r, angle θ from $\vec{p}$): $r_1 \approx r - a\cos\theta$ (from +q), $r_2 \approx r + a\cos\theta$ (from −q).

$V = (q/4\pi\varepsilon_0)(1/r_1 - 1/r_2) = (q/4\pi\varepsilon_0)(2a\cos\theta)/(r^2 - a^2\cos^2\theta)$.

For $r \gg a$: $V = (1/4\pi\varepsilon_0)(p\cos\theta/r^2)$, i.e.

$V = \vec{p}\cdot\hat{r}/(4\pi\varepsilon_0 r^2)$.

(ii) Side a: $U = (1/4\pi\varepsilon_0 a)[q(2q) + q(nq) + 2q(nq)] = (q^2/4\pi\varepsilon_0 a)(2 + 3n) = 0 \rightarrow n = -2/3$.

Q.31(b)

(b)(i) [OR] State Gauss's law in electrostatics. Apply this to obtain the electric field E at a point near a uniformly charged infinite plane sheet.

(ii) Two long straight wires 1 and 2 are kept as shown in the figure. The linear charge density of the two wires are λ1 = 10 μC/m and λ2 = −20 μC/m. Find the net force F experienced by an electron held at point P.

Answer: (i) Gauss's law: $\oint \vec{E}\cdot d\vec{A} = Q_{enc}/\varepsilon_0$. For an infinite plane sheet of surface charge density σ, by symmetry the field is perpendicular to the sheet on

both sides. Using a pillbox Gaussian surface of area A: 2EA = σA/ε0 → E = σ/(2ε0). (ii) From the figure: wire 1 (λ1 = +10 μC/m) is at the top; point P is 10 cm = 0.1 m below wire 1; wire 2 (λ2 = −20 μC/m) is 30 cm below wire 1, so P is 20 cm = 0.2 m above wire 2. Coordinate axes: î rightward, ĵ upward. E due to wire 1 at P: $E1 = \lambda1/(2\pi\varepsilon0r1) = (10\times10^{-6})/(2\pi\times8.85\times10^{-12}\times0.1) = 1.8\times10^{6}$ N/C, directed away from wire 1 (positive λ1) → downward: $E1 = -1.8\times10^{6}$ ĵ N/C. E due to wire 2 at P: $E2 = |\lambda2|/(2\pi\varepsilon0r2) = (20\times10^{-6})/(2\pi\times8.85\times10^{-12}\times0.2) = 1.8\times10^{6}$ N/C, directed toward wire 2 (negative λ2) → downward: $E2 = -1.8\times10^{6}$ ĵ N/C. Total $E = -3.6\times10^{6}$ ĵ N/C. Force on electron (charge $-e = -1.6\times10^{-19}$ C): $F = (-1.6\times10^{-19})(-3.6\times10^{6}\ \hat{j}) = 5.76\times10^{-13}\ \hat{j}$ N ≈ 5.76×10^{-13} N directed upward (in +ĵ direction).

Explanation:

The figure shows the geometry: wire 1 is at the top, wire 2 is 30 cm below wire 1 (at the bottom), point P is 10 cm below wire 1 (and thus 20 cm above wire 2).

Both electric fields at P point downward (field from positive wire 1 points away = downward;

field from negative wire 2 points toward it = downward).

The electron (negative charge) experiences an upward force.

Q.32(a)

(a)(i) A particle of mass m and charge q is moving with a velocity v in a magnetic field B as shown in the figure. Show that it follows a helical path. Hence, obtain its frequency of revolution.

(ii) In a hydrogen atom, the electron moves in an orbit of radius 2 Å making 8×10^{14} revolutions per second. Find the magnetic moment associated with the orbital motion of the electron.

Answer: (i) Frequency of revolution: f = qB/(2πm). (ii) Magnetic moment M = IA = $(qf)(\pi r^2) = e \times (8\times10^{14}) \times \pi \times (2\times10^{-10})^2 = 1.6\times10^{-19} \times 8\times10^{14} \times \pi \times 4\times10^{-20} = 1.6\times10^{-19} \times 8\times10^{14} \times 1.2566\times10^{-19} = 1.608\times10^{-23}$ A·m².

Explanation:

(i) v has component v_perp perpendicular to B (causing circular motion) and v_parallel

parallel to B (causing straight-line motion).

Combined: helical path.

For circular component: $qv_{perp} B = mv_{perp}^2/r \Rightarrow r = mv_{perp}/(qB)$.

Period $T = 2\pi r/v_{perp} = 2\pi m/(qB)$.

Frequency $f = 1/T = qB/(2\pi m)$ — independent of speed.

(ii) Current $I = ef = 1.6\times10^{-19} \times 8\times10^{14} = 1.28\times10^{-4}$ A.

Area $A = \pi r^2 = \pi\times(2\times10^{-10})^2 = 1.2566\times10^{-19}$ m².

$M = IA = 1.28\times10^{-4} \times 1.2566\times10^{-19} = 1.61\times10^{-23}$ A·m².

Q.32(b)

(b)(i) [OR] What is current sensitivity of a galvanometer? Show how the current sensitivity of a galvanometer may be increased. Increasing the current sensitivity of a galvanometer may not necessarily increase its voltage sensitivity. Explain.

(ii) A moving coil galvanometer has a resistance 15 Ω and takes 20 mA to produce full scale deflection. How can this galvanometer be converted into a voltmeter of range 0 to 100 V?

Answer: (i) Current sensitivity = $\theta/I = NAB/k$ (deflection per unit current). Increase by: increasing N, A, B or decreasing k. Voltage sensitivity = $\theta/V = NAB/(kR_G)$. Increasing N increases R_G, so voltage sensitivity may not increase. (ii) Series resistance $R_s = V/I_g - R_G = 100/(20\times10^{-3}) - 15 = 5000 - 15 = 4985$ Ω.

Explanation:

(i) $S_I = NAB/k$.

To increase: more turns, larger area, stronger B, softer spring.

$S_V = S_I/R_G = NAB/(kR_G)$.

Adding turns increases N but also increases $R_G \propto N$, so $S_V = NAB/(kN\rho/A_{wire})$ may stay constant or decrease.

(ii) For voltmeter: connect high resistance R_s in series.

$I_g \times (R_G + R_s) = V_{max}$.

$R_s = V_{max}/I_g - R_G = 100/0.020 - 15 = 5000 - 15 = 4985$ Ω.

Q.33(a)

(a)(i) Give any two differences between the interference pattern obtained in Young's double-slit experiment and a diffraction pattern due to a single slit.

(ii) Draw an intensity distribution graph in case of a double-slit interference pattern.

(iii) In Young's double-slit experiment using monochromatic light of wavelength λ, the intensity of light at a point on the screen, where path difference is λ, is K units. Find the intensity of light at a point on the screen where the path difference is λ/6.

Answer: (i) Any two: interference fringes are all of equal width, whereas in single-slit diffraction the central maximum is twice as wide as the others; interference fringes have (nearly) equal intensity, whereas diffraction maxima fall off in intensity away from the centre. (ii) Graph: equally spaced maxima of equal intensity with minima between them. (iii) Intensity = 3K/4.

Explanation:

(iii) Path difference λ => phase difference 2π => I = K.

The relation: $I = 4I_0 \cos^2(\delta/2)$ where δ is phase difference.

At $\delta = 2\pi$: $K = 4I_0 \cos^2(\pi) = 4I_0 \times 1 \Rightarrow I_0 = K/4$.

At path diff λ/6: $\delta = 2\pi/\lambda \times \lambda/6 = \pi/3$.

$I = 4I_0 \cos^2(\pi/6) = 4(K/4)(\sqrt{3}/2)^2 = K \times (3/4) = 3K/4$.

Q.33(b)

(b)(i) [OR] Draw a labelled ray diagram of a compound microscope showing image formation at least distance of distinct vision. Derive an expression for its magnifying power.

(ii) A telescope consists of two lenses of focal length 100 cm and 5 cm. Find the magnifying power when the final image is formed at infinity.

Answer: (i) With the final image at the least distance of distinct vision, the magnifying power of a compound microscope is $M = m_o \times m_e = -(v_o/u_o) \times (1 + D/f_e) \approx -(L/f_o)(1 + D/f_e)$, where L is the tube length, D = 25 cm, and f_o and

f_e are the focal lengths of the objective and eyepiece. (ii) When final image is at infinity (normal adjustment): M = −f_o/f_e = −100/5 = −20. Magnifying power = 20 (magnitude).

Explanation:

(i) Objective forms a real, inverted, magnified image (I') at distance v_o.

Eyepiece acts as a magnifier for this image.

m_o = −v_o/u_o ≈ L/f_o for object near F_o.

m_e = 1 + D/f_e (image at D) or D/f_e (image at infinity).

Total M = m_o × m_e.

(ii) M = f_o/f_e = 100/5 = 20 (in magnitude; negative sign indicates inverted image).

f_o = 100 cm (objective), f_e = 5 cm (eyepiece).