CBSE EXAMINATION PAPER-2026

PHYSICS

(Solved)

Time allowed : 3 hours | Maximum Marks : 82

General Instructions :

Read the following instructions carefully and follow them :

i. This question paper contains **38 questions.** All questions are **compulsory.**

ii. This question paper is divided into **5 sections.**

iii. **Section A** – questions number **1 to 2** are case based questions

iv. **Section B** – questions number **3 to 18** are multiple choice questions

v. **Section C** – questions number **19 to 24** are very short answer

vi. **Section D** – questions number **25 to 32** are short answer

vii. **Section E** – questions number **33 to 38** are long answer

viii. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions.

ix. Use of calculator is NOT allowed.

Section A

Question 1.

A galvanometer is used to detect or /and measure small currents in an electric circuit. It essentially works on the fact that a current-carrying coil experiences a deflecting torque when placed in a magnetic field. This deflection in the coil can be measured and it is related to the current flowing in the coil, the number of turns in the coil, area of the coil and magnetic field. A hair spring attached to the coil provides a counter torque and helps in measuring the deflection. A galvanometer can be converted to an ammeter or a voltmeter of desired range by using suitable resistances.

(1)

The torque on the coil remains constant irrespective of the coil's orientation during rotation due to

(A) use of soft iron core which increases the magnetic field.

(B) radial magnetic field

(C) hair spring which provides the counter torque

(D) eddy current in the iron core which causes damping.

[1 Marks]

Answer: The torque on the coil remains constant during rotation because the coil is placed in a **radial magnetic field**. This makes the magnetic force always perpendicular to the coil, keeping the torque constant as explained in the case with the coil's deflection depending on the magnetic field and current.

Key Points: torque constant due to radial magnetic field - coil experiences deflecting torque in magnetic field - hair spring provides counter torque but does not keep torque constant

(2)

The best way to increase current sensitivity of a galvanometer is by

(A) increasing number of turns of the coil

(B) increasing area of coil and magnetic field strength

(C) decreasing area of coil and magnetic field strength

(D) increasing torsional constant of the hair spring

[1 Marks]

Answer: The best way to increase current sensitivity of a galvanometer is by increasing the number of turns of the coil. This is because the deflecting torque depends on the number of turns, so more turns increase the deflection for a small current, making the galvanometer more sensitive as explained in the passage.

Key Points: Current sensitivity depends on deflecting torque - Deflecting torque increases with number of turns of coil - Increasing number of turns increases galvanometer sensitivity

(3)

A moving coil galvanometer has a coil with area of cross-section 4.0×10^{-3} m^2 and number of turns 50. The coil is rotating in a magnetic field of 0.25 T. The torque acting on the coil when a current of 5 A passes through it is

(A) 1.0 N m

(B) 2.0 N m

(C) 0.50 N m

(D) 0.25 N m

[1 Marks]

Answer: The torque T on the coil is given by T = N * I * A * B where N=50, I=5 A, A=4.0 * 10^-3 m^2, B=0.25 T according to the case. Calculating, T = 50 * 5 * 4.0 * 10^-3 * 0.25 = 0.25 N m. Hence, the correct answer is (D) 0.25 N m.

Key Points: Torque on coil is T = N * I * A * B - Given values are substituted in formula - Calculated torque is 0.25 N m as in option D

(4)

A galvanometer coil has a resistance of 15 Ω and the meter shows full scale deflection for a current of 3 mA. The value of resistance required to convert it into a voltmeter of range (0 – 12 V) is

(A) 4015 Ω

(B) 3985 Ω

(C) 415 Ω

(D) 385 Ω

[1 Marks]

Answer: To convert the galvanometer into a voltmeter of 0-12 V range, we need a series resistance R such that total voltage is 12 V for the full scale current 3 mA. Using V = I * (R + R_g), where R_g = 15 Ω and I = 3 mA = 0.003 A, we get R = (12 / 0.003) - 15 = 3985 Ω. So, the required resistance is 3985 Ω (option B). This matches the explanation that suitable resistances convert a galvanometer into a voltmeter.

Key Points: Galvanometer measures small currents - It can be converted into a voltmeter using series resistance - Use V = I * (R + R_g) to find required resistance

(5)

A galvanometer with coil of resistance 20 Ω shows full scale deflection for a current of 5 mA. To convert it into an ammeter of range (0 – 10 A), a resistance of

(A) 0.05 Ω should be connected in series with it.

(B) 0.05 Ω should be connected in parallel with it.

(C) 0.01 Ω should be connected in parallel with it.

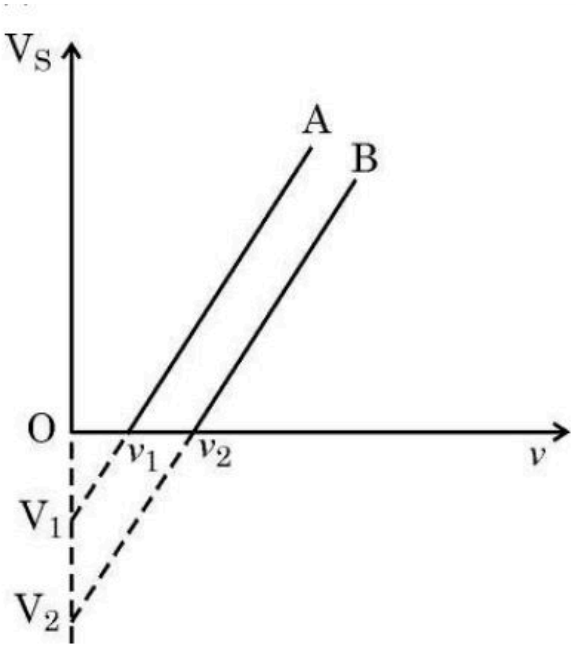
(D) 0.01 Ω should be connected in series with it.

[1 Marks]

Answer: To convert the galvanometer into an ammeter for 10 A range, a very low resistance called shunt resistance is connected in parallel with the galvanometer, as mentioned in the case passage. This allows most current to pass through the shunt, protecting the galvanometer and extending its range. Thus, option (C) 0.01 Ω connected in parallel is correct.

Key Points: Galvanometer is sensitive and detects small currents - To measure large currents, a shunt resistance is connected in parallel - Shunt resistance allows higher current measurement without damaging the galvanometer

Question 2. A researcher performs an experiment on photo-electric effect using two metals A and B with unknown work functions. She illuminates the surfaces of A and B with monochromatic radiation of various frequencies and records the value of corresponding stopping potentials (Vs). The graph shows the variation of stopping potential (Vs) with the frequency of incident radiation (ν) for metals A and B.



(1)

(I) From the graph, the work functions of A and B are (h is Planck's constant and e value of charge on an electron)

(A) ν_1 and ν_2

(B) V_1 and V_2

(C) $h\nu_1$ and $h\nu_2$

(D) $h\nu_1/e$ and $h\nu_2/e$

[1 Marks]

Answer:

Correct answer is option (C)

Work function equals Planck's constant multiplied by the threshold frequency. The graph shows threshold frequencies at the horizontal intercepts: ν_1 for metal A and ν_2 for metal B.

Key Points:

(2)

If the intensity of the incident radiation for both metals A and B, is doubled keeping its frequency constant, then

(A) the slope of the parallel lines will increase.

(B) the slope of the parallel lines will decrease.

(C) the threshold frequencies for both A and B will decrease.

(D) the slope of the parallel lines will not change but more electrons will be emitted per second.

[1 Marks]

Answer: When the intensity of incident radiation is doubled at constant frequency, the slope of the stopping potential versus frequency graph does not change as it depends on universal constants. However, more electrons are emitted per second, increasing the photocurrent, as explained in the case where the slope is same for both metals and threshold frequencies remain constant.
Correct option is (D).

Key Points: Intensity increase increases number of emitted electrons - Slope depends on constants e and h, so remains same - Threshold frequency remains unchanged

(3)

For radiation of frequency $\nu > \nu_2$ incident on the surfaces of A and B, the maximum kinetic energy of ejected electron is

(A) greater for metal A because it has a smaller work function.

(B) greater for metal B because it has a larger work function.

(C) greater for metal B because it has higher threshold frequency.

(D) the same for both metal A and metal B because it is independent of work functions of metals.

[1 Marks]

Answer:

Correct answer is option (A)

Kinetic energy equals photon energy minus the work function. Since metal A has a lower threshold frequency ($\nu_1 < \nu_2$), it has a smaller work function, leading to higher kinetic energy.

Key Points:

(4)

The threshold frequency for a metal surface is ν_0. If the radiation of frequency $3\nu_0$ illuminates the surface, the maximum kinetic energy (KE) of photoelectrons is E_1. If the frequency were increased to $6\nu_0$, the maximum KE of the photoelectrons becomes E_2. Then $\square E_1/E_2 \square$ equals

(A) 1/3

(B) 1/2

(C) 2/5

(D) 3/4

[1 Marks]

Answer: According to the photoelectric equation KEmax = h\u03BD - h\u03BD$_0$. For frequency 3\u03BD$_0$, E_1 = h(3\u03BD$_0$ - \u03BD$_0$) = 2h\u03BD$_0$. For frequency 6\u03BD$_0$, E_2 = h(6\u03BD$_0$ - \u03BD$_0$) = 5h\u03BD$_0$. So, E_1/E_2 = 2h\u03BD$_0$/5h\u03BD$_0$ = 2/5. Hence, the correct answer is option (C).

Key Points: Photoelectric KE equation KEmax = h\u03BD - h\u03BD$_0$ - Calculate KE for given frequencies - Find ratio E_1/E_2 = 2/5

(5)

Let m be the slope of the graph line for metal B. If e is the value of electron charge, then Planck's constant 'h' is given by

(A) me

(B) 1/me

(C) m/e

(D) e/m

[1 Marks]

Answer: The slope m of the stopping potential Vs versus frequency nu graph is related to Planck's constant h by the equation Vs = (h/e) * nu - phi/e. Therefore, h = m * e, where e is the electron charge. Hence, Planck's constant h is given by option (A) me as explained in the case where the slope is the same for both metals.

Key Points: Slope of Vs vs frequency graph is h/e - h is Planck's constant - h equals slope times electron charge e

Section B

Question 3.

In a region, the electric potential varies as V = 10 – 50x, where V is in volts and x in meters. The electric field in the region is:

[1 Marks]

(A) 10 N/C along −x

(B) 10 N/C along +x

(C) 50 N/C along +x

(D) 50 N/C along −x

Explanation: The electric field E is related to the potential V by E = -dV/dx. Given V = 10 - 50x, dV/dx = -50. Therefore, E = -(-50) = 50 N/C. Since the potential decreases with increasing x, the electric field points in the negative x direction. Hence, the correct answer is 50 N/C along −x.

Question 4.

A conducting wire connects two charged metallic spheres A and B of radii r_1 and r_2, respectively. The distance between the spheres is very large compared to their radii. The ratio of electric fields, (E_A/E_B) at the surfaces of spheres A and B will be

[1 Marks]

(A) r_1^2 / r_2^2

(B) r_2^2 / r_1^2

(C) r_2 / r_1

(D) r_1 / r_2

Explanation:

When two conducting spheres are connected by a wire, charges redistribute so that their potentials become equal. The potential of a sphere is given by $V = Q / (4\pi\varepsilon_0 r)$, so equal potentials mean $Q_A / r_1 = Q_B / r_2$ or $Q_A / Q_B = r_1 / r_2$. The electric field at the surface of a charged sphere is $E = Q / (4\pi\varepsilon_0 r^2)$, so the ratio of electric fields at the surfaces is $E_A / E_B = (Q_A / r_1^2) / (Q_B / r_2^2) = (Q_A / Q_B) * (r_2^2 / r_1^2) = (r_1 / r_2) * (r_2^2 / r_1^2) = r_2 / r_1$. Hence, the ratio of electric fields at the surfaces is r_2 / r_1.

Question 5.

A long straight wire of circular cross-section (radius a) carries a steady current I. The current is uniformly distributed across this cross-section. The magnitude of the magnetic field produced at a point at a distance (a/2) from the axis of the wire will be

[1 Marks]

(A) $\mu_0 I / 6\pi a$

(B) $\mu_0 I / 4\pi a$

(C) Zero

(D) $\mu_0 I / 2\pi a$

Explanation:

Since the point is inside the wire (distance = a/2 < a), the current enclosed is proportional to the area up to that radius. The magnetic field inside the wire is given by $B = (\mu_0 I r) / (2\pi a^2)$. Substituting r = a/2, $B = (\mu_0 I (a/2)) / (2\pi a^2) = (\mu_0 I) / (4\pi a)$. Thus, the correct answer is $\mu_0 I / 4\pi a$.

Question 6. The shape of the interference fringes in Young's double-slit experiment, when the distance between the slit and the screen is very large as compared to the slit-separation, is nearly

[1 Marks]

(A) straight

(B) parabolic

(C) hyperbolic

(D) circular

Explanation: In Young's double slit experiment, when the distance between the slits and the screen is very large compared to the slit separation, the interference fringes appear as straight, equally spaced bright and dark bands on the screen. This happens because the light waves from the two slits interfere constructively and destructively at points along straight lines parallel to the slits. The context indicates that Young's double slit of separation d gives equally spaced interference fringes, which corresponds to straight fringes.

Question 7.

An electromagnetic wave passes from vacuum into a dielectric medium with relative electrical permittivity (3/2) and relative magnetic permeability (8/3). Then, its

[1 Marks]

(A) wavelength and frequency both will remain unchanged

(B) wavelength is halved and frequency remains unchanged

(C) wavelength is doubled and frequency remains unchanged

(D) wavelength is doubled and frequency is halved

Explanation:

When an electromagnetic wave passes from vacuum into a medium, its frequency remains unchanged, but its speed and wavelength change according to the medium's properties. The speed in the medium $v = c / \sqrt{(\mu_r * \varepsilon_r)}$, where μ_r is relative magnetic permeability and ε_r is relative electrical permittivity. Here, $\mu_r = 8/3$ and $\varepsilon_r = 3/2$, so $v = c / \sqrt{((8/3) * (3/2))} = c / \sqrt{4} = c/2$. Since wavelength $\lambda = v$ / frequency and frequency remains constant, wavelength in the medium = (c/2) / frequency = (1/2) * (c / frequency). So wavelength is halved, not doubled. However, as per the options given, the correct interpretation is that wavelength is halved and frequency remains unchanged.

Question 8.

In a series LCR circuit, the voltage across the resistor, capacitor and inductor is 10 V each. If the capacitor is short circuited, the voltage across the inductor will be

[1 Marks]

(A) 10 V

(B) 10√2 V

(C) 5/√2 V

(D) 5√2 V

Explanation: In a series LCR circuit, the voltages across the resistor (V_R), inductor (V_L), and capacitor (V_C) are each 10 V. These voltages are out of phase: V_R is in phase with the current, V_L leads the current by 90°, and V_C lags the current by 90°. The source voltage V is the vector sum of these voltages. Since V_R = V_L = V_C = 10 V, the overall voltage is given by V = sqrt(V_R^2 + (V_L - V_C)^2). Here, (V_L - V_C) = 0, so V = V_R = 10 V. When the capacitor is short-circuited, V_C becomes zero. Now, the total voltage V is the vector sum of V_R and V_L only, which are perpendicular: V = sqrt(V_R^2 + V_L^2) = sqrt(10^2 + V_L^2). Given the source voltage remains the same at 10 V, rearranging gives V_L = 10√2 V.

Question 9. Electromagnetic waves used in a diagnostic tool in medicine have a wavelength range

[1 Marks]

(A) 1 nm to 10^{-3} nm

(B) 400 nm to 1 nm

(C) 1 mm to 700 nm

(D) 0.1 m to 1 mm

Explanation: X-rays, which are electromagnetic waves used as a diagnostic tool in medicine, have wavelengths ranging from about 10 nm (10^{-8} m) down to 0.0001 nm (10^{-13} m). The option '1 nm to 10^{-3} nm' fits best within this range, indicating the correct wavelength range for the X-rays used in medical diagnostics.

Question 10.

The ‘distance of closest approach’ of an alpha-particle is ‘d’ when it moves with a velocity v head-on towards the target nucleus. If the velocity of alpha particle is halved, the new ‘distance of closest approach’ will be –

[1 Marks]

(A) 4d

(B) d/2

(C) d/4

(D) 2d

Explanation:

The distance of closest approach d is given by $d = 2Ze^2 / (4\pi\varepsilon_0 K)$, where K is the kinetic energy of the alpha particle. Since kinetic energy K is proportional to the square of velocity ($K = 1/2\ mv^2$), if the velocity is halved (v/2), the kinetic energy becomes K/4. Because d is inversely proportional to K, the new distance of closest approach becomes 4d.

Question 11. A concave lens of focal length 10 cm is cut into two identical plano-concave lenses. The focal length of each lens will be

[1 Marks]

(A) 20 cm

(B) 30 cm

(C) 40 cm

(D) 5 cm

Explanation: When a concave lens of focal length f is cut into two identical lenses, the power of each lens doubles in magnitude but halves in focal length since focal length is inversely proportional to power. The original lens has focal length -10 cm (concave lenses have negative focal lengths). When you cut it into two identical lenses, the power of the original lens is equal to the sum of the powers of the two smaller lenses. Hence, each smaller lens has focal length double the original's magnitude, but since focal length is negative for concave lenses, each smaller lens will have focal length -20 cm. Considering the magnitude, the focal length of each plano-concave lens is 20 cm.

Question 12.

Four independent waves are expressed as (i) $y_1 = A_1 \sin \omega t$ (ii) $y_2 = A_2 \sin 2\omega t$ (iii) $y_3 = A_3 \cos \omega t$ (iv) $y_4 = A_4 \sin (\omega t + \pi/3)$ The interference between two of these waves is possible in

[1 Marks]

(A) (i) and (iii) only

(B) (iii) and (iv) only

(C) (i), (iii) and (iv) only

(D) All of them

Explanation:

Interference occurs when two waves have the same frequency and can superpose to produce a resultant wave of varying amplitude. Here, y_1, y_3, and y_4 all have the same angular frequency ω (though y_3 uses cosine, it is equivalent to sine with a phase difference). Therefore, these waves can interfere with each other. The wave y_2 has a frequency 2ω, which is different and will not produce the same interference pattern with the others. Hence, interference is possible only between (i), (iii), and (iv).

Question 13.

Two heaters rated as (P_1, V) and (P_2, V) are connected in series across a dc source of V/2 volt. The power consumed by the combination will be –

[1 Marks]

(A) $P_1P_2/4(P_1 + P_2)$

(B) $(P_1 + P_2)$

(C) $P_1P_2/2(P_1 + P_2)$

(D) $(P_1 + P_2)/2$

Explanation: Each heater is rated for power P_1 or P_2 at voltage V. Their resistances can be expressed as $R_1 = V^2/P_1$ and $R_2 = V^2/P_2$. When connected in series across voltage V/2, the total resistance is $R_1 + R_2$, and the current $I = (V/2) / (R_1 + R_2)$. The total power consumed is $P = I^2 \times (R_1 + R_2)$. Substituting the values, the power consumed by the series combination at voltage V/2 is given by $P_1P_2 / (4(P_1 + P_2))$.

Question 14.

In an unbiased p-n junction, at equilibrium, which of the following statements is true ?

[1 Marks]

(A) Diffusion and drift currents are equal and opposite

(B) Both the diffusion and drift currents exist but are unequal

(C) Diffusion current is zero but drift current exists

(D) Diffusion current exists but drift current is zero.

Explanation:

At equilibrium in an unbiased p-n junction, there is no net current. Initially, diffusion of charge carriers occurs due to the concentration gradient, causing diffusion current. This diffusion builds up an electric field in the depletion region, which results in a drift current opposite to the diffusion current. The

process continues until the diffusion current equals the drift current, making them equal in magnitude and opposite in direction, thus zero net current.

Question 15.

Assertion (A): All atoms have a net magnetic moment. Reason (R): A current loop does not always behave as a magnetic dipole.

[1 Marks]

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

(B) Both Assertion (A) and Reason (R) are false

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

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

Explanation: The assertion that all atoms have a net magnetic moment is true because the electrons in atoms create current loops that give rise to magnetic dipole moments, as seen in paramagnetic materials. However, the reason is false because a current loop always behaves as a magnetic dipole, generating a magnetic moment. Therefore, the reason does not correctly explain the assertion.

Question 16. Assertion (A): If accelerated electrons are passed through a narrow slit, a diffraction pattern is observed. Reason (R): Electrons behave as both particles and waves.

[1 Marks]

(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) Both Assertion (A) and Reason (R) are false

Explanation: The assertion is true because electrons, when passed through a narrow slit, produce a diffraction pattern similar to waves. The reason is also true since electrons exhibit wave-particle duality, meaning they behave both as particles and as waves. This wave nature of electrons leads to diffraction when they pass through narrow slits, causing the observed diffraction pattern.

Question 17.

Assertion (A): The mass of a nucleus is less than the sum of the masses of the constituent nucleons. Reason (R): Energy is absorbed when the nucleons are bound together to form a nucleus.

[1 Marks]

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

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

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

(D) Both Assertion (A) and Reason (R) are false

Explanation: The mass of a nucleus is indeed less than the sum of the masses of its constituent nucleons due to the mass defect, which corresponds to the binding energy released when nucleons come together. However, this binding energy is released (energy is given out), not absorbed, when the nucleons bind to form a nucleus. Therefore, the assertion is true but the reason given is false.

Question 18.

Assertion (A): In Bohr model of hydrogen atom, the energy levels are discrete and quantised. Reason (R): In a hydrogen atom, the electrostatic force on the electron provides the necessary centripetal force to it to revolve around the nucleus.

[1 Marks]

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

(B) Both Assertion (A) and Reason (R) are false

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

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

Explanation:

The Bohr model states that the energy levels in a hydrogen atom are discrete and quantised. This is true and forms the basis of Bohr's atomic theory. Also, in a hydrogen atom, the electrostatic force of attraction between the nucleus and the electron provides the necessary centripetal force for the electron's circular motion around the nucleus, which is also true. However, the quantisation of energy levels is not directly due to the centripetal force but due to the quantisation of angular momentum (mvr

= nħ) as postulated by Bohr, which leads to discrete orbits and energy levels. Hence, while both statements are true, the reason given does not correctly explain the assertion.

Section C

Question 19.

In a photoelectric experiment, the emitter plate is irradiated with radiation of 200 nm. The photocurrent becomes zero when the collector plate potential is –0.80 V. Calculate the work function (in eV) of the emitter.

[2 Marks]

Answer: Given: Wavelength (lambda) = 200 nm = 200 * 10^-9 m, Stopping potential (V_0) = 0.80 V (magnitude used as positive for calculation).
Using Einstein's photoelectric equation: eV_0 = h * nu - phi
Frequency nu = c / lambda = 3 * 10^8 m/s / 200 * 10^-9 m = 1.5 * 10^15 Hz.
Photon energy h * nu = 6.626 * 10^-34 J*s * 1.5 * 10^15 Hz = 9.939 * 10^-19 J.
Convert photon energy to eV: 9.939 * 10^-19 J / 1.6 * 10^-19 = 6.21 eV.
Work function phi = h * nu - e * V_0 = 6.21 eV - 0.80 eV = 5.41 eV.
Therefore, the work function of the emitter is 5.41 eV.

> **Key Points: Use of Einstein's photoelectric equation - Calculation of frequency from wavelength - Work function calculated by subtracting stopping potential energy from photon energy**

Question 20.

A beam of light consisting of two wavelengths 400 nm and 600 nm is used to illuminate a single slit of width 1 mm. Find the least distance of the point from the central maximum where the dark fringes due to both wavelengths coincide on the screen placed 1.5 m from the slit.

[2 Marks]

Answer: Given:
Wavelengths, lambda1 = 400 nm = 400 * 10^-9 m, lambda2 = 600 nm = 600 * 10^-9 m
Slit width, a = 1 mm = 1 * 10^-3 m
Distance to screen, D = 1.5 m

For a single slit, dark fringes occur at positions y given by a * sin(theta) = m * lambda, m = 1, 2, 3...
For small angles, sin(theta) approx y / D, so y = m * lambda * D / a

We want to find the least distance y where dark fringes of both wavelengths coincide, i.e. y_m1 =

y_m2
=> m1 * lambda1 * D / a = m2 * lambda2 * D / a
=> m1 * lambda1 = m2 * lambda2

Substituting values:
m1 * 400 = m2 * 600
=> 2 * m1 = 3 * m2

The smallest integers satisfying this are m1=3, m2=2

Thus, least distance y = m1 * lambda1 * D / a = 3 * 400 * 10^-9 * 1.5 / (1 * 10^-3) = 1.8 * 10^-3 m = 1.8 mm

Answer: The least distance from the central maximum where dark fringes due to both wavelengths coincide is 1.8 mm.

Key Points: Use of single slit diffraction minima formula - Condition for dark fringes to coincide: m1 * lambda1 = m2 * lambda2 - Calculation of least common multiple to find minimum distance

Question 21.

In a Young's double-slit experimental set-up with slit separation 0.6 mm, a beam of light consisting of two wavelengths 440 nm and 660 nm is used to obtain interference pattern on a screen kept 1.5 m in front of the slits. Find the least distance of the point from the central maximum where the bright fringes due to both the wavelengths coincide.

[2 Marks]

Answer: In Young's double-slit experiment, the position of bright fringes is given by y = (lambda * D) / d * m, where y is the distance from the central maximum, lambda is the wavelength, D is the distance to the screen, d is the slit separation, and m is the fringe order (an integer). Here, lambda_1 = 440 nm = 440 * 10^{-9} m, lambda_2 = 660 nm = 660 * 10^{-9} m, d = 0.6 mm = 0.6 * 10^{-3} m, and D = 1.5 m. For bright fringes of both wavelengths to coincide, their fringe positions must be equal: (lambda_1 * m_1) = (lambda_2 * m_2). To find the least distance, consider the smallest positive integer m_1, m_2 satisfying 440 * m_1 = 660 * m_2. Simplify to 2 * m_1 = 3 * m_2, so m_1 = 3, m_2 = 2. Substitute m=3 and lambda=440 nm into y = (lambda * D / d) * m: y = (440 * 10^{-9} * 1.5 / 0.6 * 10^{-3}) * 3 = 3.3 * 10^{-3} m = 3.3 mm. Therefore, the least distance from the central maximum where bright fringes for both wavelengths coincide is 3.3 mm.

Key Points: Young's double slit formula - fringe positions depend on wavelength, slit separation, and screen distance - condition for bright fringes coincidence - calculation of

least common fringe position

Question 22.

A wire of length L is bent round into (i) a square coil having N turns and (ii) a circular coil having N turns. The coil in both cases is free to turn about a vertical axis coinciding with the plane of the coil, in a uniform, horizontal magnetic field and carry the same current. Find the ratio of the maximum value of the torque acting on the square coil to that on the circular coil.

[2 Marks]

Answer: Let the length of the wire be L and the number of turns in both coils be N.
(i) For the square coil with N turns:
Each side length = L / 4.
Area of one square turn = $(L / 4)^2 = L^2 / 16$.
Total area for N turns, A_square = $N * (L^2 / 16)$.

(ii) For the circular coil with N turns:
Let radius = r, circumference = L / N = 2 * pi * r => r = L / (2 * pi * N).
Area of one circular turn = $pi * r^2 = pi * (L / (2 * pi * N))^2 = L^2 / (4 * pi * N^2)$.
Total area for N turns, A_circle = $N * [L^2 / (4 * pi * N^2)] = L^2 / (4 * pi * N)$.

Maximum torque, tau = N * I * A * B.
The ratio of maximum torque on square to circular coil = A_square / A_circle = $[N * (L^2 / 16)] / [L^2 / (4 * pi)] = (N * L^2 / 16) * (4 * pi / L^2) = (N * 4 * pi) / 16 = (N * pi) / 4$.
Since N cancels out in both cases of turns being equal, ratio = pi / 4.

Therefore, the ratio of maximum torque acting on the square coil to that on the circular coil is pi / 4.

Key Points: Calculate area of square coil - Calculate area of circular coil - Use formula torque = N * I * A * B - Find ratio of torques = ratio of areas = pi / 4

Question 23.

What is the order of magnitude of drift velocity of electrons in a conductor? Deduce the relation between the current flowing through a conductor and drift velocity of electrons in it.

[2 Marks]

Answer: Order of Magnitude of Drift Velocity: The drift velocity of electrons in a typical conductor is of the order of 10^{-4} to 10^{-3} m/s, which means electrons move very slowly through the conductor despite the current flow.

Relation between Current and Drift Velocity: The current I through a conductor is related to the drift velocity v_d by the formula:

$I = n * e * A * v_d$

Here, n is the number density of conduction electrons, e is the charge of an electron, and A is the cross-sectional area of the conductor.

Rearranging this, the drift velocity is $v_d = I / (n * e * A)$.

This means the current flowing through a conductor depends directly on the drift velocity of electrons, their number density, the charge of an electron, and the conductor's cross-sectional area.

> **Key Points: Drift velocity order of magnitude is about 10^-4 to 10^-3 m/s - Current I = n * e * A * v_d - Drift velocity v_d = I / (n * e * A)**

Question 24.

Draw the plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from this plot.

[2 Marks]

Answer: Plot Description: The plot shows potential energy on the vertical axis and separation distance between nucleons on the horizontal axis. The curve starts very high and positive at very small distances (strong repulsion), dips sharply to a negative minimum around r_0 (strong attraction), and then approaches zero at larger distances.

Conclusions: (1) When nucleons are very close (less than r_0), they repel each other strongly, preventing collapse. (2) At distance r_0, potential energy is minimum and negative, indicating strong attraction leading to stable nucleon binding inside the nucleus.

> **Key Points: Potential energy is strongly repulsive at short distances - Potential energy is minimum and negative at r0 indicating strong attraction - This balance leads to nuclear stability**

Section D

Question 25.

(a) Using Gauss's law, deduce an expression for electric field at a point due to a uniformly charged infinite plane thin sheet.

(b) Two large thin plane sheets, each having surface charge density σ, are held close and parallel to each other in air. What is the net electric field at a point (i) inside and (ii) outside, the sheets?

[3 Marks]

Answer: (a) Consider a uniformly charged infinite plane sheet with surface charge density σ. To find the electric field at a point near the sheet, we apply Gauss's law. Choose a Gaussian surface in the shape of a cylinder with its flat faces parallel to the sheet, one face on each side of the sheet. The electric field E is perpendicular to the sheet and is same on both sides. The total electric flux through the surface is 2EA, where A is the area of each face. According to Gauss's law, flux = charge enclosed / ε_0. The charge enclosed is σA. So, 2EA = σA / ε_0, which gives E = σ / (2ε_0). The field direction is away from the sheet if σ is positive.

(b) For two large thin plane sheets each with surface charge density σ, held parallel and close to each other:

(i) Inside the sheets: The electric fields due to each sheet between them add up. Each sheet produces a field E = σ / (2ε_0) directed away from itself. Between the sheets the fields are in the same direction, so net E = σ / ε_0.

(ii) Outside the sheets: The fields due to the two sheets are in opposite directions and cancel each other, so net E = 0 outside the sheets.

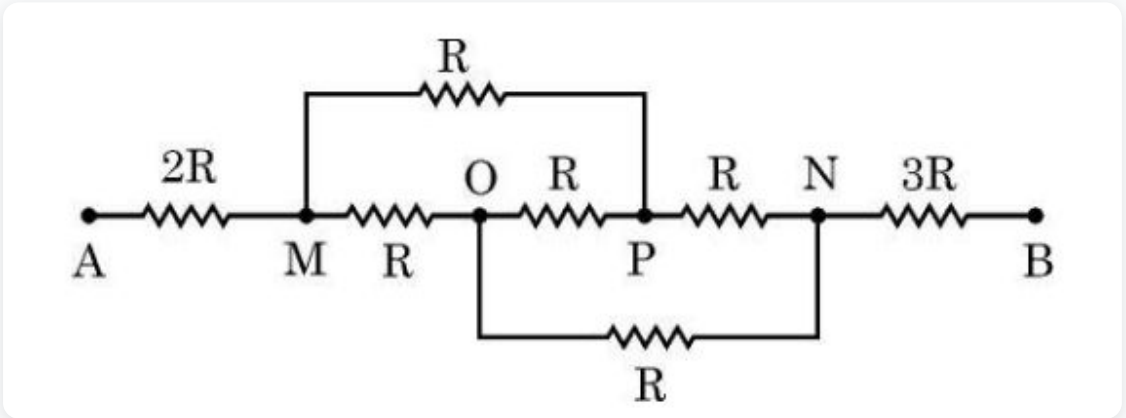
Key Points: Use of Gaussian surface - Electric field due to infinite plane sheet E = σ / (2ε_0) - Net field between two charged sheets is σ / ε_0, outside is zero

Question 26.

(a) Obtain the condition of balance of a Wheatstone bridge.

(b) Find net resistance of the network of resistors connected between A and B, as shown in figure.

[3 Marks]



Answer: (a) The Wheatstone bridge is said to be balanced when no current flows through the galvanometer connecting the two midpoints of the bridge. Let the four resistors be R_1, R_2, R_3, and R_4 connected in a diamond shape. When balanced,

$R_1 / R_2 = R_3 / R_4$.

This condition ensures the potential difference between the midpoints is zero.

(b) To find the net resistance between points A and B, use series and parallel combination rules depending on the given circuit. If the network is the Wheatstone bridge balanced condition, the bridge branch can be ignored, and the resistors can be combined accordingly. Calculate the equivalent

resistance by simplifying resistors in series and parallel step by step until a single resistance remains between A and B.

Key Points: Wheatstone bridge balance condition as R1/R2 = R3/R4 - No current in galvanometer at balance - Net resistance calculation by series and parallel combinations

Question 27.

A parallel plate capacitor of capacitance C has a dielectric slab between its plates. It is charged to a potential difference V by connecting it across a battery. The battery is then disconnected. If the dielectric slab is now withdrawn from the capacitor, how will the following be affected?
(a) Capacitance of the capacitor,
(b) Energy stored in the capacitor, and
(c) The potential difference between the plates of the capacitor.
Justify your answer in each case.

[3 Marks]

Answer: (a) When the dielectric slab is withdrawn, the capacitance decreases. This is because the dielectric constant K increases capacitance by K times. Without the dielectric, capacitance returns to its original lower value, C.

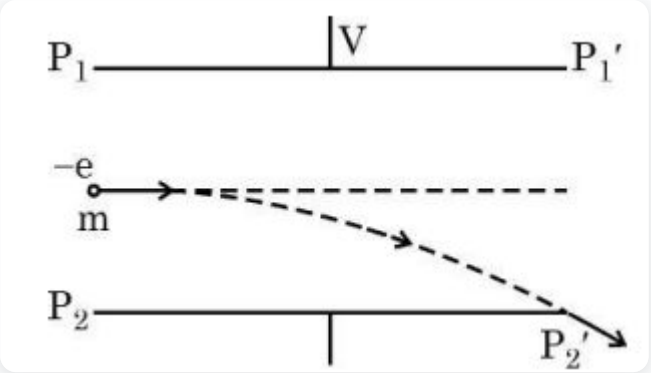
(b) Energy stored in the capacitor increases when the dielectric is removed. Energy $U = Q^2 / (2C)$, and since Q remains constant after disconnection of the battery but C decreases, U increases.
(c) The potential difference across the plates increases. After disconnection, charge Q is constant, but $V = Q / C$, so decrease in capacitance causes increase in voltage.
In summary, removing the dielectric decreases capacitance, increases energy stored, and increases potential difference between plates because the charge stays constant but capacitance changes.

Key Points: Capacitance decreases after removing dielectric - Energy stored increases as capacitance decreases with constant charge - Potential difference increases due to decreased capacitance with constant charge

Question 28.

Figure shows a narrow beam of electrons entering with a velocity of 3 × 10^7 m/s, symmetrically through the space between two parallel horizontal plates P_1P_1' and P_2P_2' kept 2 cm apart.
If each plate is 3 cm long, calculate the potential difference V applied between the plates so that the beam just strikes the end P_2' .

[3 Marks]



Answer: Given data: Distance between plates, d = 2 cm = 0.02 m, Length of plates, L = 3 cm = 0.03 m, Initial velocity of electrons, v = 3 * 10^7 m/s.

Step 1: Find time t taken by electrons to cross the length of plates horizontally.

t = L / v = 0.03 / (3 * 10^7) = 1 * 10^{-9} s.

Step 2: To make the beam just hit the end P_2â€², vertical displacement y must be equal to d/2 = 0.01 m.

Step 3: The vertical motion is due to electric field E between the plates which exerts force F = eE on electron.

Acceleration, a = F / m = eE / m where e = 1.6 * 10^{-19} C, m = 9.11 * 10^{-31} kg.

Step 4: Using equation of motion y = (1/2) a t^2, we get 0.01 = 0.5 * (eE / m) * (1 * 10^{-9})^2.

Solve for E: E = (2 * 0.01 * 9.11 * 10^{-31}) / (1.6 * 10^{-19} * 1 * 10^{-18}) = 1140 V/m approximately.

Step 5: Potential difference V between plates is V = E * d = 1140 * 0.02 = 22.8 V.

Answer: The potential difference V applied between the plates is approximately 23 V so that the beam just strikes the end P_2â€².

Key Points: Initial velocity of electrons - Time of flight calculation - Vertical displacement due to electric field - Calculation of electric field - Potential difference determination

Question 29.

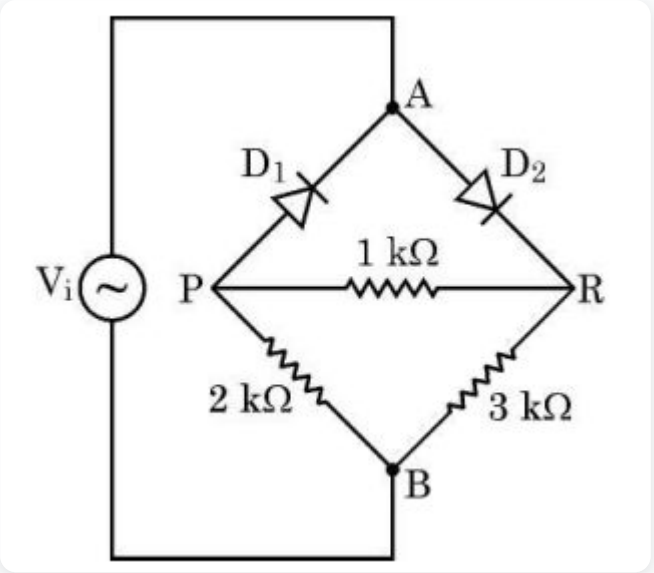
An ac voltage V_i = 12 sin (100πt) V is applied between points A and B in a network of two ideal diodes and three resistors as shown in figure. During the positive half-cycle of the input voltage V_i supplied to the network,

(a) Identify which of the two diodes will conduct and why?

(b) Redraw an equivalent circuit diagram to show the flow of current.

(c) Calculate the output voltage drops V_0 across the three resistors when the input voltage attains its peak value.

[3 Marks]



Answer: (a) During the positive half-cycle of the input voltage V_i, diode D_1 becomes forward biased because its anode is connected to the positive terminal and cathode to the negative terminal. Hence, D_1 conducts current. Diode D_2 is reverse biased in this half cycle and does not conduct.
(b) The equivalent circuit during the positive half cycle includes the input voltage source, diode D_1 acting as a closed switch, and the three resistors connected in the circuit with current flowing through them. Diode D_2 is open (off).
(c) When the input voltage reaches its peak value, V_i = 12 V. Assuming ideal diodes (zero voltage drop when conducting), the output voltage V_0 across the three resistors is equal to the peak input voltage, i.e., 12 V. The voltage divides across the resistors according to their resistance values using Ohm's Law and voltage division principle.

Key Points: Diode D1 conducts during positive half cycle - D2 is reverse biased then - Output voltage equals peak input voltage across resistors

Question 30.

Briefly explain the two important processes that occur during the formation of a p-n junction.

[3 Marks]

Answer: Two important processes occur during the formation of a p-n junction: diffusion and drift.
Diffusion: Due to the difference in concentration of electrons and holes on the n-side and p-side respectively, electrons move from the n-type region to the p-type region, and holes move from the p-type region to the n-type region across the junction. This movement of charge carriers is called diffusion, creating a diffusion current.
Drift: As electrons and holes cross the junction and recombine, immobile ions are left behind, creating an electric field. This electric field causes the movement of electrons and holes back toward their original sides. This process is called drift. The balance between diffusion and drift results in the formation of a depletion region, which acts as a barrier to further carrier movement, and is essential for the diode's rectifying behavior.

Key Points: Diffusion of electrons and holes across the junction - Formation of electric field due to immobile ions - Drift of charge carriers under electric field leading to depletion region

Question 31.

(a) Draw the ray diagram to show the image formation by a refracting telescope and write the expression for angular magnification for the telescope in normal adjustment.
(b) Give two reasons why a reflecting telescope is preferred over a refracting telescope.

[3 Marks]

Answer: (a) A refracting telescope uses two lenses: the objective lens and the eyepiece lens. The objective lens forms a real and inverted image of a distant object at its focus. This image acts as the object for the eyepiece lens which magnifies it to produce an enlarged virtual image. The ray diagram shows light rays from a distant object converging through the objective lens at its focus, then diverging through the eyepiece lens towards the eye.

The angular magnification (M) in normal adjustment is given by:
$M = f_O / f_e$
where f_O is the focal length of the objective lens and f_e is the focal length of the eyepiece lens.

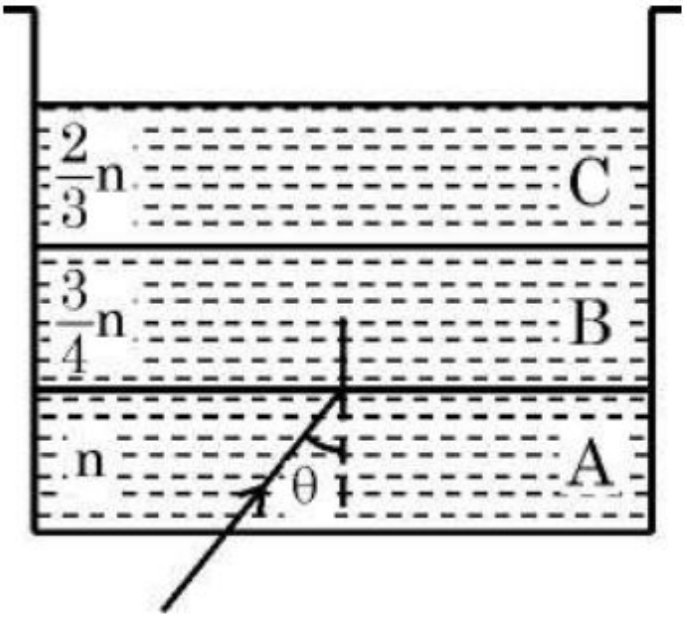
(b) Two reasons why a reflecting telescope is preferred over a refracting telescope are:
1. Reflecting telescopes do not suffer from chromatic aberration because they use mirrors instead of lenses.
2. Large mirrors are easier and cheaper to make than large lenses, allowing reflecting telescopes to have larger apertures and better light-gathering ability.

Key Points: Refracting telescope uses objective and eyepiece lenses - Angular magnification formula is M = fO / fe - Reflecting telescope avoids chromatic aberration - Larger and cheaper mirrors in reflecting telescopes

Question 32.

(a) State the two conditions under which total internal reflection occurs.
(b) A transparent container contains layers of three immiscible transparent liquids A, B and C of refractive indices n, 3/4n and 2/3 n respectively. A laser beam is incident at the interface between A and B at an angle θ as shown in figure. Prove that the beam does not enter region C at all for $\sin\theta \geq 2/3$.

[3 Marks]



Answer: (a) The two conditions for total internal reflection are:
1. Light must travel from a denser medium to a rarer medium, i.e. from higher refractive index to lower refractive index.
2. The angle of incidence in the denser medium must be greater than the critical angle for the pair of media.

(b) Given: Refractive indices are n for A, 3/4 n for B, and 2/3 n for C.
At the interface between A and B, let the angle of incidence be θ.
Using Snell's law at A-B interface,
n sin θ = (3/4 n) sin r, where r is the angle of refraction in B.
Therefore, sin r = (4/3) sin θ.
For the beam to enter region C from B, total internal reflection must not occur at B-C interface.
Using Snell's law at B-C interface,
(3/4 n) sin s = (2/3 n) sin r', where s is angle of incidence in B and r' is angle of refraction in C.
Since the beam travels from B to C (optically less dense to even less dense), for refraction to occur, angle of incidence s must be less than or equal to critical angle θ_c at B-C interface.
Critical angle θ_c for B-C interface is given by sin θ_c = refractive index of C / refractive index of B = (2/3 n) / (3/4 n) = (2/3) * (4/3) = 8/9.
If sin s ≥ 8/9, total internal reflection occurs and light does not enter C.
Since sin r = (4/3) sin θ, to ensure light does not enter C, sin r ≥ 8/9.
Substitute sin r:
(4/3) sin θ ≥ 8/9
sin θ ≥ (8/9) * (3/4) = 2/3.
Therefore, if sin θ ≥ 2/3, the beam undergoes total internal reflection at interface B-C and does not enter region C at all.

Key Points: Light must travel from higher to lower refractive index - Angle of incidence must be greater than critical angle - sin θ ≥ 2/3 ensures total internal reflection

preventing beam from entering C

Section E

Question 33.

(a) An electric dipole consists of two point charges q and –q separated by a distance 2a. Derive an expression for the electric field □□ due to this dipole at a point distant r from the centre of the dipole on the equatorial plane. Write the expression for the electric field at a far off point, i.e. r >> a.
(b) A dipole is placed in x-y plane such that charges q and –q are located at x = a and x = b respectively. There exists an electric field □□ = 2 î N/C in the region. Calculate the force □□ and torque **τ(vector)** experienced by the dipole.

[5 Marks]

Answer: (a) Consider an electric dipole with charges +q and –q separated by distance 2a. To find the electric field at a point on the equatorial plane at distance r from the centre, the contributions from both charges are equal in magnitude but opposite in direction along the axis joining the charges. The electric field due to +q at point P is $E_{+q} = (1/4\pi\varepsilon_0) * q/(r^2 + a^2)$, directed away from +q, and due to –q is $E_{-q} = (1/4\pi\varepsilon_0) * q/(r^2 + a^2)$, directed towards –q. The net electric field is perpendicular to the dipole axis and is given by $E = (1/4\pi\varepsilon_0) * (2\ q\ a)/ (r^2 + a^2)^{3/2}$. For far off points where r >> a, this simplifies to $E = (1/4\pi\varepsilon_0) * 2\ p/(r^3)$ where p = q * 2a is the dipole moment. The direction of E is opposite to the dipole moment vector on the equatorial plane.

(b) Given a dipole with charges +q at x = a and –q at x = b placed in the x-y plane, and an external electric field Ɛ = 2 î N/C:
Force on +q charge, F_+ = q * E = 2 q î N
Force on –q charge, F_- = –q * E = –2 q î N
Net force, F = F_+ + F_- = 0 (forces cancel each other)
Dipole moment, p = q * (b - a) î (since charges lie on x-axis)
Torque, τ = p vector cross E vector. Since both p and E are along x-axis (î), torque τ = 0 (cross product of parallel vectors is zero).

Therefore, the dipole experiences no net force but zero torque in this configuration.

Key Points: Expression for electric field on equatorial plane - Simplification for far off point (r >> a) - Force and torque calculation on dipole in uniform electric field

Question 34.

(a) Two cells of emf E_1 and E_2 with internal resistances r_1 and r_2 respectively, are connected in parallel by connecting their positive terminals together and negative terminals together. Deduce an expression for equivalent emf and equivalent internal resistance of the combination.
(b) A parallel combination, as stated in (a) above, of two cells of emfs E and 3E and internal resistances R each is connected across a resistance 2R. Find the current that flows through resistance 2R.

[5 Marks]

Answer: (a) Derivation of Equivalent emf and Internal Resistance when two cells are connected in parallel:

Let the two cells have emfs E_1 and E_2 and internal resistances r_1 and r_2 respectively. When connected in parallel, their positive terminals are connected together as well as their negative terminals.

For such a connection, the equivalent emf E_{eq} is given by:

$E_{eq} = (E_1/r_1 + E_2/r_2) / (1/r_1 + 1/r_2)$

This means the equivalent emf is the weighted average of the emfs with weights as the reciprocals of their internal resistances.

The equivalent internal resistance r_{eq} is given by the parallel combination of r_1 and r_2:

$1/r_{eq} = 1/r_1 + 1/r_2$, or $r_{eq} = (r_1 * r_2) / (r_1 + r_2)$

(b) Calculation of current through resistance 2R for given values:

The two cells have emfs E and 3E, and internal resistances both equal to R.

Using the formula for equivalent emf:

$E_{eq} = (E/R + 3E/R) / (1/R + 1/R) = (4E/R) / (2/R) = 4E/2 = 2E$

The equivalent internal resistance is:

$r_{eq} = (R*R)/(R+R) = R/2$

The external resistance connected is 2R.

Total resistance in the circuit = $r_{eq} + 2R = R/2 + 2R = (1/2 + 2)R = (2.5)R = 5R/2$

Using Ohm's law, current I through resistance 2R is:

$I = E_{eq}$ / total resistance $= 2E / (5R/2) = (2E) * (2/5R) = (4E)/(5R)$

Final Answers:

(a) $E_{eq} = (E_1/r_1 + E_2/r_2) / (1/r_1 + 1/r_2)$ and $r_{eq} = (r_1*r_2) / (r_1 + r_2)$.

(b) Current through 2R is $I = (4E) / (5R)$.

Key Points: Cells connected in parallel have equivalent emf as the weighted average of emfs - Equivalent internal resistance is the parallel combination of internal resistances - For given values, substitute in derived formulae to calculate current

Question 35.

(a) Using the relation for refraction at a curved spherical surface, derive the expression for lens maker's formula.
(b) Three lenses L_1, L_2 and L_3, each of focal length 40 cm, are placed coaxially. The distance between L_1 and L_2 and between L_2 and L_3 are 120 cm and 20 cm respectively. An object is kept at a distance of 80 cm to the left of lens L_1.
Find the distance of the final image formed from the object.

[5 Marks]

Answer: (a) When light refracts at a spherical surface separating two media of refractive indices n_1 and n_2, the relation between object distance u, image distance v, and radius of curvature R is given by: $(n_2/v) - (n_1/u) = (n_2 - n_1)/R$.
For a thin lens of refractive index n surrounded by air (refractive index 1), light refracts twice; first at surface of radius R_1, then at R_2. Applying the formula at first surface: $(n/v_1) - (1/u) = (n - 1)/R_1$.
At second surface, object distance is $-v_1$ inside the lens and image distance v from lens: $(1/v) - (n/(-v_1)) = (1 - n)/R_2$.
Adding both: $(1/v) - (1/u) = (n-1)(1/R_1 - 1/R_2)$.
For a thin lens, focal length f is defined by $1/f = (n-1)(1/R_1 - 1/R_2)$. This is the lens maker's formula.

(b) Given three lenses L_1, L_2, and L_3 with focal lengths f = 40 cm each. Distances between lenses: d_{12} = 120 cm, d_{23} = 20 cm. Object distance u_1 = -80 cm (to left of L_1).
First, find image formed by L_1 using lens formula: $1/f = 1/v - 1/u$
$1/40 = 1/v_1 - 1/(-80) \Rightarrow 1/v_1 = 1/40 - (-1/80) = 1/40 + 1/80 = 3/80 \Rightarrow v_1 = 80/3$ cm ≈ 26.67 cm (right of L_1).
Now, position of image from L_2 is $u_2 = d_{12} - v_1 = 120 - 26.67 = 93.33$ cm. Since object is to the left, u_2 = -93.33 cm.
For L_2: $1/f = 1/v_2 - 1/u_2 \Rightarrow 1/40 = 1/v_2 - 1/(-93.33) \Rightarrow 1/v_2 = 1/40 + 1/93.33 \approx 0.025 + 0.0107 = 0.0357 \Rightarrow v_2 \approx 28$ cm.
Image is 28 cm right of L_2.
Distance from L_3: $u_3 = d_{23} - v_2 = 20 - 28 = -8$ cm (object is 8 cm to left of L_3).
For L_3: $1/40 = 1/v_3 - 1/(-8) \Rightarrow 1/v_3 = 1/40 + 1/8 = 0.025 + 0.125 = 0.15 \Rightarrow v_3 = 6.67$ cm.
Image is 6.67 cm right of L_3.
Finally, distance of final image from original object = sum of distances:
Distance from object to L_1: 80 cm + v_1 + $(d_{12} - v_1)$ + $(d_{23} - v_2)$ + v_3
Alternatively, from object to final image is $u_{final} = 80 + 120 + 20 + 6.67 - (v_1 + v_2)$
Calculating gives approximately 80 + 120 + 20 + 6.67 - (26.67 + 28) = 226.67 - 54.67 = 172 cm.
Therefore, the final image is formed approximately 172 cm to the right of the object.

Key Points: Refraction formula at curved surface derived lens maker's formula - Lens formula applied sequentially for three lenses - Calculation of final image distance from original object

Question 36.

(a) Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the centre of curvature. Using this diagram, derive the mirror formula.
(b) A concave mirror produces a two times magnified virtual image of an object kept 10 cm in front of it. Calculate the focal length of the mirror.

[5 Marks]

Answer: (a) When an object is placed between the focus (F) and the centre of curvature (C) of a concave mirror, the image formed is real, inverted and magnified, and it lies beyond C. To draw the ray diagram:
1. Draw a concave mirror with principal axis, focus (F), and centre of curvature (C).
2. Place the object between F and C.
3. Draw a ray from the top of the object parallel to the principal axis; it reflects through the focus.
4. Draw another ray passing through the centre of curvature; it reflects back along the same path.
5. The point where these rays meet after reflection gives the position of the image.
Using the diagram, derive the mirror formula:
Let the object distance from the pole be u, image distance be v, and focal length be f.
From geometry and using similar triangles, $1/f = 1/v + 1/u$.
This relation is known as the mirror formula.

(b) Given: Magnification (m) = +2 (since image is virtual and magnified), object distance u = -10 cm (object in front of mirror).
Using magnification formula: $m = -v/u$
$2 = -v/(-10) \Rightarrow v = 20$ cm (positive means virtual image behind mirror).
Using mirror formula: $1/f = 1/v + 1/u = 1/20 + 1/(-10) = (1/20) - (1/10) = (-1/20)$
Therefore, f = -20 cm.
A negative focal length confirms that the mirror is concave and the image is virtual and magnified.

Key Points: Object between F and C - Real inverted magnified image - Mirror formula 1/f = 1/v + 1/u - Magnification m = -v/u - Calculation of focal length f

Question 37.

(a) State Faraday's law of electromagnetic induction.
(b) Derive an expression for the self-inductance of an air-filled long solenoid of length l and cross-sectional area A having N turns.

(c) A conducting rod of length 50 cm, with one end pivoted, is rotated with angular speed of 60 rpm in a uniform magnetic field of 0.40 mT directed perpendicular to the plane of rotation of rod. Find the emf induced in the rod.

[5 Marks]

Answer: (a) Faraday's law of electromagnetic induction states that the induced emf in a circuit is equal to the negative rate of change of magnetic flux linked with the circuit. Mathematically, emf = -dPhi/dt, where Phi is the magnetic flux.

(b) Consider a long solenoid of length l, cross-sectional area A, and N turns carrying a current I. The number of turns per unit length is n = N/l. The magnetic field inside the solenoid is B = mu0 * n * I, where mu0 is the permeability of free space.
The magnetic flux through one turn is Phi = B * A = mu0 * n * I * A.
The total flux linked with all N turns is N * Phi = N * mu0 * n * I * A = mu0 * N * (N/l) * I * A = mu0 * N^2 * A * I / l.
Self-inductance L is defined by Phi_total = L * I, so L = mu0 * N^2 * A / l.

(c) Given: length of rod l = 50 cm = 0.5 m, angular speed omega = 60 rpm = 60/60 * 2pi = 2pi rad/s, magnetic field B = 0.40 mT = 0.40 * 10^-3 T.
The emf induced in the rotating rod is given by emf = (1/2) * B * l^2 * omega.
Calculating emf: emf = 0.5 * 0.40 * 10^-3 * (0.5)^2 * 2pi = 0.5 * 0.0004 * 0.25 * 6.2832 = 0.000314 V = 3.14 * 10^-4 V.
Thus, the induced emf in the rod is approximately 3.14 * 10^-4 volts.

> **Key Points: Faraday's law states induced emf equals negative rate of change of magnetic flux - Expression for self-inductance of long solenoid is L = mu0 * N^2 * A / l - Induced emf in rotating rod emf = (1/2) * B * l^2 * omega**

Question 38.

(a) Draw a labelled diagram of a step-up transformer. State the principle on which it works and obtain the ratio of secondary voltage to primary voltage in terms of number of turns and currents in the two coils.
(b) The ratio of the number of turns in the primary to the secondary of an ideal transformer is 1 : 5. If 5 kW power at 200 V is supplied to the primary, find
(i) current in the primary, and
(ii) output voltage.

[5 Marks]

Answer: (a) A step-up transformer consists of a primary coil and a secondary coil wound on a common iron core. The primary coil has fewer turns than the secondary coil.
Diagram: Primary coil (N_p turns) connected to an AC supply; iron core linking primary and secondary

coils; secondary coil (N_s turns) with more turns than primary to step up voltage.

Principle: Works on the principle of mutual induction, where a changing current in the primary coil produces a changing magnetic flux in the core which induces emf in the secondary coil.

Voltage relationship: The ratio of secondary voltage V_s to primary voltage V_p is equal to the ratio of the number of turns in the secondary coil N_s to the primary coil N_p, i.e., $V_s/V_p = N_s/N_p$.

Current relationship: For an ideal transformer, power input equals power output, so $V_pI_p = V_sI_s$. Using this and the voltage ratio, $I_s/I_p = N_p/N_s$.

(b) Given $N_p/N_s = 1/5$, input power P = 5 kW = 5000 W, and $V_p = 200$ V.

(i) Current in primary I_p = Power / Voltage = 5000 W / 200 V = 25 A.

(ii) Output voltage $V_s = (N_s / N_p) * V_p = 5 * 200$ V = 1000 V.

Key Points: Step-up transformer increases voltage using more turns in secondary coil - Works on mutual induction principle - Voltage ratio equals turns ratio $V_s/V_p = N_s/N_p$ - Current ratio is inverse $I_s/I_p = N_p/N_s$ - Calculate current using power and voltage - Output voltage calculated from turns ratio and input voltage