KSEAB PYQ 2020

Physics

1. Write the SI unit of electric flux

2. Graphically represent the variation of resistivity of a semiconductor with absolute temperature.

3. Give any one use of electromagnet

4. What is the significance of Lenz's law?

5. How does capacitive reactance vary with frequency?

6. Arrange the following electromagnetic waves in ascending order of their wavelength Radio waves, Gamma rays, Infrared waves, X-rays.

7. Why does sky appear blue?

8. Mention a method to increase the resolving power of a microscope.

9. Write the nuclear reaction equation for alpha decay of ${}^{238}_{92}U$

10. Draw the logic symbol of NOR gate.

11. State and explain Coulomb's law in electrostatics.

12. A parallel plate capacitor with air between the plates has a capacitance C .
What will be the capacitance if
(a) the distance between the plates is doubled?
(b) the space between the plates is filled with a substance of dielectric constant 5 ?

13. Write two limitations of Ohm's law.

14. In a region, an electric field $\vec{E} = 5x10^3\hat{j}NC^{-1}$ and a magnetic field of $\vec{B} = 0.1\hat{k}Y$ are applied A beam of charged particles are projected along X-direction. Find the velocity of charged particles which move undeflected in this crossed fields.

15. Define "retentivity" and "coercivity"

16. Mention two sources of energy loss in transformer.

17. What is displacement current? Give the expression for it.

18. An alpha particle, a proton and an electron are moving with equal kinetic energy. Which one of these particles has the longest de Broglie wavelength? Give reason.

19. Establish the relation between electric field and electric potential.

20. Derive the expression for the energy stored in a charged capacitor.

21. Give the principle of cyclotron and draw the neat labelled schematic diagram of cyclotron.

22. Mention three properties of diamagnetic materials.

23. Arrive at the relation between focal length and radius of curvature of a spherical concave mirror.

24. Using Huygen's principle, show that the angle of incidence is equal to the angle of reflection when a plane wave front is reflected by a plane surface.

25. Define work function. Write Einstein's photoelectric equation and explain the terms.

26. Give three differences between intrinsic and extrinsic semiconductors.

27. Derive the expression for conductivity of a material: $\sigma = \frac{ne^2\tau}{m}$ Where the terms have their usual meaning.

28. Obtain the expression for the force between two conductors carrying current. Hence define "ampere".

29. With the help of a labelled diagram, derive the expression for instantaneous emf induced in an AC generator.

30. Obtain the expression for the fringe width of interference fringes in Young's Double slit experiment.

31. Using Bohr's postulates, derive the expression for the radius of nth stationary orbit of electron in hydrogen atom. Hence write the expression for Bohr radius.

32. What is rectification? Explain the working of a p-n junction diode as a half wave rectifier. Draw the input and output wave forms.

33. Two point charges $q_A = 5\mu C$ and $q_B = -5\mu C$ are located at A and B separated by 0.2 m in vacuum.

(a) What is the electric field at the midpoint O of the line joining the charges?

(b)If a negative test charge of magnitude $2nC$ is placed at O. what is the force experienced by the test charge?

34 (a) Three resistors $3\Omega, 4\Omega$ and 12Ω are connected in parallel. What is the effective resistance of the combination?

(b) If the combination is connected to a battery of emf 6 V and internal resistance 0.5Ω, find the current drawn from the battery and terminal potential difference across the battery.

35 A series LCR circuit contains a pure inductor of inductance 5.0 H , a capacitor of capacitance $20p$ F and a resistor of resistance 40Ω.

(a) Find the resonant frequency of the circuit.

(b) Calculate the Quality factor (Q-factor) of the circuit.

(c) What is the impedance at resonant condition?

36. At what angle should a ray of light be incident on the face of an equilateral prism, so that it just suffers total internal reflection at the other face? The refractive index of the material of the prism is 1.5

37 A copper coin has a mass of 630 g . Calculate the nuclear energy that would be required to separate all the neutrons and protons from each other. The coin is entirely made of $^{63}_{29}CU$ atoms

Mass of $^{63}_{29}CU$ atom $= 62.92960$ u

Mass of proton $= 100727u$

Mass of neutron $= 1.00866u$

Avogadro's number $= 6.022 \times 10^{23}$

Hints and Solutions

Solution 1: N m²/C (or V m)

Solution 2:
Resistivity ρ changes exponentially with absolute temperature T according to the relation:
$\rho(T) = \rho_0 \exp[E_g / (2k_B T)]$
where Eg is the band gap energy and k_B is the Boltzmann constant.
As temperature increases, more charge carriers cross the energy gap, causing a steep, non-linear exponential drop in resistance.

Solution 3: Used in electromagnetic lifting cranes to safely lift and transport heavy iron scrap, steel bars, and girders.

Solution 4:
Lenz's law is a direct consequence of the law of conservation of energy.
The mechanical energy expended in moving a magnet against the opposing magnetic force set up by the induced current is converted into electrical energy.

Solution 5:
Capacitive Reactance Equation:
$X_C = 1 / (2\pi fC)$
Since X_C is inversely proportional to frequency (f), it decreases non-linearly to zero as frequency approaches infinity, and becomes infinite for direct current (f = 0).

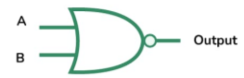
Solution 6: Gamma rays < X-rays < Infrared waves < Radio waves

Solution 7:
Due to Rayleigh scattering, the intensity of scattered light is inversely proportional to the fourth power of the wavelength ($I \propto 1/\lambda^4$).
Since blue light has a significantly shorter wavelength than red light, it scatters much more intensely throughout the upper layers of the atmosphere.

Solution 8:
By filling the objective lens space with an oil-immersion medium of high refractive index (n), which increases the numerical aperture (n sin β).
Resolving Power = $2n \sin\beta / (1.22\ \lambda)$

Solution 9: ${}^{238}U_{92} \rightarrow {}^{234}Th_{90} + {}^{4}He_{2} + Q$

Solution 10:



Solution 11:
Coulomb's Law Statement:
The electrostatic force of attraction or repulsion between two stationary point charges is directly proportional to the product of the magnitudes of the charges and inversely proportional to the square of the distance between them.
Mathematical Expression:
$F = 1 / (4\pi\varepsilon_0) \cdot (q_1 q_2 / r^2)$
where ε_0 is the permittivity of free space, and the value of $1 / (4\pi\varepsilon_0)$ is approximately 9×10^9 N m²/C².

Solution 12:
Original Capacitance Formula:
$C = \varepsilon_0 A / d$
a) When the distance between plates is doubled (d' = 2d):
$C' = \varepsilon_0 A / (2d) = \frac{1}{2}C$
The capacitance is halved.
b) When the space is completely filled with a dielectric constant K = 5:
$C'' = K \cdot (\varepsilon_0 A / d) = 5C$
The capacitance is increased fivefold.

Solution 13:
1. Non-Ohmic Devices: The direct linear proportionality between voltage and current fails completely in semiconductors, vacuum tubes, and p-n junction diodes.
2. Non-Uniqueness of V-I Relations: The current variation depends explicitly on the sign of the applied

voltage, or can showcase a negative resistance slope region where current drops as voltage grows (e.g., Thyristors, GaAs devices).

Solution 14:
Velocity Selector Equilibrium condition:
$qE = qvB$
Isolating velocity v:
$v = E / B$
Substituting the given parameters:
$v = (5 \times 10^3) / 0.1$
$v = 5 \times 10^4$ m/s
Direction of the velocity vector: Directed linearly along the positive X-axis.

Solution 15:
Retentivity:
The residual magnetic flux density left inside a ferromagnetic sample when the external magnetizing field intensity is reduced to absolute zero.
Coercivity:
The magnitude of the reverse magnetizing field intensity required to entirely reduce the residual magnetic flux density to zero.

Solution 16:
1. Joule Copper Losses: Power dissipated as heat (I^2R losses) inside the resistance of the primary and secondary copper wire loops.
2. Core Eddy Current Losses: Induced circular currents winding within the iron laminate frame, generating parasitic thermal waste minimized via laminated insulation plates.

Solution 17:
Displacement Current Formula:
$I_d = \varepsilon_0 \cdot (d\Phi_E / dt)$
Derivation / Definition:
It is the current originating from a time-varying electric displacement field or changing electric flux (Φ_E) passing through a surface, satisfying Maxwell's modified Ampere's Law loop.

Solution 18:
The electron possesses the longest de Broglie wavelength.
Standard Wavelength Formula:
$\lambda = h / p = h / \sqrt{2mK}$
Given that all three particles possess equal kinetic energy K:
$\lambda \propto 1 / \sqrt{m}$
Because the electron possesses the smallest rest mass compared to alpha particles and protons, it yields the largest spatial wavelength λ.

Solution 19:
Consider a source charge producing an electric field E. The work done dW in moving a unit positive test charge by a displacement dx against the electrostatic force is:
$dW = -E \cdot dx$
By definition, this work done is equal to the change in electrostatic potential dV between those two coordinates:
$dW = dV$
Equating the expressions:
$dV = -E \cdot dx$
Rearranging for the field intensity vector yields the spatial derivative:
$E = -dV / dx$

Solution 20:
Let a capacitor of capacitance C be charged to a temporary charge q, establishing a potential difference $v = q / C$. The small work done dW in adding an incremental charge dq is:
$dW = v \cdot dq = (q / C) \cdot dq$
The total work done W required to build the state from 0 to full charge target Q is the integral:
$W = \int$ [from 0 to Q] $(q / C) \cdot dq$
$W = 1 / C \cdot [q^2 / 2]$ [from 0 to Q]
$W = Q^2 / 2C$
This mechanical charging work stands stored as electric field potential energy U:
$U = Q^2 / 2C$
Substituting $Q = CV$ yields the alternate quadratic voltage relationship:

$U = ½CV^2$

Substituting C = Q / V yields the linear parameter equation:

U = ½QV

Solution 21:

Working Principle:

A charged particle moving perpendicularly through a uniform magnetic field describes a circular path at a frequency independent of its linear speed and orbital radius, while a synchronized high-frequency alternating electric field continually accelerates the particle across the gap.

Schematic Construction Components:

1. Central Positive Ion Injection Source.
2. Dual D-shaped hollow metallic evacuators called Dees (D_1 and D_2).
3. High-Frequency Alternating Radio-Oscillator connected directly across the Dees.
4. Large powerful Electromagnet pole pieces providing a vertical uniform B field.
5. An electrostatic exit deflector plate guiding the accelerated beam out towards the target window.

Solution 22:

1. Induced Magnetization: Develops a feeble net magnetization oriented in a direction strictly opposite to the externally applied field.
2. Spatial Fields Dynamics: When placed inside a non-uniform field, it experiences a small force pushing it from regions of stronger field intensity towards weaker zones.
3. Magnetic Susceptibility and Permeability: The magnetic susceptibility χ is negative and exceptionally small ($-1 \leq \chi < 0$), meaning the relative permeability μ_r is slightly less than unity ($\mu_r < 1$).

Solution 23:

Consider a paraxial ray incident at point M on a concave mirror of small aperture, reflecting through the principal focus F. Let C be the center of curvature and P be the pole.

From the law of reflection, the angle of incidence equals the angle of reflection:

$\angle i = \angle r = \theta$

Let a normal line be drawn from C to M. Then, ∠MCP = θ (alternate interior angles).

Also, the exterior angle of triangle FCN is ∠MFP = 2θ.

For paraxial rays, the distance from the perpendicular foot to P is negligible, so tangents approximate the angles:

$\tan(\theta) \approx \theta = MD / CD$

$\tan(2\theta) \approx 2\theta = MD / FD$

Substituting θ into the second linear expression yields:

$2 \cdot (MD / CD) = MD / FD$

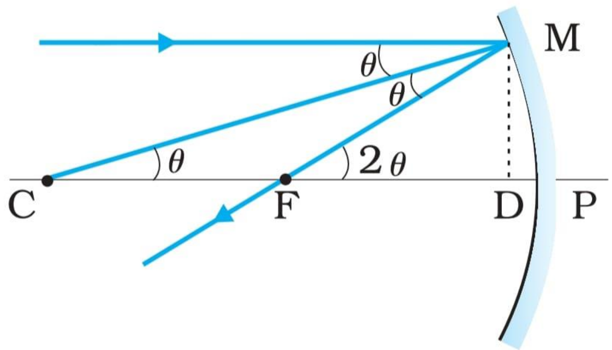
$2 / CD = 1 / FD$

Since CD corresponds to the radius of curvature R, and FD corresponds to the focal length f:

$2 / R = 1 / f$

Rearranging terms yields the final expression:

$f = R / 2$



Solution 24:

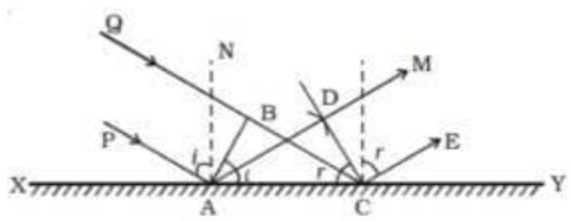
Let a plane wavefront AB be incident on a plane reflecting surface XY at an angle i. Let v be the wave speed in the medium.

Let t be the total time taken by the secondary wavelet to travel from point B to point C on the surface. Therefore:

$BC = v \cdot t$

During this exact time window t, the secondary wave starting out from point A spreads out over a radius equal to $v \cdot t$ to form a reflected sphere segment at point D.

Thus:
AD = v · t
Construct a tangent plane CD from point C to this sphere segment. CD represents the true reflected wavefront forming angle r with the surface.
In the right-angled triangles ΔABC and ΔADC:
1. The hypotenuse side AC is shared in common between both geometries.
2. The right angles match: ∠ABC = ∠ADC = 90°
3. The calculated spatial lengths match: BC = AD = v · t
By the Right-Angle Hypotenuse Side (RHS) congruence criterion:
ΔABC ≅ ΔADC
Since the geometric structures are identical, their corresponding interior base angles are exactly equal via CPCT:
∠i = ∠r



Solution 25:
Work Function (Φ_0):
The minimum energy required by an electron to escape from a metal surface without any excess velocity.
Einstein's Photoelectric Equation Formulation:
Total Incident Photon Energy = Work Function + Maximum Kinetic Energy of Emitted Electron
$hf = \Phi_0 + K_{max}$
Rearranging for maximum kinetic energy yields the standard linear form:
$K_{max} = hf - \Phi_0$
where h is Planck's constant, f is the frequency of incident radiation, and Φ_0 is the characteristic threshold energy barrier.

Solution 26:
1. Material Chemical Purity: Intrinsic semiconductors are chemically pure crystals with no intentional impurities; extrinsic semiconductors are intentionally doped with specific trivalent or pentavalent impurity atoms.
2. Equilibrium Charge Concentrations: In intrinsic systems, electron density equals hole density ($n_e = n_h = n_i$). In extrinsic systems, carrier levels become asymmetric ($n_e \gg n_h$ for n-type; $n_h \gg n_e$ for p-type).
3. Conduction Drivers: Electrical conductivity in intrinsic semiconductors is extremely low and depends purely on thermal generation; in extrinsic semiconductors, conductivity is high and controlled primarily by the specific doping density.

Solution 27:
Let an electric field E be applied across a conductor of length l. The electric force on a free electron of mass m and charge e is F = eE.
The uniform acceleration experienced by the electron is given by Newton's law:
$a = eE / m$
If τ is the average relaxation time between successive collisions, the average drift velocity v_d acquired by the electron becomes:
$v_d = a \cdot \tau = (eE\tau / m)$
The total current I passing through a conductor cross-sectional area A is related to drift velocity by:
$I = n e A v_d$
Substituting the drift velocity expression into the current equation:
$I = n e A \cdot (eE\tau / m)$
$I = (n e^2 A \tau / m) \cdot E$
Current density J is defined as current per unit area (J = I / A):
$J = (n e^2 \tau / m) \cdot E$
According to the microscopic form of Ohm's Law, J = σE, where σ is the electrical conductivity.
Comparing coefficients yields the definitive structural relation:
$\sigma = n e^2 \tau / m$

Solution 28:
Consider two long, straight parallel conductors A and B separated by a distance d, carrying steady currents I_1 and I_2 respectively.
The magnitude of the magnetic field B_A produced by conductor A at any point along conductor B is given by Ampere's Law:
$B_A = \mu_0 I_1 / (2\pi d)$
According to the Lorentz force law, conductor B experiences a magnetic force because it carries current I_2 through this field B_A.
The force F acting on a segment of length L of conductor B is:
$F = I_2 \cdot L \cdot B_A$
Substituting the expression for B_A into the force equation:
$F = I_2 \cdot L \cdot [\mu_0 I_1 / (2\pi d)]$
$F = \mu_0 I_1 I_2 L / (2\pi d)$
The force per unit length f is defined as F / L:
$f = \mu_0 I_1 I_2 / (2\pi d)$
By applying Fleming's Left-Hand Rule, the force is directed towards conductor A if the currents flow in the same direction (attractive force).
Definition of the Ampere:
One Ampere is that steady current which, if maintained in two straight parallel conductors of infinite length and negligible circular cross-section, placed 1 meter apart in a vacuum, produces between these conductors a force equal to 2×10^{-7} Newtons per meter of length.

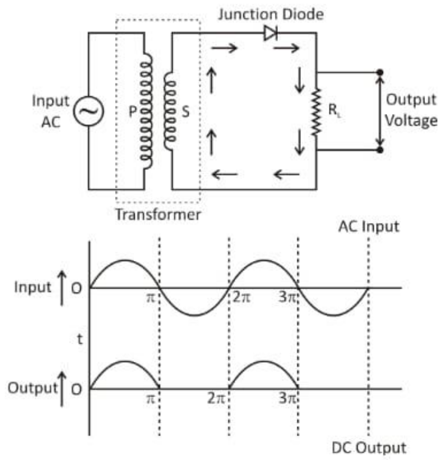
Solution 29:
Consider a rectangular coil of area A with N turns rotating with a constant angular velocity ω in a uniform magnetic field B.
The magnetic flux Φ linked with the coil at any instantaneous time t, where the normal to the coil makes an angle $\theta = \omega t$ with the magnetic field, is:
$\Phi = N \cdot (B \cdot A \cos\theta) = N B A \cos(\omega t)$
According to Faraday's law of electromagnetic induction, the induced electromotive force e is given by the negative rate of change of magnetic flux:
$e = -d\Phi / dt$
Substituting the instantaneous flux expression into the derivative equation:
$e = -d/dt\,[N B A \cos(\omega t)]$
Since N, B, and A are constants, differentiating the cosine term gives:
$e = -N B A \cdot [-\omega \sin(\omega t)]$
$e = N B A \omega \sin(\omega t)$
When $\sin(\omega t) = 1$, the induced electromotive force reaches its maximum peak value, which we define as $e_0 = N B A \omega$.
Substituting e_0 back into the expression yields the standard sinusoidal voltage equation:
$e = e_0 \sin(\omega t)$

Solution 30:
Consider two coherent sources S_1 and S_2 separated by a distance d. Let a screen be placed parallel to the sources at a distance D.
Let P be a point on the screen at a distance y from the central axis. The path difference between the waves arriving at P is $\Delta = S_2P - S_1P$.
From the coordinate geometry of the setup:
$(S_2P)^2 = D^2 + (y + d/2)^2$
$(S_1P)^2 = D^2 + (y - d/2)^2$
Subtracting the equations eliminates D^2:
$(S_2P)^2 - (S_1P)^2 = [y^2 + yd + d^2/4] - [y^2 - yd + d^2/4]$
$(S_2P)^2 - (S_1P)^2 = 2yd$
Factoring the left-hand side into a product of sum and difference:
$(S_2P - S_1P) \cdot (S_2P + S_1P) = 2yd$
Since D >> d, we can approximate the path sum as $S_2P + S_1P \approx 2D$. Substituting this approximation gives:
$\Delta \cdot (2D) = 2yd$
$\Delta = yd / D$
For constructive interference (Bright Fringes), the path difference must be an integer multiple of the wavelength ($\Delta = n\lambda$):
$yd / D = n\lambda$
$y_n = n\lambda D / d$
Fringe width β is defined as the separation between two

consecutive bright fringes:
$\beta = y_{(n+1)} - y_n$
$\beta = (n + 1)\lambda D/d - n\lambda D/d$
$\beta = \lambda D / d$

Solution 31:
According to Bohr's model of the hydrogen atom, the stable orbital rotation of an electron around a nucleus relies on the centripetal force balanced by the electrostatic Coulomb attraction:
$m v^2 / r = e^2 / (4\pi\varepsilon_0 r^2)$
Multiplying both sides by r isolates the kinetic energy energy term:
$m v^2 = e^2 / (4\pi\varepsilon_0 r)$
Bohr's second postulate states that the orbital angular momentum of an electron is quantized as an integral multiple of $h / 2\pi$:
$m v r = n h / (2\pi)$
Isolating velocity v from the quantization equation gives:
$v = n h / (2\pi m r)$
Substituting this velocity expression into the balanced force equation:
$m \cdot [n h / (2\pi m r)]^2 = e^2 / (4\pi\varepsilon_0 r)$
$m \cdot [n^2 h^2 / (4\pi^2 m^2 r^2)] = e^2 / (4\pi\varepsilon_0 r)$
Simplifying the expression and canceling terms yields:
$n^2 h^2 / (4\pi^2 m r) = e^2 / (4\pi\varepsilon_0)$
Isolating the orbital radius r for the n-th state yields the definitive formula:
$r_n = \varepsilon_0 n^2 h^2 / (\pi m e^2)$
For the ground state of the hydrogen atom where n = 1, this expression defines the Bohr radius a_0:
$a_0 = \varepsilon_0 h^2 / (\pi m e^2)$

Solution 32:
Rectification Definition:
The process of converting an alternating current (which periodically reverses direction) into a unidirectional direct current.
Working Mechanism of a Half-Wave Rectifier:
An alternating input voltage is applied across a p-n junction diode in series with a load resistor R_L via a step-down transformer.
1. During the Positive Half-Cycle: The diode becomes forward-biased, lowering its depletion barrier and allowing current to pass easily through the load resistor R_L.
2. During the Negative Half-Cycle: The diode becomes reverse-biased, increasing its internal resistance and blocking current flow completely.
As a result, only the positive cycles appear across the load, producing a pulsating direct current.



Solution 33:
Given Data: $q_A = 5\ \mu C = 5 \times 10^{-6}$ C, $q_B = -5\ \mu C = -5 \times 10^{-6}$ C, distance AB = 0.2 m.
The distance from each charge to the midpoint O is r = 0.1 m.
a) Electric field calculation at the midpoint O:
The electric field E_A produced by the positive charge qA points away from A (towards B).
$E_A = 1 / (4\pi\varepsilon_0) \cdot (|q_A| / r^2)$
$E_A = (9 \times 10^9) \cdot (5 \times 10^{-6}) / (0.1)^2 = 4.5 \times 10^6$ N/C
The electric field E_B produced by the negative charge qB points towards B.
$E_B = 1 / (4\pi\varepsilon_0) \cdot (|q_B| / r^2)$
$E_B = (9 \times 10^9) \cdot (5 \times 10^{-6}) / (0.1)^2 = 4.5 \times 10^6$ N/C
Since both fields point in the same direction (from A to B), the total electric field E is their sum:
$E = E_A + E_B$
$E = 4.5 \times 10^6 + 4.5 \times 10^6 = 9.0 \times 10^6$ N/C

Direction: Directed along the vector line OB (towards charge B).

b) Force experienced by a negative test charge $q = -2$ nC $= -2 \times 10^{-9}$ C placed at O:

$F = |q| \cdot E$

$F = (2 \times 10^{-9}) \cdot (9.0 \times 10^{6})$

$F = 1.8 \times 10^{-2}$ N $= 0.018$ N

Direction: Because the test charge is negative, the force vector points in the direction opposite to the electric field. Thus, it is directed along the vector line OA (towards charge A).

Solution 34:

Given Data: $R_1 = 3\ \Omega$, $R_2 = 4\ \Omega$, $R_3 = 12\ \Omega$, Emf $E = 6$ V, internal resistance $r = 0.5\ \Omega$.

a) Effective parallel resistance Rp calculation:

$1 / Rp = 1 / R_1 + 1 / R_2 + 1 / R_3$

$1 / Rp = 1/3 + 1/4 + 1/12$

Finding a common denominator of 12:

$1 / Rp = (4 + 3 + 1) / 12 = 8 / 12 = 2 / 3$

$Rp = 1.5\ \Omega$

b) Total current drawn from the battery (I) and terminal voltage (V):

Total resistance of the circuit $= Rp + r = 1.5 + 0.5 = 2.0\ \Omega$

$I = E / (Rp + r)$

$I = 6 / 2.0 = 3.0$ A

The terminal potential difference V across the battery is given by:

$V = E - I \cdot r$

$V = 6 - (3.0 \times 0.5) = 6 - 1.5 = 4.5$ V

Solution 35:

Given Data: $L = 5.0$ H, $C = 20\ \mu F = 20 \times 10^{-6}$ C, $R = 40\ \Omega$.

a) Resonant angular frequency ω_0 and linear frequency f_0 calculation:

$\omega_0 = 1 / \sqrt{(L \cdot C)}$

$\omega_0 = 1 / \sqrt{(5.0 \times 20 \times 10^{-6})} = 1 / \sqrt{(10^{-4})} = 1 / 10^{-2} = 100$ rad/s

$f_0 = \omega_0 / (2\pi)$

$f_0 = 100 / (2 \times 3.1416) = 15.92$ Hz

b) Quality factor (Q-factor) calculation:

$Q = 1 / R \cdot \sqrt{(L / C)}$

$Q = 1 / 40 \cdot \sqrt{(5.0 / (20 \times 10^{-6}))}$

$Q = 1 / 40 \cdot \sqrt{250000}$

$Q = 1 / 40 \cdot 500 = 12.5$

c) Impedance Z at resonant condition:

At resonance, inductive reactance equals capacitive reactance (X_L = X_C), simplifying the impedance equation to its purely resistive term:

$Z = R$

$Z = 40\ \Omega$

Solution 36:

Given Data: Equilateral prism angle $A = 60°$, refractive index $\mu = 1.5$.

For the ray to just suffer total internal reflection at the second face, the angle of refraction r_2 inside that boundary surface must equal the critical angle c:

$\sin(r_2) = \sin(c) = 1 / \mu$

$\sin(r_2) = 1 / 1.5 = 2/3$

$r_2 = \arcsin(0.6667) = 41.81°$

Using the structural prism relation relating interior refraction angles to the apex angle ($r_1 + r_2 = A$):

$r_1 = A - r_2$

$r_1 = 60° - 41.81° = 18.19°$

Applying Snell's law at the first entry face surface:

$\mu = \sin(i) / \sin(r_1)$

$\sin(i) = \mu \cdot \sin(r_1)$

$\sin(i) = 1.5 \times \sin(18.19°)$

$\sin(i) = 1.5 \times 0.3122 = 0.4683$

Isolating the angle of incidence i:

$i = \arcsin(0.4683) = 27.92°$

Solution 37:

Given Data: mass of coin = 63.0 g, atomic mass of Cu = 62.92960 u, $Z = 29$, $N = 63 - 29 = 34$.

Mass of a free proton = 1.00727 u, mass of a free neutron = 1.00866 u.

1. Calculation of mass defect Δm for a single copper nucleus:

Mass of separated constituent nucleons $= (Z \cdot m_p) + (N \cdot m_n)$

Mass = (29 × 1.00727 u) + (34 × 1.00866 u)

Mass = 29.21083 u + 34.29444 u = 63.50527 u

Δm = Mass of separated nucleons - Actual mass of nucleus

Δm = 63.50527 u - 62.92960 u = 0.57567 u

2. Binding energy calculation for a single nucleus:

E_nucleus = 0.57567 × 931.5 MeV = 536.24 MeV

3. Total number of atoms inside the 63.0 g copper coin:

Given the molar mass of copper matches the coin weight at 63.0 g/mol, the sample contains exactly 1 mole of atoms:

Number of atoms = Avogadro's Number = 6.022×10^{23} atoms

4. Total energy required to separate all nucleons inside the coin:

Total Energy = $E_{nucleus}$ × Total number of atoms

Total Energy = 536.24 MeV × 6.022×10^{23}

Total Energy = 3.2292×10^{26} MeV

Converting MeV into Joules (1 MeV = 1.6×10^{-13} J):

Total Energy = $3.2292 \times 10^{26} \times 10^{6} \times 1.6 \times 10^{-19}$ J

Total Energy = 5.174×10^{13} J