

PHYSICS (042)

Class XII · Sample Question Paper 2026–27

Answers, Solutions and Marking Scheme

Maximum Marks: 70 Time Allowed: 3 hours

GENERAL INSTRUCTIONS

- There are 33 questions in all. All questions are compulsory.
- This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
- All the sections are compulsory.
- Section A contains sixteen questions — twelve MCQ and four Assertion–Reason based — of 1 mark each; Section B contains five questions of two marks each; Section C contains seven questions of three marks each; Section D contains two case study based questions of four marks each; and Section E contains three long answer questions of five marks each.
- There is no overall choice. However, an internal choice has been provided in two questions in Section B, one question in Section C, and all three questions in Section E. You have to attempt only one of the choices in such questions.
- Use of calculators is not allowed.
- You may use the following values of physical constants wherever necessary:

$$c = 3 \times 10^8 \text{ m s}^{-1} \quad m_e = 9.1 \times 10^{-31} \text{ kg} \quad m_p = 1.7 \times 10^{-27} \text{ kg} \quad e = 1.6 \times 10^{-19} \text{ C}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1} \quad h = 6.63 \times 10^{-34} \text{ J s} \quad \epsilon_0 = 8.854 \times 10^{-12} \text{ C}^2 \text{ N}^{-1} \text{ m}^{-2}$$

$$\text{Avogadro's number} = 6.023 \times 10^{23} \text{ per gram mole} \quad \text{radius of nucleus} \approx 10^{-15} \text{ m}$$

SECTION A (16 × 1 = 16)

This section comprises 12 multiple choice questions and 4 Assertion–Reason based questions of 1 mark each. One mark is awarded for the correct option only; there are no part marks.

Question 1 1 mark

A point charge $+Q$ is placed at the centre of a spherical Gaussian surface of radius R . If the radius of the sphere is doubled, the electric flux through the surface will

- A. become half B. become double C. remain the same D. become four times

ANSWER AND SOLUTION

Correct option: C. remain the same

By Gauss's law, the electric flux through a closed surface is

$$\Phi = \frac{Q}{\epsilon_0}$$

The flux depends only on the charge enclosed, and not on the shape or size of the Gaussian surface. Doubling the radius therefore leaves the flux unchanged.

Question 2 1 mark

If two identical heaters, each rated (1000 W, 220 V), are connected in parallel to a 220 V supply, then the total power consumed is

- A. 200 W B. 250 W C. 2000 W D. 2500 W

ANSWER AND SOLUTION

Correct option: C. 2000 W

Each heater operates at its rated voltage, so each consumes its rated power. For a parallel combination the powers add:

$$P = P_1 + P_2 = 1000 + 1000 = 2000 \text{ W}$$

Question 3 1 mark

An infinitely long cylinder is kept parallel to a uniform magnetic field B directed along the negative y -axis. What will be the direction of the induced current as seen from the y -axis?

- A. clockwise of the negative y -axis B. anticlockwise of the negative y -axis
C. no current will be induced D. along the direction of the magnetic field

ANSWER AND SOLUTION

Correct option: C. no current will be induced

The cylinder is stationary and the magnetic field is uniform and constant. The magnetic flux linked with the cylinder therefore does not change with time, so by Faraday's law no emf and hence no current is induced.

Question 4 1 mark

If the electric field associated with an electromagnetic wave is given by

$$\vec{E} = 30 \sin(0.2\pi \times 10^{-4} \text{ m}^{-1} x - 0.6\pi \times 10^4 \text{ Hz } t) \hat{j}$$

then the direction of propagation of the wave is along

- A. $\hat{i}$ B. $-\hat{i}$ C. $\hat{k}$ D. $-\hat{k}$

ANSWER AND SOLUTION

Correct option: A. $\hat{i}$

The phase of the wave is of the form $(kx - \omega t)$, which represents a wave travelling in the direction of increasing x .

Hence the wave propagates along the $+x$ direction, i.e. along $\hat{i}$.

(Consistency check: $v = \frac{\omega}{k} = \frac{0.6\pi \times 10^4}{0.2\pi \times 10^{-4}} = 3 \times 10^8 \text{ m s}^{-1}$, and $\vec{E}$ along $\hat{j}$ with propagation along $\hat{i}$ gives $\vec{B}$ along $\hat{k}$.)

Question 5 1 mark

Which one of the following phenomena is not explained by Huygens' construction of a wavefront?

- A. Diffraction B. Refraction C. Reflection D. Origin of spectra

ANSWER AND SOLUTION

Correct option: D. Origin of spectra

Diffraction, refraction and reflection are all wave phenomena and follow from Huygens' construction. The origin of spectra arises from transitions between quantised energy levels of atoms and cannot be explained by the wave construction.

Question 6 1 mark

If a wavefront from a star in a nearby galaxy is detected by a telescope at the top of some mountain in India, then the shape of the wavefront detected will be

- A. diverging spherical B. converging spherical C. plane D. cylindrical

ANSWER AND SOLUTION

Correct option: C. plane

The star is at an extremely large distance and therefore acts as a distant point source. A small portion of a spherical wavefront of very large radius is effectively plane, so the wavefront detected is plane.

Question 7 1 mark

The binding energy per nucleon curve shows a maximum around mass number $A = 56$. What does this imply about nuclei near iron (Fe)?

- A. They are the least stable nuclei.
- B. They are the most tightly bound nuclei.
- C. They undergo spontaneous fission releasing maximum energy.
- D. They cannot participate in nuclear reactions.

ANSWER AND SOLUTION

Correct option: B. They are the most tightly bound nuclei.

A maximum in the binding energy per nucleon means that the nucleons are held most tightly, so these nuclei are the most stable.

Spontaneous fission is characteristic of very heavy nuclei, not of nuclei near iron; and nuclei near iron can still take part in nuclear reactions. Since iron lies at the bottom of the energy valley, both fusion of lighter nuclei and fission of heavier nuclei release energy by moving towards it.

Question 8 1 mark

A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. The direction of the movement of the ball and of its magnetic moment would be

	Direction of the movement of the ball	Direction of the magnetic moment
A.	Towards the bar magnet	Opposite to that of the bar magnet
B.	Towards the bar magnet	Same direction as that of the bar magnet
C.	Away from the bar magnet	Same direction as that of the bar magnet
D.	Away from the bar magnet	Opposite to that of the bar magnet

ANSWER AND SOLUTION

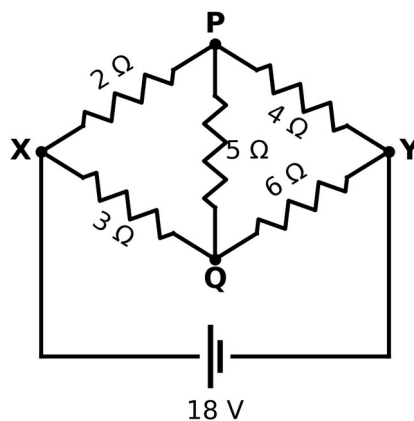
Correct option: D. Away from the bar magnet, and opposite to that of the bar magnet

On being dipped in liquid nitrogen the temperature of the ball falls below its critical temperature and it becomes a superconductor. A superconductor is a perfect diamagnet, expelling the magnetic field from its interior.

A diamagnetic body acquires a magnetic moment opposite to the applied field and is repelled by the magnet, so the ball moves away from the bar magnet.

Question 9 1 mark

A bridge circuit is shown in the following figure. The total current flowing in the circuit is



- A. 18 A B. 5 A C. 5/18 A D. 18/5 A

For Visually Impaired Students only

In a Wheatstone bridge, all the four arms have equal resistance R . If the resistance of the galvanometer arm is $2R$, the equivalent resistance of the combination as seen by the battery is

- A. $2R$ B. R C. $R/2$ D. $R/4$

ANSWER AND SOLUTION

Correct option: B. 5 A

The bridge is balanced, because $\frac{2\Omega}{4\Omega} = \frac{3\Omega}{6\Omega}$. No current flows through the 5Ω arm, so it may be ignored.

The arms $(2\Omega + 4\Omega) = 6\Omega$ and $(3\Omega + 6\Omega) = 9\Omega$ are then in parallel:

$$R_{XY} = \frac{6 \times 9}{6 + 9} = \frac{18}{5} \Omega$$

$$I = \frac{V}{R} = \frac{18}{18/5} = 5 \text{ A}$$

ANSWER AND SOLUTION — FOR VISUALLY IMPAIRED STUDENTS

Correct option: B. R

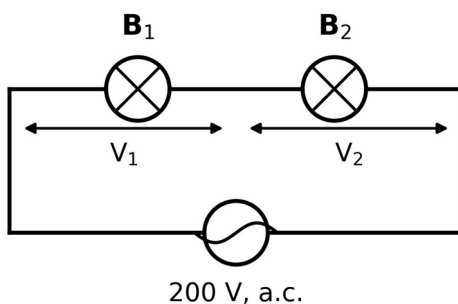
All four arms are equal, so the bridge is balanced and no current flows through the galvanometer arm of resistance $2R$; it is therefore ineffective.

The combination reduces to $(R + R)$ in parallel with $(R + R)$:

$$R_{eq} = \frac{2R \times 2R}{2R + 2R} = R$$

Question 10 1 mark

Two electric bulbs, B_1 and B_2 , are connected in series to an a.c. supply of 200 V. The power ratings printed on the bulbs are B_1 : 200 V, 60 W and B_2 : 200 V, 100 W.



Using their rated voltage–power information, the ratio of their resistances R_1/R_2 is

- A. 5 : 3 B. 3 : 5 C. 3 : 4 D. 4 : 3

ANSWER AND SOLUTION

Correct option: A. 5 : 3

Here $P_1 = 60$ W and $P_2 = 100$ W, both rated at the same voltage $V = 200$ V.

$$R_1 = \frac{V^2}{P_1} \quad \text{and} \quad R_2 = \frac{V^2}{P_2}$$

$$\frac{R_1}{R_2} = \frac{P_2}{P_1} = \frac{100}{60} = \frac{5}{3}, \text{ i.e. } 5 : 3$$

Question 11 1 mark

If a nucleus is scaled to the size of a football, approximately 22 cm, then the radius of the orbit of the electron will be approximately

- A. 22 cm B. 22 m C. 22 km D. 22000 km

ANSWER AND SOLUTION

Correct option: C. 22 km

A typical nuclear radius is about 10^{-15} m, while the radius of an atom (the electron orbit) is about 10^{-10} m.

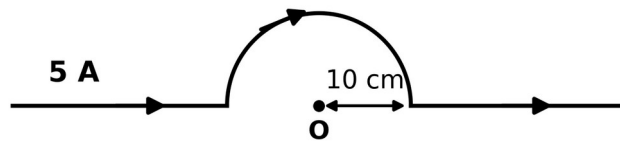
$$\frac{r_{\text{atom}}}{r_{\text{nucleus}}} \approx \frac{10^{-10}}{10^{-15}} = 10^5$$

Scaling the nucleus up to 22 cm = 0.22 m scales the orbit by the same factor:

$$0.22 \times 10^5 = 22000 \text{ m} = 22 \text{ km}$$

Question 12 1 mark

A current of 5 A is passing through a long wire which has a semicircular loop of radius 10 cm, as shown in the figure.



The magnetic field produced at the centre of the loop is

- A. $2\pi \mu\text{T}$ B. $4\pi \mu\text{T}$ C. $5\pi \mu\text{T}$ D. $8\pi \mu\text{T}$

ANSWER AND SOLUTION

Correct option: C. $5\pi \mu\text{T}$

The two straight portions lie along the line through the centre O, so each has $d\vec{l} \times \hat{r} = 0$ and contributes nothing at O. Only the semicircular arc contributes, giving half the field of a full circular loop:

$$B = \frac{\mu_0 I}{4R} = \frac{4\pi \times 10^{-7} \times 5}{4 \times 0.10} \text{ T} = 5\pi \times 10^{-6} \text{ T} = 5\pi \mu\text{T}$$

Assertion–Reason Based Questions

For questions 13 to 16, two statements are given — one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the options given below:

- A. Both Assertion and Reason are true and Reason is the correct explanation of Assertion.
 B. Both Assertion and Reason are true but Reason is not the correct explanation of Assertion.
 C. Assertion is true but Reason is false.
 D. Both Assertion and Reason are false.

Question 13 1 mark

Assertion (A): In Rutherford's scattering experiment, most of the alpha particles passed through the gold foil undeflected.

Reason (R): The electrons in the atom are very light and do not affect the path of the alpha particles significantly.

ANSWER AND SOLUTION

Correct option: B. Both Assertion and Reason are true but Reason is not the correct explanation of Assertion.

(A) is true: most alpha particles pass straight through because almost the whole atom is empty space, the positive charge and mass being concentrated in a very small nucleus.

(R) is also true, since an electron is far lighter than an alpha particle and cannot deflect it appreciably. But the undeflected passage is explained by the emptiness of the atom, not by the lightness of the electrons, so (R) does not explain (A).

Question 14 1 mark

A convex lens of focal length 20 cm is used to form a real image of a point object placed 30 cm from the lens. The lens is then immersed in water of refractive index 1.33 (the lens material has refractive index 1.5).

Assertion (A): The focal length of the lens increases when it is immersed in water.

Reason (R): The focal length of a lens depends on the relative refractive index of the lens material with respect to the surrounding medium, as given by the lens maker's formula.

ANSWER AND SOLUTION

Correct option: A. Both Assertion and Reason are true and Reason is the correct explanation of Assertion.

By the lens maker's formula,

$$\frac{1}{f} = \left(\frac{\mu_{lens}}{\mu_{medium}} - 1 \right) \left(\frac{1}{R_1} - \frac{1}{R_2} \right)$$

In air the factor is $(1.5 - 1) = 0.5$; in water it is $\left(\frac{1.5}{1.33} - 1 \right) \approx 0.128$. The smaller factor makes $\frac{1}{f}$ smaller, so f increases. Hence (R) correctly explains (A).

Question 15 1 mark

In Young's double slit experiment, the distance between the slits is 0.25 mm and the screen is placed 1.0 m away. A student uses monochromatic light of wavelength 500 nm.

Assertion (A): The fringe width observed on the screen will be 2.0 mm.

Reason (R): The fringe width in YDSE is directly proportional to the slit separation and inversely proportional to the wavelength of light.

ANSWER AND SOLUTION

Correct option: C. Assertion is true but Reason is false.

$$\beta = \frac{\lambda D}{d} = \frac{500 \times 10^{-9} \times 1.0}{0.25 \times 10^{-3}} = 2.0 \times 10^{-3} \text{ m} = 2.0 \text{ mm}$$

So (A) is true. However, the fringe width is inversely proportional to the slit separation and directly proportional to the wavelength, so (R) states the dependence the wrong way round and is false.

Question 16 1 mark

Assertion (A): If a conductor is placed in an external electric field, the electric field inside the conductor becomes infinity in electrostatic equilibrium.

Reason (R): Free electrons inside the conductor rearrange themselves in such a way that the internal electric field is in the same direction as that of the external field.

ANSWER AND SOLUTION

Correct option: D. Both Assertion and Reason are false.

The free electrons of a conductor redistribute themselves until the field they produce exactly cancels the external field inside the conductor. The net electric field inside a conductor in electrostatic equilibrium is therefore zero, not infinite, so (A) is false.

The induced internal field is opposite to the external field, not in the same direction, so (R) is also false.

SECTION B (5 × 2 = 10)

This section comprises 5 very short answer type questions of 2 marks each.

Question 17 2 marks

The electric and magnetic fields associated with an electromagnetic radiation in a medium are given as follows:

$$E = 30 \sin(2\pi \times 10^{18} \text{ rad s}^{-1} t + \pi \times 10^{10} \text{ m}^{-1} x) \text{ V m}^{-1}$$

$$B = 10^{-7} \sin(2\pi \times 10^{18} \text{ rad s}^{-1} t + \pi \times 10^{10} \text{ m}^{-1} x) \text{ T}$$

- What is the refractive index of the medium through which the wave is propagating?
- Find the frequency of the wave and identify the electromagnetic wave.

ANSWER AND SOLUTION

I. Refractive index of the medium, $\mu = \frac{c}{v_{\text{medium}}}$, with $c = 3 \times 10^8 \text{ m s}^{-1}$.

$$v_{\text{medium}} = \frac{\omega}{k} = \frac{2\pi \times 10^{18}}{\pi \times 10^{10}} = 2 \times 10^8 \text{ m s}^{-1}$$

$$\mu = \frac{3 \times 10^8}{2 \times 10^8} = 1.5$$

II. Angular frequency $\omega = 2\pi \times 10^{18} \text{ rad s}^{-1}$, and $\omega = 2\pi\nu$.

$$\nu = 10^{18} \text{ Hz}$$

A frequency of about 10^{18} Hz lies in the X-ray region of the electromagnetic spectrum.

MARKING SCHEME

I: $\nu_{\text{medium}} = 2 \times 10^8 \text{ m s}^{-1} - \frac{1}{2} \cdot \mu = 1.5 - \frac{1}{2}$ II: $\nu = 10^{18} \text{ Hz} - \frac{1}{2} \cdot \text{identification as X-rays} - \frac{1}{2}$

Question 18 2 marks

Write the nature of the path of free electrons in a conductor in the

- presence of an electric field,
- absence of an electric field.

ANSWER AND SOLUTION

- In the presence of an electric field, each free electron experiences a force opposite to the direction of the field and acquires a small drift velocity. The electrons continue to collide frequently with the ions of the lattice, so the path is a zig-zag one on which a slow, steady drift opposite to the field is superposed. This net drift constitutes the electric current.
- In the absence of an electric field, the free electrons move randomly in all directions with thermal velocities, following a zig-zag path between successive collisions. There is no preferred direction, the average velocity is zero and no net current flows.

MARKING SCHEME

Path in the presence of the field (zig-zag with a net drift opposite to $\vec{E}$) — 1 · path in the absence of the field (random thermal motion, no net drift) — 1

Question 19 2 marks

Two like charges $+q$ and $+q$ are placed at a distance d apart. What work must be done by an external agent to bring another charge $+q$ from infinity to the midpoint of the line joining the two given charges?

ANSWER AND SOLUTION

At the midpoint, the distance from each of the two charges is $\frac{d}{2}$.

Potential at the midpoint due to one charge:

$$V_1 = \frac{kq}{d/2} = \frac{2kq}{d}$$

Potential due to both charges:

$$V = 2 \times \frac{2kq}{d} = \frac{4kq}{d}$$

Work done by the external agent in bringing $+q$ from infinity to that point:

$$W = qV = \frac{4kq^2}{d}, \text{ where } k = \frac{1}{4\pi\epsilon_0}$$

MARKING SCHEME

Distance $\frac{d}{2}$ from each charge — $\frac{1}{2} \cdot V_1 = \frac{2kq}{d} - \frac{1}{2} \cdot V = \frac{4kq}{d} - \frac{1}{2} \cdot W = \frac{4kq^2}{d} - \frac{1}{2}$

Question 20 2 marks

(A) A certain magnetic substance is found to have a relative permeability of 800. What type of magnetic material is it? Write any two characteristics that such a material exhibits.

OR

(B) State Gauss's law of magnetism. Also discuss its significance.

ANSWER AND SOLUTION — 20 (A)

Given: relative magnetic permeability $\mu_r = 800$.

Since $\mu_r \gg 1$, the material is a ferromagnetic material.

Two characteristics:

1. It is strongly attracted by a magnetic field, because its magnetic permeability and susceptibility are very large and positive.
2. It retains magnetism even after the external magnetic field is removed; it shows hysteresis and can be made into a permanent magnet.

MARKING SCHEME

Identifying the material as ferromagnetic — 1 · any two correct characteristics — $\frac{1}{2} \times 2$

ANSWER AND SOLUTION — 20 (B)

Gauss's law for magnetism states that the net magnetic flux through any closed surface is always zero:

$$\Phi_B = \oint \vec{B} \cdot d\vec{S} = 0$$

Significance:

1. Isolated magnetic poles (magnetic monopoles) do not exist; the simplest magnetic element is a dipole.
2. Magnetic field lines neither begin nor end at any point — they always form continuous closed loops.

MARKING SCHEME

Correct statement of the law with the mathematical form — 1 · any two points of significance — $\frac{1}{2} \times 2$

Question 21 2 marks

(A)

- I. Why are hydrogen spectral lines considered to be a fingerprint of the element?
- II. If the energy of an electron of the hydrogen atom in the ground state is -13.6 eV, what should be the minimum energy of a photon which can ionize the atom?

OR

(B) State Bohr's quantization condition for defining a stationary orbit. How does the de Broglie hypothesis explain the stationary orbit?

ANSWER AND SOLUTION — 21 (A)

I. The energy levels of the hydrogen atom are quantised, so transitions between them emit or absorb photons of a definite, characteristic set of wavelengths. The resulting line spectrum is a unique pattern for hydrogen — no other element gives the same set of lines — and it therefore serves as a fingerprint by which hydrogen can be identified wherever it occurs.

II. Ionization means raising the electron from the ground state ($E_1 = -13.6$ eV) to $E_\infty = 0$.

$$E_{\min} = E_\infty - E_1 = 0 - (-13.6) = 13.6 \text{ eV}$$

MARKING SCHEME

I: line spectrum unique to the element / quantised energy levels — 1 II: $E_{\min} = 13.6$ eV — 1

ANSWER AND SOLUTION — 21 (B)

Bohr's quantization condition: an electron can revolve only in those circular orbits for which the angular momentum is an integral multiple of $\frac{h}{2\pi}$, and while in such a stationary orbit it does not radiate energy.

$$mvr = \frac{nh}{2\pi}, \quad n = 1, 2, 3, \dots$$

where m is the mass of the electron, v its speed, r the radius of the orbit and n the principal quantum number.

Explanation by the de Broglie hypothesis: a moving electron behaves as a matter wave of wavelength $\lambda = \frac{h}{mv}$.

The orbit is stable only if this wave closes on itself, i.e. forms a standing wave, which requires the circumference to be an integral multiple of the wavelength:

$$2\pi r = n\lambda = \frac{nh}{mv}$$

$$mvr = \frac{nh}{2\pi}$$

This is exactly Bohr's quantization condition. Thus the stationary orbits are those in which the electron's matter wave forms a standing wave, so that the electron does not radiate.

MARKING SCHEME

Statement of the quantization condition with $mvr = \frac{nh}{2\pi}$ — 1 · de Broglie standing-wave explanation leading to the same relation — 1

SECTION C (7 × 3 = 21)

This section comprises 7 short answer type questions of 3 marks each.

Question 22 3 marks

Compare the energy band diagrams of metals, insulators and semiconductors.

- I. Explain how the band gap determines conductivity.
- II. Apply this reasoning to justify why diamond (C) is an insulator while tin (Sn) is a conductor, though both are elements of group IV.

ANSWER AND SOLUTION

Metals: the valence and conduction bands overlap, or the conduction band is partially filled. A very large number of free electrons is available at room temperature, so the conductivity is high.

Insulators: the valence band is full and is separated from the empty conduction band by a large forbidden gap ($E_g > 3$ eV). Thermal energy at room temperature (≈ 0.026 eV) cannot excite electrons across it, so the conductivity is negligible.

Semiconductors: the forbidden gap is small ($E_g \approx 1$ eV). A few electrons are excited thermally into the conduction band, leaving holes behind, and the conductivity lies between that of metals and insulators. It rises with temperature and can be controlled by doping.

I. The band gap fixes how many carriers can be excited into the conduction band at a given temperature, and hence fixes the conductivity: the larger the gap, the fewer the carriers and the poorer the conduction.

II. Diamond has a very large band gap (≈ 5.4 eV) because of its strong covalent network, so practically no electrons reach the conduction band at room temperature and it behaves as an insulator. In tin the bands overlap, giving free electrons at the Fermi level, so it conducts like a metal. Both are group IV elements, but it is the magnitude of the band gap, not the group, that decides the conductivity.

MARKING SCHEME

Band description of metals, insulators and semiconductors — 1 · (I) role of the band gap in carrier availability — 1 · (II) diamond (large gap) versus tin (overlapping bands) — 1

Question 23 3 marks

Explain:

- I. It is easier to start a car engine on a warm day than on a chilly day.
- II. The resistance of our body is very large, and yet one experiences a strong shock (sometimes even fatal) when one accidentally touches the live wire of, say, a 240 V supply.
- III. Heat is generated continuously in an electric heater, but its temperature becomes constant after some time.

ANSWER AND SOLUTION

- I. The internal resistance of a car battery decreases as the temperature rises. On a warm day the battery can therefore supply a larger current to the starter motor, which makes starting the engine easier.
- II. The human body is sensitive to very small currents — a current of only a few milliamperes through the body is enough to cause a severe shock, and a few tens of milliamperes can be fatal. Even with a large body resistance, 240 V drives a current of this order.
- III. As the heater warms up, it begins to lose heat to the surroundings at a rate that increases with its temperature. A stage is soon reached at which the rate of loss of heat becomes equal to the rate at which heat is produced electrically, and from then on the temperature remains constant.

MARKING SCHEME

(I) internal resistance falls with temperature, larger current — 1 · (II) body sensitive to a few mA — 1 · (III) rate of heat loss equals rate of heat production — 1

Question 24 3 marks

The atomic mass of $^{16}_8\text{O}$ is 15.99493 u. Calculate the binding energy per nucleon of the oxygen nucleus.

(Given: mass of proton = 1.00727 u, mass of neutron = 1.00866 u, $1\text{ u} = 931.5\text{ MeV}/c^2$.)

ANSWER AND SOLUTION

For $^{16}_8\text{O}$: $Z = 8$ protons and $N = A - Z = 8$ neutrons.

Sum of the masses of the constituent nucleons:

$$Zm_p + Nm_n = 8(1.00727) + 8(1.00866) \\ = 8.05816 + 8.06928 = 16.12744\text{ u}$$

Mass defect:

$$\Delta m = 16.12744 - 15.99493 = 0.13251\text{ u}$$

Binding energy:

$$B = \Delta m \times 931.5 = 0.13251 \times 931.5 \approx 123.4\text{ MeV}$$

Binding energy per nucleon:

$$\frac{B}{A} = \frac{123.4}{16} \approx 7.71\text{ MeV}$$

MARKING SCHEME

Sum of nucleon masses = 16.12744 u — 1 · $\Delta m = 0.13251\text{ u}$ and $B \approx 123.4\text{ MeV}$ — 1 · $\frac{B}{A} \approx 7.71\text{ MeV}$ — 1

Question 25 3 marks

A diamond has a refractive index of 2.42.

- I. A ray of light inside the diamond strikes the surface at an angle of incidence of 30° . State whether it will undergo refraction or total internal reflection.
- II. Explain why diamonds sparkle when cut properly.

ANSWER AND SOLUTION

I. For diamond, $\mu = 2.42$. The critical angle for the diamond–air surface is

$$\theta_c = \sin^{-1}\left(\frac{1}{\mu}\right) = \sin^{-1}\left(\frac{1}{2.42}\right) = \sin^{-1}(0.413) \approx 24.4^\circ$$

The angle of incidence inside the diamond is 30° , and $30^\circ > \theta_c$.

Hence the ray does not emerge; it undergoes total internal reflection inside the diamond.

II. Because the critical angle of diamond is so small, light entering a well-cut stone strikes most of the internal facets at angles greater than θ_c and is totally internally reflected again and again. The light is thus trapped and travels inside the stone until it escapes through a few facets at the top, emerging in concentrated flashes. The cutter chooses the facet angles precisely so that this happens, which is what makes a properly cut diamond sparkle.

MARKING SCHEME

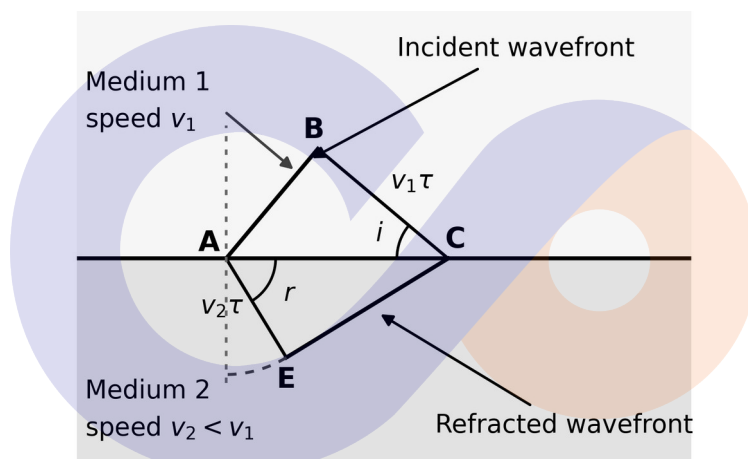
$\theta_c = \sin^{-1}\left(\frac{1}{2.42}\right) \approx 24.4^\circ - 1 \cdot 30^\circ > \theta_c$, hence total internal reflection — 1 · explanation of sparkling by repeated total internal reflection at correctly angled facets — 1

Question 26 3 marks

Derive Snell's law of refraction using Huygens' wave theory. What prediction of the wave theory was later experimentally verified?

ANSWER AND SOLUTION

Huygens' principle: every point on a wavefront acts as a source of secondary wavelets, and the new wavefront at a later instant is the common tangent (envelope) to these wavelets.



Let a plane wavefront AB be incident on the boundary between two media at an angle of incidence i , the speeds of light in the two media being v_1 and v_2 and the angle of refraction being r .

Let A reach the boundary first. In the further time τ taken by B to reach the boundary at C,

$$BC = v_1 \tau \quad \text{and the wavelet from A grows to radius } AE = v_2 \tau$$

The refracted wavefront is the tangent CE drawn from C to this wavelet. From the geometry of the figure,

$$\sin i = \frac{BC}{AC}, \quad \sin r = \frac{AE}{AC}$$

$$\frac{\sin i}{\sin r} = \frac{BC}{AE} = \frac{v_1 \tau}{v_2 \tau} = \frac{v_1}{v_2}$$

Since the refractive index of a medium is $n = \frac{c}{v}$, we have $\frac{v_1}{v_2} = \frac{n_2}{n_1}$, and therefore

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}, \quad \text{i.e. } n_1 \sin i = n_2 \sin r$$

This is Snell's law of refraction.

Prediction later verified: the wave theory requires light to travel more slowly in an optically denser medium ($v \propto \frac{1}{n}$), whereas the corpuscular theory required it to travel faster. Foucault's measurement showed that the speed of light in water is less than in air, confirming the wave theory.

MARKING SCHEME

Statement of Huygens' principle with a correct labelled figure — 1 · construction with $BC = v_1 \tau$, $AE = v_2 \tau$ and the two sine relations — $1 \cdot n_1 \sin i = n_2 \sin r$ and the verified prediction (light slower in a denser medium) — 1

Question 27 3 marks

(A)

- I. An ammeter has an internal resistance of 13Ω and is originally designed to measure currents only up to 100 A. To extend its range for high-current measurements, a shunt resistor is connected in parallel with it. After adding the shunt, the same meter can now read currents as high as 750 A without damage. Using the principle of current division in parallel circuits, determine the value of the shunt resistance required to increase the measuring range of the ammeter.
- II. The coil of a moving coil galvanometer is wound over a metal frame. Why?

OR

(B)

- I. A small current loop behaves like a tiny magnet when placed in a magnetic field. Using this idea, explain what physical quantity determines the strength and orientation of such a magnetic dipole. Also state the SI unit of this quantity.
- II. A steel wire of length ℓ has a magnetic moment m . It is bent into a semicircular arc. What is its new magnetic moment?

ANSWER AND SOLUTION — 27 (A)

- I. The original ammeter may be treated as the galvanometer, with $G = 13 \Omega$ and full-scale current $I_g = 100$ A. The shunt S carries the rest of the current, so

$$S = \frac{I_g G}{I - I_g} = \frac{100 \times 13}{750 - 100} = \frac{1300}{650} = 2 \Omega$$

- II. The metal frame provides electromagnetic damping. As the coil swings, eddy currents induced in the frame oppose its motion, so the oscillations are damped quickly and the coil settles at its deflected position almost at once (a dead-beat galvanometer).

MARKING SCHEME

I: correct shunt relation $S = \frac{I_g G}{I - I_g}$ — 1 · substitution — $\frac{1}{2}$ · $S = 2 \Omega$ — $\frac{1}{2}$ II: electromagnetic damping by induced (eddy) currents — 1

ANSWER AND SOLUTION — 27 (B)

- I. The quantity is the magnetic dipole moment $\vec{m}$ of the loop. For a plane loop of N turns, each of area A , carrying a current I ,

$$\vec{m} = NIA \hat{n}$$

Its magnitude fixes the strength of the equivalent magnet, and its direction (given by the right-hand rule, along the normal $\hat{n}$ to the plane of the loop) fixes the orientation of the dipole. The torque on the loop is $\vec{\tau} = \vec{m} \times \vec{B}$.

SI unit: ampere metre² (A m²), equivalently joule per tesla (J T⁻¹).

- II. Pole strength of the straight wire, $q_m = \frac{m}{\ell}$. Bending does not change the pole strength; it changes only the separation between the poles.

When the wire is bent into a semicircular arc of radius R , $\ell = \pi R$, so $R = \frac{\ell}{\pi}$, and the new separation between the ends is the diameter $2R$.

$$\text{New magnetic moment} = q_m \times 2R = \left(\frac{m}{\ell}\right) \times \frac{2\ell}{\pi} = \frac{2m}{\pi}$$

MARKING SCHEME

I: magnetic dipole moment, $\vec{m} = NIA \hat{n} \rightarrow 1 \cdot \text{SI unit } A m^2 \text{ (or } J T^{-1}) \rightarrow \frac{1}{2}$ II: $q_m = \frac{m}{\ell} \rightarrow \frac{1}{2} \cdot \ell = \pi R$ giving separation

$$2R = \frac{2\ell}{\pi} \rightarrow \frac{1}{2} \cdot \text{new moment } \frac{2m}{\pi} \rightarrow \frac{1}{2}$$

Question 28 3 marks

- I. A bar magnet falls from a height through a metal ring. Its acceleration will be less than g . Explain.
 II. A coil of copper wire is wound uniformly on a wooden equilateral triangular frame. If each side of the triangle is increased to 5 times its original length, while keeping the number of turns per unit length unchanged, how does the self-inductance of the coil change?

ANSWER AND SOLUTION

I. As the magnet approaches the ring, the magnetic flux linked with the ring changes and an emf, and hence an induced current, is set up in it. By Lenz's law this induced current opposes the change producing it, so it opposes the motion of the magnet. The ring therefore exerts a retarding force on the falling magnet, and the net downward force is less than its weight. Hence the acceleration of the magnet is less than g .

II. For a coil, the self-inductance is

$$L = \frac{\mu_0 N^2 A}{\ell}$$

With the number of turns per unit length unchanged, increasing each side to 5 times gives

$$N \rightarrow 5N, \quad A \rightarrow 5^2 A = 25A, \quad \ell \rightarrow 5\ell$$

$$\frac{L'}{L} = \frac{(5N)^2 \times 25A / 5\ell}{N^2 A / \ell} = \frac{25 \times 25}{5} = 125$$

Hence $L' = 125L$; the self-inductance becomes 125 times its original value.

MARKING SCHEME

I: induced current opposing the motion (Lenz's law) and hence $a < g \rightarrow 1$ II: $L = \frac{\mu_0 N^2 A}{\ell} \rightarrow \frac{1}{2} \cdot N \rightarrow 5N \rightarrow \frac{1}{2} \cdot$

$$A \rightarrow 25A, \ell \rightarrow 5\ell \rightarrow \frac{1}{2} \cdot L' = 125L \rightarrow \frac{1}{2}$$

SECTION D (2 × 4 = 8)

This section comprises 2 case study based questions of 4 marks each.

Question 29 1 + 1 + 1 + 1 marks

In 2023, researchers developed flexible semiconductor films using organic polymers that could be printed like newspaper sheets. These films can bend, fold and still conduct electricity efficiently. Unlike traditional silicon chips, polymer semiconductors are lightweight, biodegradable and can be integrated into clothing or medical patches. Imagine a shirt that monitors your heartbeat, or a bandage that tracks wound healing in real time. Such innovations extend the idea of semiconductors beyond rigid circuits, showing how manipulating band gaps and carrier mobility in new materials can revolutionize electronics for healthcare, sustainability and wearable technology.

I. Which advantage of semiconductors makes them ideal for wearable devices like smart shirts?

- A. High voltage operation (~100 V) B. Bulky design and short life
C. Low power consumption and reliability D. Requirement of external heating

II. Carbon (diamond) has a band gap of 5.4 eV, while silicon has 1.1 eV. Why is silicon used in electronic devices but not diamond?

- A. Diamond has too many free electrons.
B. Diamond's band gap is too large for thermal excitation at room temperature.
C. Silicon has weaker covalent bonds than diamond.
D. Diamond cannot form covalent bonds.

III. In an intrinsic semiconductor at room temperature

- A. only electrons contribute to conduction. B. only holes contribute to conduction.
C. the number of electrons equals the number of holes. D. no conduction occurs at all.

IV. How will you use the concept of majority and minority carriers to explain the efficiency of polymer semiconductors in wearable technology?

ANSWER AND SOLUTION

I. Correct option: C. Low power consumption and reliability.

Wearable devices must run continuously from a very small battery, so a material that switches at low voltage, draws little power and works dependably over long periods is required; semiconductors provide exactly this.

II. Correct option: B. Diamond's band gap is too large for thermal excitation at room temperature.

With $E_g \approx 5.4$ eV, thermal energy at room temperature cannot lift electrons into the conduction band of diamond, so almost no carriers are available. Silicon, with $E_g \approx 1.1$ eV, has enough carriers and its conductivity can also be controlled by doping.

III. Correct option: C. the number of electrons equals the number of holes.

In an intrinsic semiconductor electrons and holes are produced only in pairs by thermal breaking of covalent bonds, so $n_e = n_h = n_i$.

IV. In a doped polymer semiconductor the current is carried almost entirely by the majority carriers — electrons in an n-type film and holes in a p-type film. Choosing the dopant and its concentration fixes the number of these carriers, and the mobility of the polymer chains fixes how easily they move, so the conductivity can be tuned to the value needed while the film is still able to bend and stretch. Minority carriers are few, and their chief role is recombination, which limits the current and affects the stability and response time of the device. Keeping the majority carrier concentration high and the minority carrier recombination low therefore allows such films to carry the required current at low voltage and low power, which is what makes them suitable for smart clothing and medical patches.

MARKING SCHEME

(I) correct option — 1 · (II) correct option — 1 · (III) correct option — 1 · (IV) correct explanation in terms of majority and minority carriers — 1



Question 30 1 + 1 + 1 + 1 marks

In 1905, Albert Einstein explained the photoelectric effect by proposing that light consists of discrete packets of energy called photons. Each photon carries an energy $E = h\nu$. When a photon strikes a metal surface, it can transfer its energy to an electron. If the photon's energy exceeds the work function of the metal, the electron can be emitted with maximum kinetic energy $K_{\max} = h\nu - \phi_0$. This discovery challenged the classical wave theory, which predicted that electron emission should depend only on the intensity of light. Instead, experiments showed that the emission of electrons depends on frequency too, proving the particle nature of light.

- I. Define the term work function.
- II. Why does an increase in the intensity of light not increase the maximum kinetic energy of photoelectrons?
- III. A metal surface has a work function of 2 eV. Light of frequency 1.2×10^{15} Hz falls on it. Which statement is correct?
 - A. No electron is emitted because the intensity is low.
 - B. Electrons are emitted with maximum kinetic energy less than 2 eV.
 - C. Electrons are emitted with maximum kinetic energy greater than 0 eV.
 - D. Electron emission depends only on the intensity of light and not on the frequency.
- IV. Which observation(s) directly contradict the classical wave theory of light?
 - A. Photoelectric current increases with intensity.
 - B. The maximum kinetic energy depends only on the frequency and not on the intensity.
 - C. The electrons are emitted instantaneously.
 - D. Both B and C.

ANSWER AND SOLUTION

- I. The work function ϕ_0 of a metal is the minimum energy required to free an electron from the surface of the metal, i.e. the least energy a photon must supply for an electron to just escape with zero kinetic energy.
- II. Increasing the intensity increases the number of photons arriving per second, but not the energy of each photon, which depends only on the frequency ($E = h\nu$). Since each electron is emitted by absorbing a single photon, $K_{\max} = h\nu - \phi_0$ is unchanged; only the number of emitted electrons, and hence the photoelectric current, increases.

III. Correct option: C. Electrons are emitted with maximum kinetic energy greater than 0 eV.

$$E = h\nu \approx 4.14 \times 10^{-15} \times 1.2 \times 10^{15} \approx 5 \text{ eV}$$

$$K_{\max} = E - \phi_0 = 5 - 2 = 3 \text{ eV}$$

Since $K_{\max} = 3 \text{ eV}$, which is greater than zero (and not less than 2 eV), option C is the correct statement.

IV. Correct option: D. Both B and C.

Classical wave theory requires the energy of the emitted electrons to grow with intensity and predicts a measurable time lag while the electron accumulates enough energy. The observations that $K_{\max}$ depends only on frequency and that emission is instantaneous therefore both contradict it, and both follow from the photon picture.

MARKING SCHEME

(I) definition of work function — 1 · (II) intensity changes the number of photons, not the photon energy — 1 · (III) correct option (with $K_{\max} = 3 \text{ eV}$) — 1 · (IV) correct option — 1

SECTION E (3 × 5 = 15)

This section comprises 3 long answer type questions of 5 marks each.

Question 31 5 marks

(A)

- I. An isolated conductor cannot have a large capacitance. Why?
- II. How would you connect 6 μF , 9 μF and 18 μF capacitors to obtain (i) the minimum capacitance and (ii) the maximum capacitance?
- III. The capacitance of a parallel plate capacitor increases as the area of the plates increases. What are the other two factors on which the capacitance depends?

OR

- (B) I. Show that the electric field at any point is equal to the negative of the potential gradient at that point.
- II. A small metallic sphere is gradually charged in open air. It is observed that electrical breakdown of air occurs when the electric field at its surface reaches $2.5 \times 10^6 \text{ V m}^{-1}$. If the sphere is to attain a maximum potential of $5 \times 10^5 \text{ V}$ without causing any discharge, determine the minimum radius the insulated sphere must have.

ANSWER AND SOLUTION — 31 (A)

- I. For an isolated spherical conductor of radius R ,

$$C = 4\pi\epsilon_0 R$$

Since ϵ_0 is a constant, the capacitance of an isolated conductor is fixed by its size alone. To obtain even a capacitance of 1 F the radius would have to be about $9 \times 10^9 \text{ m}$, which is far larger than the Earth. A conductor of practicable size therefore has a very small capacitance.

- II. (i) The capacitance is least when the capacitors are joined in series:

$$\frac{1}{C_{\min}} = \frac{1}{6} + \frac{1}{9} + \frac{1}{18} = \frac{3+2+1}{18} = \frac{6}{18} = \frac{1}{3}$$

$$C_{\min} = 3 \mu\text{F}$$

- (ii) The capacitance is greatest when they are joined in parallel:

$$C_{\max} = 6 + 9 + 18 = 33 \mu\text{F}$$

- III. The capacitance of a parallel plate capacitor also depends on

- (i) the separation between the plates, $C \propto \frac{1}{d}$;
- (ii) the permittivity of the medium filling the space between the plates, $C \propto \epsilon$.

MARKING SCHEME

I: $C = 4\pi\epsilon_0 R$ with the reasoning that a large C needs an impracticably large size — 2 II: (i) series connection and $C_{\min} = 3 \mu\text{F}$ — 1 (ii) parallel connection and $C_{\max} = 33 \mu\text{F}$ — 1 III: separation d and permittivity ϵ — $\frac{1}{2} \times 2$

ANSWER AND SOLUTION — 31 (B)

- I. Consider a small positive test charge q placed in an electric field $\vec{E}$, and let it be displaced through a very small distance $d\vec{r}$.

Force on the charge:

$$\vec{F} = q\vec{E}$$

Work done by the field in this displacement:

$$dW = \vec{F} \cdot d\vec{r} = q\vec{E} \cdot d\vec{r} \dots (1)$$

By definition, the change in potential equals the negative of the work done by the field per unit charge:

$$dV = -\frac{dW}{q}$$

Using (1),



$$dV = -\frac{q\vec{E} \cdot d\vec{r}}{q} = -\vec{E} \cdot d\vec{r}$$

$$E = -\frac{dV}{dr}$$

That is, the electric field at any point equals the negative of the potential gradient at that point; the negative sign shows that the field points in the direction of decreasing potential.

II. For a charged sphere of radius r , the potential and the surface field are $V = \frac{1}{4\pi\epsilon_0} \frac{q}{r}$ and $E = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2}$, so that $V = Er$.

$$r = \frac{V}{E} = \frac{5 \times 10^5}{2.5 \times 10^6} = 0.2 \text{ m}$$

The sphere must therefore have a minimum radius of 0.2 m (20 cm).

MARKING SCHEME

$$I: dW = q\vec{E} \cdot d\vec{r} = 1 \cdot dV = -\frac{dW}{q} = 1 \cdot E = -\frac{dV}{dr} \text{ with interpretation } -1 \quad II: V = Er = 1 \cdot r = 0.2 \text{ m} = 1$$

Question 32 5 marks

(A) A compound microscope consists of an objective lens of focal length 2 cm and an eyepiece of focal length 5 cm. The object is placed 2.2 cm from the objective lens.

- Calculate the position of the image formed by the objective lens.
- The eyepiece is so placed that the final image is formed at infinity. Find the magnifying power of the microscope.
- Explain briefly why the compound microscope provides much higher magnification compared to a simple magnifier.

OR

(B) An astronomical telescope uses an objective lens of focal length 100 cm and an eyepiece of focal length 5 cm.

- Calculate the magnifying power of the telescope when the final image is formed at infinity.
- If the least distance of distinct vision of the observer is 25 cm, calculate the magnifying power when the final image is formed at this distance.
- Explain why the objective lens of an astronomical telescope is made with a large focal length and aperture, while the eyepiece has a small focal length.

ANSWER AND SOLUTION – 32 (A)

I. For the objective, $f_o = 2$ cm and $u_o = -2.2$ cm. Using the lens formula,

$$\frac{1}{f_o} = \frac{1}{v_o} - \frac{1}{u_o}$$

$$\frac{1}{2} = \frac{1}{v_o} - \frac{1}{-2.2} \Rightarrow \frac{1}{v_o} = \frac{1}{2} - \frac{1}{2.2} = \frac{2.2 - 2}{4.4} = \frac{0.2}{4.4}$$

$$v_o = 22 \text{ cm}$$

The image formed by the objective lies 22 cm behind it, on the other side of the lens from the object.

II. With the final image at infinity, the magnifying power of a compound microscope is

$$M = \left(\frac{v_o}{u_o} \right) \left(\frac{D}{f_e} \right), \text{ where } D = 25 \text{ cm}$$

$$M = \left(\frac{22}{2.2} \right) \left(\frac{25}{5} \right) = 10 \times 5 = 50$$

III. A simple magnifier has only one lens, so the magnification is produced in a single stage and is limited. A compound microscope magnifies in two stages: the objective first forms a real, enlarged image of the very small

object, and the eyepiece then acts as a magnifier on that image. The total magnifying power is the product of the two magnifications, which is therefore far greater than that of a single lens.

MARKING SCHEME

I: lens formula with correct sign convention — $1 \cdot v_o = 22 \text{ cm} — 1$ II: $M = \left(\frac{v_o}{u_o} \right) \left(\frac{D}{f_e} \right) — 1 \cdot M = 50 — 1$ III: magnification in two stages, product of the two — 1

ANSWER AND SOLUTION — 32 (B)

Given: $f_o = 100 \text{ cm}$, $f_e = 5 \text{ cm}$, $D = 25 \text{ cm}$.

I. For normal adjustment (final image at infinity),

$$M = \frac{f_o}{f_e} = \frac{100}{5} = 20$$

II. When the final image is formed at the least distance of distinct vision,

$$M = \frac{f_o}{f_e} \left(1 + \frac{f_e}{D} \right) = \frac{100}{5} \left(1 + \frac{5}{25} \right) = 20 \times 1.2 = 24$$

III. The magnifying power of a telescope is $\frac{f_o}{f_e}$, so a large f_o and a small f_e together give a high magnification. A large aperture of the objective is needed as well, because it gathers more light from faint distant objects, making the image brighter, and it also improves the resolving power of the telescope.

MARKING SCHEME

I: $M = \frac{f_o}{f_e} = 20 — 2$ II: $M = \frac{f_o}{f_e} \left(1 + \frac{f_e}{D} \right) = 24 — 2$ III: large f_o and small f_e for magnification, large aperture for brightness and resolution — 1

Question 33 5 marks

(A)

- I. A certain electrical device is used to convert an alternating voltage of smaller magnitude into a much larger alternating voltage without violating the law of conservation of energy. With the help of a neat labelled diagram, describe the principle on which this device operates and explain how it increases the voltage.
- II. State the basic working mechanism of the device and mention the condition required in its input signal for proper functioning.
- III. Give one reason why this device does not operate with 100% efficiency in practical situations.

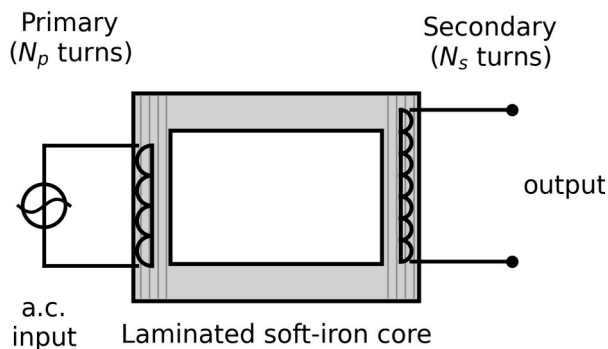
OR

(B)

- I. What do you mean by the resonance condition of a series LCR circuit? Write an expression for the resonant frequency.
- II. Describe the use of a series resonant circuit in the tuning of a radio receiver.

ANSWER AND SOLUTION — 33 (A)

- I. The device is a step-up transformer.



Principle — mutual induction: when an alternating current flows in the primary coil it sets up a time-varying magnetic flux in the laminated soft-iron core. The core carries almost the whole of this flux to the secondary coil, where the changing flux induces an alternating emf by Faraday's law.

For an ideal transformer the flux per turn is the same in both coils, so

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

If $N_s > N_p$, then $V_s > V_p$ and the device steps the voltage up.

There is no violation of conservation of energy, because for an ideal transformer

$$\text{input power} = \text{output power, i.e. } V_p I_p = V_s I_s$$

so the current in the secondary falls in exactly the same ratio in which the voltage rises.

II. Working mechanism: the primary is fed with an alternating voltage, which produces an alternating magnetic flux in the core; this changing flux links the secondary and induces an alternating emf in it. Energy is thus transferred from the primary to the secondary entirely through the changing flux in the core, with no electrical connection between the two windings.

Condition on the input: the input must be alternating current. With direct current the flux is steady, there is no change of flux, and no emf is induced in the secondary.

III. Any one of the following: copper (winding resistance) losses, eddy current losses in the core, hysteresis loss in the core, or flux leakage between the coils. Because of such losses the output power is always less than the input power, so the efficiency is less than 100%.

MARKING SCHEME

I: identification as a step-up transformer with a correct labelled diagram — 1 · principle of mutual induction — $\frac{1}{2} \cdot \frac{V_s}{V_p} = \frac{N_s}{N_p}$ with $N_s > N_p$ — $\frac{1}{2} \cdot V_p I_p = V_s I_s$, no violation of energy conservation — 1 II: working mechanism and the requirement of an a.c. input — 1 III: any one loss correctly named — 1

ANSWER AND SOLUTION — 33 (B)

I. A series LCR circuit contains a resistor R , an inductor L and a capacitor C joined in series across an a.c. source. The circuit is said to be in resonance when the inductive reactance becomes equal to the capacitive reactance:

$$X_L = X_C \Rightarrow \omega_0 L = \frac{1}{\omega_0 C}$$

At resonance the net reactance $X = X_L - X_C = 0$, so the impedance falls to its minimum value $Z = R$, the current is maximum for the given applied voltage, and the current is in phase with the voltage — the circuit behaves as a purely resistive one.

From $\omega_0 L = \frac{1}{\omega_0 C}$ the resonant angular frequency is $\omega_0 = \frac{1}{\sqrt{LC}}$, so the resonant frequency is

$$f_0 = \frac{\omega_0}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

II. Each radio station transmits electromagnetic waves of a definite frequency. The input stage of a radio receiver contains a series resonant (LCR) circuit in which the inductance is fixed and the capacitance is made variable.

By adjusting the variable capacitor, the resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$ is made equal to the frequency of the desired station. For that frequency the impedance of the circuit is minimum, so the current — and hence the signal voltage developed — is maximum.

Signals of all other frequencies are far from resonance, meet a much larger impedance and produce only very small currents, so they are effectively rejected. In this way the receiver is tuned to one particular station.

MARKING SCHEME

I: resonance condition $X_L = X_C$ — 1 · consequences ($Z = R$ minimum, current maximum) — 1 · $f_0 = \frac{1}{2\pi\sqrt{LC}}$ — 1 II:

variable C tuned so that f_0 equals the station frequency — 1 · minimum impedance, maximum current for that station and rejection of others — 1

