CBSE Class 12 Physics Board Paper 2026 (55/3/1) with Solutions

PREVIOUS YEAR PAPER · CLASS XII · PHYSICS (042) · BOARD EXAM 2026 · Q.P. CODE 55/3/1

TIME ALLOWED	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
3 hours	70	33 (A 16 · B 5 · C 7 · D 2 · E 3)	

GENERAL INSTRUCTIONS

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 33 questions. All questions are compulsory.
2. This question paper is divided into five sections – Sections A, B, C, D and E.
3. In Section A – Questions no. 1 to 16 are Multiple Choice type questions. Each question carries 1 mark.
4. In Section B – Questions no. 17 to 21 are Very Short Answer type questions. Each question carries 2 marks.
5. In Section C – Questions no. 22 to 28 are Short Answer type questions. Each question carries 3 marks.
6. In Section D – Questions no. 29 and 30 are Case Study-based questions. Each question carries 4 marks.
7. In Section E – Questions no. 31 to 33 are Long Answer type questions. Each question carries 5 marks.
8. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the Sections except Section A.
9. Use of calculators is not allowed.
10. You may use: $c = 3 \times 10^{8}$ m/s; $h = 6.63 \times 10^{-34}$ J s; $e = 1.6 \times 10^{-19}$ C; $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1}; $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}; $1/(4\pi\varepsilon_0) = 9 \times 10^{9}$ N m^2 C^{-2}; mass of electron 9.1×10^{-31} kg; mass of neutron 1.675×10^{-27} kg; mass of proton 1.673×10^{-27} kg; Avogadro's number 6.023×10^{23} per gram mole; Boltzmann's constant 1.38×10^{-23} J K^{-1}.
11. This is the official 2026 board paper (Q.P. Code 55/3/1). The step marks shown in the solutions are our marking scheme in the CBSE style; CBSE's own marking scheme may award steps differently.
12. The answer key and the marking scheme are at the end of this booklet. Attempt the paper in 3 hours before you look at them.

Questions: CBSE board examination 2026, Q.P. Code 55/3/1, as published by CBSE at cbse.gov.in; figures redrawn. Answers, step marks and worked solutions © Master Testing Agency. Free for personal practice; not for resale. Master Testing Agency is an independent test-prep publisher, not affiliated with, endorsed by or connected to the Central Board of Secondary Education (CBSE) or any other exam-conducting body.

Chapters: Full syllabus · **Topics:** Electric Charges and Fields · Electrostatic Potential and Capacitance · Current Electricity · Moving Charges and Magnetism · Magnetism and Matter · Electromagnetic Induction · Alternating Current · Electromagnetic Waves · Ray Optics · Wave Optics · Dual Nature of Radiation and Matter · Atoms · Nuclei · Semiconductor Electronics

SECTION A

Multiple choice questions of 1 mark each (Q13–16 assertion-reason).

1. A particle of mass m and charge q starts from rest and moves in an electric field $\mathbf{E} = E_0 \hat{i}$. After travelling a distance x in the field along x-axis, the kinetic energy of the particle will be : 1

(A) $q E_0 x^2$ (B) $q E_0 x$

(C) $q^2 E_0 x$ (D) $q^2 E_0^2 x$

2. A square loop of side 50 cm is placed in a uniform magnetic field of 3·0 T acting perpendicular to the plane of the loop. If the loop is rotated through an angle of 90° in 0·3 s, the value of emf induced in the loop would be : 1

Options : (A) 0·25 V (B) 0·50 V (C) 0·75 V (D) 1·0 V

3. A plane electromagnetic wave travels through a medium and the magnetic field associated with it is given by 1

$B = 5 \times 10^{-8} \sin (3 \times 10^{10} t - 150 x)$ T

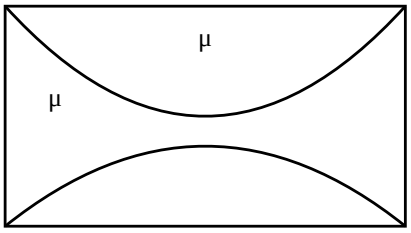
where x is in metres and t is in seconds.

The velocity of the wave is :

(A) $2{\cdot}0 \times 10^8$ ms^{-1} (B) $4{\cdot}5 \times 10^7$ ms^{-1}

(C) $3{\cdot}5 \times 10^7$ ms^{-1} (D) $2{\cdot}5 \times 10^8$ ms^{-1}

4. A thin plano-convex lens and a thin equi-concave lens are kept coaxially in contact as shown in the figure. Assuming both the lenses are made of glass of refractive index μ, and R is the radius of curvature of each curved surface, the focal length of the combination is : 1



(A) $\frac{R}{\mu - 1}$ (B) $-\frac{R}{\mu - 1}$

(C) $\frac{2R}{\mu - 1}$ (D) $-\frac{2R}{\mu - 1}$

5. The phase difference between the two superimposing waves that give rise to a bright spot in a Young's double-slit experiment is (n is an integer) : 1

(A) $2n\pi$ (B) $2n\pi + \frac{\pi}{4}$

(C) $2n\pi + \frac{\pi}{2}$ (D) $2n\pi + \pi$

6. A telescope has an objective lens of focal length 144 cm and an eyepiece of focal length 6·0 cm. The magnifying power and the length of telescope tube will be respectively : 1

(A) 24, 150 cm (B) 42, 138 cm

(C) 24, 138 cm (D) 42, 150 cm

7. In which of the following, total internal reflection does ***not*** occur ? 1

(A) Twinkling of stars (B) Brilliance of diamonds

(C) Optical fibre (D) Reflecting prism

8. Radiation of wavelength 200 nm is incident on a photosensitive surface of work function 4·2 eV. The kinetic energy of fastest photoelectrons emitted from this surface will be close to : 1

(A) 3·5 eV (B) 3·0 eV

(C) 2·5 eV (D) 2·0 eV

9. A proton and an alpha particle have equal momentum. The ratio of their kinetic energies (E_p/E_a) and de Broglie wavelengths associated with them (λ_p/λ_a) respectively are : 1

(A) 2, 1 (B) 1, 2

(C) 4, 1 (D) 1, 4

10. If r_1 and r_2 are the radii of atomic nuclei of mass numbers 64 and 27 respectively, then the value of $(\frac{r_1}{r_2})$ is : 1

(A) 1 (B) $\frac{4}{3}$

(C) $\frac{3}{4}$ (D) $\frac{27}{64}$

11. When the forward bias voltage in a semiconductor diode is changed from 0·8 V to 1·0 V, the forward current changes by 2·0 mA. The forward bias resistance of the diode will be : 1

(A) 200 Ω (B) 175 Ω

(C) 100 Ω (D) 125 Ω

12. The process named ‘minority carrier injection’ in a p-n junction diode occurs during : 1

(A) forward biasing (B) reverse biasing

(C) no biasing at low temperature (D) no biasing at high temperature

13. **Assertion (A) :** In a Wheatstone bridge circuit, if we interchange the position of the cell and the galvanometer, the balance condition $\frac{P}{Q} = \frac{R}{S}$ remains unchanged. 1

Reason (R) : $\frac{P}{Q} = \frac{R}{S} \Rightarrow \frac{Q}{S} = \frac{P}{R}$ so balance condition remains same.

(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.

14. **Assertion (A) :** The cylindrical soft iron core in a moving coil galvanometer only makes the magnetic field radial and does not affect the strength of the magnetic field. 1

Reason (R) : In a moving coil galvanometer, the plane of the coil is always perpendicular to the magnetic field.

(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.

15. **Assertion (A) :** Photoelectric current depends upon the intensity of the incident radiation. 1

Reason (R) : Stopping potential is independent of the intensity of the incident radiation.

(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.

16. **Assertion (A) :** Nuclear forces are always attractive. 1

Reason (R) : The nuclear force between protons and neutrons in a nucleus is a weak force.

(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).

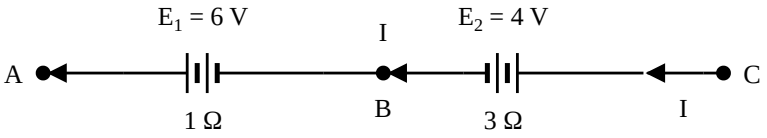
(C) Assertion (A) is true, but Reason (R) is false.

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

SECTION B

Very short answer (VSA) questions of 2 marks each.

17. (a) In the given figure, a steady current I flows through the circuit when points A and C are connected by a wire of negligible resistance. Find the potential difference between points B and C. 2



OR

(b) A battery of emf 21 V and internal resistance 3 Ω is connected to a resistor. If the current in the circuit is 3 A, find :
(i) the resistance of the resistor.
(ii) the terminal voltage of the battery.

18. Explain why diffraction of sound is more common in daily experience than that of light. 2

19. Explain the terms mass defect and binding energy. How are they related ? 2

20. A particle of mass M at rest splits up into two particles of masses m_1 and m_2 having non-zero velocities. Calculate the ratio of the de Broglie wavelengths associated with the two particles. 2

21. How are charge carriers created in an intrinsic semiconductor ? Explain. 2

SECTION C

Short answer (SA) questions of 3 marks each.

22. (a) Establish the relation between drift velocity of electrons (v_d) and electric current (I) in a conductor. 3
(b) How is v_d affected when the length of the conductor is doubled, keeping the voltage applied across the conductor constant ?

23. (a) A circular coil of 30 turns and radius 8·0 cm carrying a current of 6 A is suspended vertically in a uniform horizontal magnetic field of 1·0 T. The field lines make an angle of 30° with the plane of the coil. Calculate the magnitude of the external torque that must be applied to prevent the coil from turning. What would happen if the circular coil is replaced by a planar coil of irregular shape that encloses the same area, keeping other parameters unchanged ? 3

OR

(b) An alpha particle (mass $6{\cdot}4 \times 10^{-27}$ kg and charge $3{\cdot}2 \times 10^{-19}$ C) having 8·0 MeV energy, enters a region of a uniform magnetic field of 0·5 T. If the field is directed perpendicular to the velocity of the particle, find the radius of the circular path described by the particle. Mention the condition under which the particle in this region (i) describes a helical path, and (ii) goes straight undeviated.

24. (a) Discuss the behaviour of an inductor connected to (i) a dc source, and (ii) a high frequency ac source. 3
(b) What is the phase relation between current and voltage in an ideal inductor connected to an ac source ? Draw a phasor diagram for the circuit.

25. (a) Depict the variation of electric field (**E**) and magnetic field (**B**) with respect to the direction of propagation of an electromagnetic wave. Write their two important characteristics. 3

(b) Show that $\frac{1}{\sqrt{\varepsilon_0 \mu_0}}$ gives the velocity of an electromagnetic wave in free space.

26. A ray of light is travelling through a rectangular glass slab (refractive index $\frac{3}{2}$) and is incident on the horizontal glass-air surface at the critical angle for the two media. The slab is then brought in contact with water (refractive index $\frac{4}{3}$) such that a thin horizontal layer of water is formed on the surface of the slab. Find the angle at which the ray will emerge into air from the water-air surface. 3

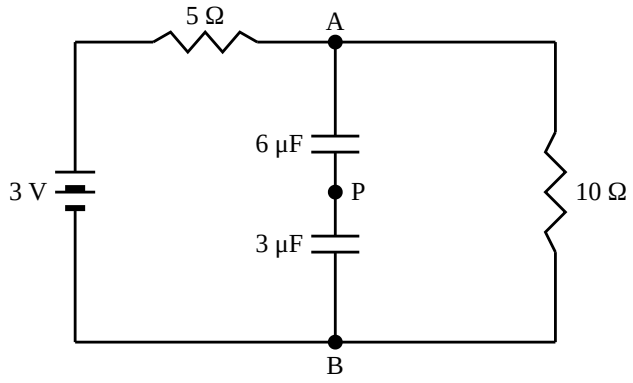
27. Differentiate between nuclear fission and nuclear fusion. Give one example for each with nuclear reaction. 3

28. With the help of circuit diagrams, briefly explain the forward biasing and the reverse biasing of a p-n junction diode. 3

SECTION D

Case study based questions of 4 marks each.

29. Capacitors are manufactured with certain standard capacitances and working voltages. However, these standard values may not be the ones that are actually needed in a particular application. Two or more capacitors can be grouped in series or in parallel to achieve desired capacitance and voltage. When connected in series, the total capacitance decreases while the voltage rating increases, whereas in parallel connections, the total capacitance increases and maintains the same voltage rating. A capacitor stores energy in the electric field between its plates and stored energy is proportional to the square of the voltage and capacitance $U = \frac{1}{2}CV^2$, where symbols have their usual meanings.



Two capacitors, one of 3 μF and the other of 6 μF, are connected in series in the circuit as shown in the figure, for a long time.

(i) The total capacitance of the circuit is :
(A) 6 μF (B) 3 μF (C) 9 μF (D) 2 μF [1]

(ii) The current in the 10 Ω resistor is :
(A) 0·3 A (B) 0·6 A (C) 0·2 A (D) 0 [1]

(iii) The potential difference between point A and B is :
(A) 2 V (B) 0·3 V (C) 0·2 V (D) 3 V [1]

(iv) The value of charge on the plates of the 6 μF capacitor is :
(A) 6 μC (B) 4 μC (C) 12 μC (D) 8 μC [1]

OR

(iv) The wire between two capacitors is cut at point P. The current in the circuit will :
(A) increase (B) decrease (C) remain the same (D) first increase then become stable [1]

30. A charged particle +q in an electric field **E** experiences a force in the direction of the electric field. As a result, its kinetic energy changes. Similarly, the charged particle also experiences a force when it moves in a magnetic field **B**. But this magnetic force is perpendicular to both velocity **v** of the charged particle and the magnetic field **B**, so it cannot change the kinetic energy of the charged particle. Consider two charged particles 1 and 2 of masses m and $\frac{m}{2}$ having charges − q and +2q respectively. They are accelerated from rest through the same potential difference V and acquire kinetic energy K_1 and K_2. Then they enter in a region of uniform magnetic field **B** perpendicular to their velocities.

(i) The ratio of their kinetic energies $(\frac{K_1}{K_2})$ is :

(A) $\frac{1}{2}$ (B) $\frac{1}{4}$ (C) 4 (D) 1 [1]

(ii) The ratio of the radii of the circular paths described by them $(\frac{r_1}{r_2})$ is :

(A) $\frac{1}{\sqrt{2}}$ (B) $\sqrt{2}$ (C) $\frac{1}{2}$ (D) 2 [1]

(iii) Suppose particles 1 and 2 enter the magnetic field $\mathbf{B} = B_0 \hat{k}$ with velocities $\mathbf{v}_1 = v_1 \hat{\imath}$ and $\mathbf{v}_2 = v_2 \hat{\imath}$. Then :

(A) both particles revolve clockwise (B) both particles revolve anticlockwise (C) particle 1 revolves clockwise while particle 2 revolves anticlockwise (D) particle 1 revolves anticlockwise while particle 2 revolves clockwise [1]

(iv) If period of revolution for particle 1 is 4 s, then for particle 2, the period will be :

(A) 1 s (B) 2 s (C) 4 s (D) 8 s [1]

OR

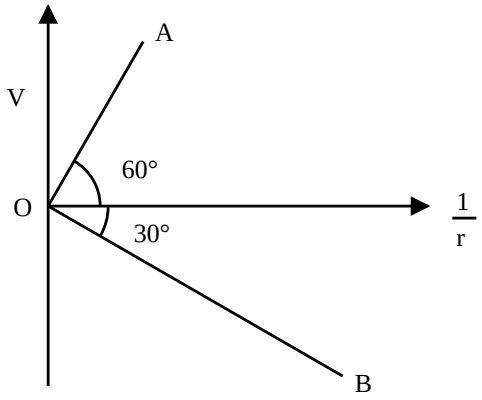
(iv) If the value of momentum for particles 1 and 2 are p_1 and p_2, then :

(A) $p_1 = \frac{p_2}{2}$ (B) $p_1 = p_2$ (C) $p_1 = 2p_2$ (D) $p_1 = 4p_2$ [1]

SECTION E

Long answer (LA) questions of 5 marks each.

31. (a) (i) In the figure, OA and OB show the variation of electric potential V at a point due to two point charges Q_1 and Q_2 with $\frac{1}{r}$ respectively. Here r represents the distance of the point from the two point charges. 5



(I) Identify the nature of the two charges Q_1 and Q_2.

(II) What is the value of $(\frac{Q_1}{Q_2})$? Justify your answer.

(ii) Two point charges − 2 μC and 5 μC are placed at (− 30 cm, 0) and (30 cm, 0) respectively in an external electric field $\mathbf{E} = \frac{A}{x^2}\,\hat{\imath}$, where $A = 9 \times 10^5\ Nm^2\ C^{-1}$. Find the electrostatic potential energy of this configuration.

OR

(b) (i) Two infinitely long straight wires having linear charge densities − λ and 3λ are held vertically parallel to each other, distance r apart in free space. Find the nature and magnitude of the force/length exerted by one wire on the other.

(ii) A small hollow conducting sphere of radius r_1 is given a charge Q. It is surrounded by a concentric conducting spherical shell of inner radius r_2 and outer radius r_3, having charge − 3q.

If a point charge 2q were kept at the centre, find :

(I) the electric flux through a concentric spherical Gaussian surface of radius x for (1) $x < r_1$, and (2) $r_1 < x < r_2$.

(II) electric field at a point distant x from the centre for (1) $x > r_3$, and (2) $r_1 < x < r_2$.

(III) surface charge density on the inner surface of (1) sphere, and (2) shell.

32. (a) (i) A light bulb and an open coil inductor are connected in series across an ac source of variable frequency. How will the glow of the bulb be affected when : 5

(I) an iron bar is inserted inside the coil, and

(II) the frequency of the source is decreased ?

Justify your answers. Assume that in each above case other factors remain unchanged.

(ii) An ac voltage V = 280 sin (100π t) volt is connected across a series LCR circuit in which R = 400 Ω, L = $\frac{5}{\pi}$ H and C = $\frac{50}{\pi}$ μF. Taking $\sqrt{2}$ = 1·4, calculate :

(I) impedance of the circuit.

(II) rms value of current that flows in the circuit.

(III) power factor of the circuit.

OR

(b) (i) State Lenz's law and explain that it follows the law of conservation of energy.

(ii) Write the dimensional formula for self-inductance.

The current in a coil changes from 8·0 A to 2·0 A in 0·6 s. If an average emf induced in the coil is 50 V, calculate the self-inductance of the coil.

33. (a) (i) A point object is kept in front of a convex spherical surface of radius of curvature R. Draw the ray diagram to show the formation of image and derive the relation between the object and image distance (u and v) in terms of refractive index n of the medium and R. 5

(ii) A convex lens of focal length of 20 cm is used to form the image of an object placed 30 cm away from the lens. Find the position and nature of the image formed.

OR

(b) (i) Two thin converging lenses of focal length f_1 and f_2 are placed coaxially in contact. Derive expression for the focal length of the combination.

(ii) A beam of coherent light of wavelength 550 nm is incident normal to the plane of a pair of two slits S_1 and S_2 each of width $1{\cdot}2 \times 10^{-6}$ m separated by 1·1 mm. Dark and bright fringes are observed on a screen 2·2 m away from the plane of the slits.

Calculate :

(I) fringe width.

(II) distance of the second dark fringe from the central maximum.

(III) what will happen when the entire apparatus is immersed in water.

END OF THE QUESTION PAPER

ANSWER KEY — SECTION A

Q1	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
(B)	(A)	(B)	(A)	(A)	(A)	(D)	(C)	(B)	(C)	(A)	(A)	(D)	(B)	(D)

MARKING SCHEME AND WORKED SOLUTIONS

Marks for each step are shown in brackets, as in the CBSE marking scheme. Any correct alternative method earns full marks.

Q1. Answer (B). Work done by the field = force × distance = $qE_0 \times x$, which equals the kinetic energy gained from rest.

Q2. (1 marks) Answer: 2.5 V by the printed data (none of the options); 0.25 V, option (A), if the field is 0·3 T.
Initial flux $\Phi = BA = 3.0 \times (0.50)^2 = 0.75$ Wb; after turning through 90° the plane is along the field and $\Phi = 0$. Average emf = $\Delta\Phi/\Delta t = 0.75/0.3 = 2.5$ V. [½]
None of the printed options is 2.5 V (both the English and the Hindi text print 3·0 T). With a field of 0·3 T the answer would be 0.25 V, option (A), which is probably what was intended. Write the working and check CBSE's marking scheme for the option it accepted. [½]

Q3. Answer (A). $v = \omega/k = (3 \times 10^{10})/150 = 2.0 \times 10^{8}$ m s^{-1}.

Q4. Answer (B). Plano-convex: $1/f_1 = (\mu - 1)/R$. Equi-concave: $1/f_2 = -2(\mu - 1)/R$. In contact: $1/F = 1/f_1 + 1/f_2 = -(\mu - 1)/R$, so $F = -R/(\mu - 1)$.

Q5. Answer (A). Constructive interference (a bright spot) needs a phase difference of an even multiple of π: $2n\pi$.

Q6. Answer (A). In normal adjustment $m = f_0/f_e = 144/6 = 24$ and the tube length $L = f_0 + f_e = 150$ cm.

Q7. Answer (A). Twinkling of stars is due to atmospheric refraction (a changing refractive index of the air). The other three use total internal reflection.

Q8. Answer (D). $E = hc/\lambda = 1240$ eV nm/200 nm ≈ 6.2 eV. K_max = 6.2 − 4.2 = 2.0 eV.

Q9. Answer (C). $E = p^2/2m$: with equal p, E_p/E_α = m_α/m_p = 4. $\lambda = h/p$: equal momenta give equal wavelengths, ratio 1.

Q10. Answer (B). $R = R_0A^{(1/3)}$: $r_1/r_2 = (64/27)^{(1/3)} = 4/3$.

Q11. Answer (C). $r = \Delta V/\Delta I = 0.2$ V/2.0 mA = 100 Ω.

Q12. Answer (A). In forward bias holes from the p-side enter the n-side (where they are minority carriers) and electrons from the n-side enter the p-side: minority carrier injection.

Q13. Answer (A). After the interchange the balance condition reads Q/S = P/R (equivalently P/R = Q/S), and this follows from P/Q = R/S (both say PS = QR). So the balance is unaffected and R explains A. Answer (A).

Q14. Answer (D). The soft iron core both makes the field radial and increases its strength: A is false. In a radial field the plane of the coil is always parallel to the field lines (the normal is perpendicular to B): R is false. Answer (D).

Q15. Answer (B). Both are true: more intensity means more photoelectrons per second, while the stopping potential depends only on frequency. R does not explain A. Answer (B).

Q16. Answer (D). The nuclear force is attractive beyond about 0.8 fm but strongly repulsive at smaller separations: A is false. It is the strongest force in nature: R is false. Answer (D).

Q17. (2 marks) Answer: (a) $V_B - V_C = -5.5$ V; (b) 4 Ω, 12 V.
(a) As drawn, the positive terminal of E_1 faces A and that of E_2 faces C, so the cells oppose each other. With A joined to C: $I = (6 - 4)/(1 + 3) = 0.5$ A, flowing from C to B to A through the cells, as the arrows show. [1]
Going from C to B through E_2 (from its + to its − terminal) and the 3 Ω in the direction of the current: $V_B = V_C - 4 - 0.5 \times 3$, so $V_B - V_C = -5.5$ V (C is 5.5 V higher than B). [1]
OR (b) (i) $I = E/(R + r)$: $3 = 21/(R + 3)$, so $R + 3 = 7$ and $R = 4$ Ω. [1]
(ii) $V = E - Ir = 21 - 3 \times 3 = 12$ V ($= IR = 3 \times 4$). [1]

Q18. (2 marks) Answer: λ of sound ~ size of everyday obstacles; λ of light is far smaller.
Diffraction is noticeable only when the size of the obstacle or opening is comparable to the wavelength. [1]
Sound has wavelengths of about 1 cm to 15 m, the size of doors, windows and walls, so it bends round them easily. Light has wavelengths of about 400–700 nm, far smaller than everyday objects, so its diffraction is rarely noticed. [1]

Q19. (2 marks) Answer: $E_b = \Delta M\, c^2$.
Mass defect: the mass of a nucleus is less than the total mass of its separate nucleons; $\Delta M = [Zm_p + (A - Z)m_n] - M$. [1]
Binding energy: the energy needed to separate a nucleus completely into its nucleons (equally, the energy released when it forms). They are related by $E_b = \Delta M\, c^2$. [1]

Q20. (2 marks) Answer: 1 : 1.
Momentum is conserved: initial momentum is zero, so $m_1v_1 = m_2v_2$ in magnitude (opposite directions): $p_1 = p_2$. [1]
$\lambda = h/p$, so $\lambda_1/\lambda_2 = p_2/p_1 = 1$. [1]

Q21. (2 marks) Answer: thermal generation of electron-hole pairs.
At room temperature some covalent bonds break because of thermal energy; the freed electron becomes a conduction electron and leaves a vacancy, a hole, with an effective positive charge. [1]
Electrons and holes are thus created in pairs, so $n_e = n_h = n_i$; a neighbouring bound electron can fill a hole, so holes also move and carry current. [1]

Q22. (3 marks) Answer: $I = neAv_d$; v_d is halved.
(a) Let n be the number of free electrons per unit volume and A the cross-section. In time Δt the electrons within a length $v_d\Delta t$ cross a section: charge $\Delta q = neAv_d\Delta t$. [1]
$I = \Delta q/\Delta t = neAv_d$. [1]
(b) $v_d = eE\tau/m = eV\tau/(mL)$. With V constant, doubling L halves E and hence halves v_d. [1]

Q23. (3 marks) Answer: (a) ≈ 3.1 N m; the same for any shape of equal area; (b) r = 0.8 m.
(a) The field makes 30° with the plane, so the angle θ between the normal to the coil and B is 60°. $\tau = NIAB \sin\theta$. [1]
$\tau = 30 \times 6 \times \pi(0.08)^2 \times 1.0 \times \sin 60° = 30 \times 6 \times 0.0201 \times 0.866 \approx 3.1$ N m: an equal and opposite external torque must be applied. [1]
The torque depends only on N, I, the area A and B, not on the shape, so a planar coil of any shape with the same area needs the same torque. [1]
OR (b) $K = 8.0$ MeV $= 8.0 \times 10^6 \times 1.6 \times 10^{-19} = 1.28 \times 10^{-12}$ J; $p = \sqrt{(2mK)} = \sqrt{(2 \times 6.4 \times 10^{-27} \times 1.28 \times 10^{-12})} = 1.28 \times 10^{-19}$ kg m s^{-1}. [1]
$r = p/(qB) = 1.28 \times 10^{-19}/(3.2 \times 10^{-19} \times 0.5) = 0.8$ m. [1]
(i) Helical path: the velocity has components both along and perpendicular to B (angle between v and B other than 0°, 90°, 180°). (ii) Undeviated: v is parallel or antiparallel to B (the force $qv \times B$ is zero). [½ + ½]

Q24. (3 marks) Answer: short at dc, nearly open at high frequency; I lags V by π/2.
(a) (i) With steady dc, once the current is established there is no change of flux and no back emf; an ideal inductor offers no opposition ($X_L = 0$ at $\omega = 0$) and behaves like a plain wire. [1] (ii) $X_L = \omega L$ is very large at high frequency, so the inductor almost blocks the current (behaves nearly as an open circuit). [1]
(b) The current lags the voltage by π/2. Phasor diagram: V along the reference direction and I drawn 90° behind it (clockwise from V for anticlockwise rotation). [1]

Q25. (3 marks) Answer: E ⊥ B ⊥ direction of travel, in phase; $c = 1/\sqrt{(\mu_0\varepsilon_0)} \approx 3 \times 10^8$ m/s.
(a) Diagram: for a wave along z, E oscillates along x and B along y, both sinusoidal and in phase. [1]
Characteristics: E and B are perpendicular to each other and to the direction of propagation (transverse wave); they oscillate in phase with $E_0/B_0 = c$. [1]
(b) In free space the speed is $v = E_0/B_0 = c$. Putting in $\mu_0 = 4\pi \times 10^{-7}$ T m A^{-1} and $\varepsilon_0 = 8.854 \times 10^{-12}$ C^2 N^{-1} m^{-2}: $1/\sqrt{(\mu_0\varepsilon_0)} = 1/\sqrt{(1.113 \times 10^{-17})} \approx 3.0 \times 10^8$ m s^{-1}, the measured speed of light; Maxwell's equations give the wave speed as $1/\sqrt{(\mu_0\varepsilon_0)}$. [1]

Q26. (3 marks) Answer: 90° (grazing the surface).
Critical angle for glass–air: $\sin C = 1/1.5 = 2/3$. [1]
The surfaces are parallel, so n sin(angle) is the same in each layer: $1.5 \times (2/3) = (4/3) \sin r = 1 \times \sin e$. In water $\sin r = 3/4$ ($r \approx 48.6°$), so the ray enters the water. [1]
At the water–air surface $\sin e = 1$: $e = 90°$. The ray emerges grazing along the water-air surface. [1]

Q27. (3 marks) Answer: fission splits a heavy nucleus; fusion joins light nuclei.
Fission: a heavy nucleus splits into two lighter nuclei of medium mass, releasing energy (and neutrons). Example: $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$ + about 200 MeV. [1½]
Fusion: light nuclei combine to form a heavier nucleus, releasing energy; it needs a very high temperature. Example: $^{2}_{1}H + {}^{2}_{1}H \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$ + 3.27 MeV. [1½]

Q28. (3 marks) Answer: forward: barrier lowered, large current; reverse: barrier raised, tiny current.
Forward bias: p-side to the positive terminal and n-side to the negative (diagram). The applied voltage opposes the barrier potential: the depletion layer narrows, the barrier falls to $V_0 - V$, majority carriers diffuse across and a large current (mA) flows. [1½]
Reverse bias: p-side to the negative terminal and n-side to the positive (diagram). The applied voltage adds to the barrier: the depletion layer widens, the barrier rises to $V_0 + V$, and only a tiny current (μA) of minority carriers flows until breakdown. [1½]

Q29. (4 marks) Answer: (i) D; (ii) C; (iii) A; (iv) B (OR: C).
(i) (D) In series: $1/C = 1/3 + 1/6 = 1/2$, $C = 2$ μF. [1]
(ii) (C) After a long time no current flows through the capacitors; the 3 V cell drives current through 5 Ω and 10 Ω in series: $I = 3/15 = 0.2$ A. [1]
(iii) (A) V_{AB} = V across 10 Ω = $0.2 \times 10 = 2$ V. [1]
(iv) (B) The series pair carries the same charge $Q = CV = 2\ \mu F \times 2\ V = 4\ \mu C$ on each. [1]
OR (iv) (C) No steady current flows in the capacitor branch, so cutting it at P leaves the current unchanged. [1]

Q30. (4 marks) Answer: (i) A; (ii) D; (iii) D; (iv) A (OR: B).
(i) (A) $K = |q|V$: $K_1 = qV$, $K_2 = 2qV$, so $K_1/K_2 = 1/2$. [1]
(ii) (D) $r = p/(|q|B) = \sqrt{(2mK)}/(|q|B)$. $p_1 = \sqrt{(2m \cdot qV)}$, $p_2 = \sqrt{(2(m/2)(2qV))} = p_1$, so $r_1/r_2 = |q_2|/|q_1| = 2$. [1]
(iii) (D) The force is $q\,v \times B$ with $v \times B = \hat{i} \times \hat{k} = -\hat{j}$. Viewed from the +z side (B pointing towards the viewer), the positive particle 2 revolves clockwise and the negative particle 1 anticlockwise. [1]
(iv) (A) $T = 2\pi m/(|q|B)$: $T_2/T_1 = (m/2)/(2q) \div (m/q) = 1/4$, so $T_2 = 1$ s. [1]
OR (iv) (B) $p = \sqrt{(2mK)}$: $p_1 = \sqrt{(2m \cdot qV)}$ and $p_2 = \sqrt{(2 \cdot (m/2) \cdot 2qV)} = \sqrt{(2mqV)}$, so $p_1 = p_2$. [1]

Q31. (5 marks) Answer: (a) Q_1 positive, Q_2 negative, $Q_1/Q_2 = -3$; U = 8.85 J; (b) $3\lambda^2/(2\pi\varepsilon_0 r)$, attractive; $2q/\varepsilon_0$, $(Q + 2q)/\varepsilon_0$; $(Q - q)/(4\pi\varepsilon_0 x^2)$, $(Q + 2q)/(4\pi\varepsilon_0 x^2)$; $-2q/(4\pi r_1^2)$, $-(Q + 2q)/(4\pi r_2^2)$.

(a) (i) V = kQ/r, so the slope of V against 1/r is kQ. (I) OA has a positive slope: Q_1 is positive; OB has a negative slope: Q_2 is negative. [1]

(II) Slope of OA = $\tan 60° = \sqrt{3}$; slope of OB = $-\tan 30° = -1/\sqrt{3}$. $Q_1/Q_2 = \sqrt{3}/(-1/\sqrt{3}) = -3$. [1]

(ii) The external field has magnitude A/r^2, so its potential at distance r is A/r (taking it as the radial field of this standard problem; both charges are 0.30 m away): $V = 9 \times 10^5/0.3 = 3 \times 10^6$ V. [1]

Energy in the external field: $q_1V + q_2V = (-2 \times 10^{-6} + 5 \times 10^{-6}) \times 3 \times 10^6 = -6 + 15 = 9$ J. Mutual energy: $kq_1q_2/d = 9 \times 10^9 \times (-2 \times 10^{-6})(5 \times 10^{-6})/0.6 = -0.15$ J. [1]

Total U = 9 − 0.15 = 8.85 J. [1]

OR (b) (i) Field of one wire at the other: $E = \lambda_1/(2\pi\varepsilon_0 r)$. Force per length = $\lambda_2 E = (\lambda)(3\lambda)/(2\pi\varepsilon_0 r) = 3\lambda^2/(2\pi\varepsilon_0 r)$. The charges are opposite, so the force is attractive. [2]

(ii) (I) (1) Only 2q is enclosed: $\Phi = 2q/\varepsilon_0$. (2) Q + 2q is enclosed: $\Phi = (Q + 2q)/\varepsilon_0$. [1]

(II) (1) Total enclosed Q + 2q − 3q = Q − q: $E = (Q - q)/(4\pi\varepsilon_0 x^2)$. (2) $E = (Q + 2q)/(4\pi\varepsilon_0 x^2)$. [1]

(III) (1) The inner surface of the sphere carries −2q (induced by 2q): $\sigma = -2q/(4\pi r_1^2)$. (2) The inner surface of the shell carries −(Q + 2q): $\sigma = -(Q + 2q)/(4\pi r_2^2)$. [1]

Q32. (5 marks) Answer: (a) dimmer; brighter; Z = 500 Ω, I_{rms} = 0.4 A, cos φ = 0.8; (b) $[ML^2T^{-2}A^{-2}]$, L = 5 H.

(a) (i) (I) The iron bar increases L, so $X_L = \omega L$ increases, the current falls and the bulb glows dimmer. [1] (II) Lowering the frequency lowers X_L, the current rises and the bulb glows brighter. [1]

(ii) ω = 100π: $X_L = 100\pi \times 5/\pi = 500$ Ω; $X_C = 1/(100\pi \times 50 \times 10^{-6}/\pi) = 200$ Ω. (I) $Z = \sqrt{(400^2 + 300^2)} = 500$ Ω. [1]

(II) $V_{rms} = 280/\sqrt{2} = 280/1.4 = 200$ V; $I_{rms} = 200/500 = 0.4$ A. [1]

(III) cos φ = R/Z = 400/500 = 0.8. [1]

OR (b) (i) Lenz's law: the induced current flows in a direction that opposes the change of flux producing it. [1]

If it aided the change, the current would grow by itself and give energy without work being done, violating energy conservation. Because it opposes, work must be done against it (for example in pushing a magnet towards a coil), and this work appears as electrical energy. [1½]

(ii) $L = \varepsilon/(dI/dt)$: $[M\,L^2\,T^{-2}\,A^{-2}]$. [1]

$L = |\varepsilon|\Delta t/|\Delta I| = 50 \times 0.6/6.0 = 5$ H. [1½]

Q33. (5 marks) Answer: (a) $n/v - 1/u = (n - 1)/R$; 60 cm behind the lens, real, inverted, magnified 2×; (b) $1/f = 1/f_1 + 1/f_2$; 1.1 mm; 1.65 mm; fringes narrower (≈ 0.83 mm).

(a) (i) Ray diagram: object O in air on the axis, a ray to a point N on the surface refracts towards the normal CN and meets the axis at the real image I in the medium (index n). [1]

For small angles $i = \alpha + \gamma$, $r = \gamma - \beta$ and Snell's law $i = nr$ give $\alpha + n\beta = (n - 1)\gamma$, with $\alpha = MN/OM$, $\beta = MN/MI$, $\gamma = MN/MC$. With the sign convention (OM = −u, MI = +v, MC = +R): $n/v - 1/u = (n - 1)/R$. [2]

(ii) $1/v = 1/f + 1/u = 1/20 - 1/30 = 1/60$: v = +60 cm, on the other side of the lens. m = v/u = −2: the image is real, inverted and twice the size. [2]

OR (b) (i) The first lens forms an image at v_1: $1/v_1 - 1/u = 1/f_1$. This image is the object for the second lens in contact: $1/v - 1/v_1 = 1/f_2$. [1½]

Adding: $1/v - 1/u = 1/f_1 + 1/f_2$, so the combination has $1/f = 1/f_1 + 1/f_2$. [1]

(ii) (I) $\beta = \lambda D/d = 550 \times 10^{-9} \times 2.2/(1.1 \times 10^{-3}) = 1.1 \times 10^{-3}$ m = 1.1 mm. [1]

(II) Dark fringes at $(2n - 1)\lambda D/2d$; the second (n = 2) is at $1.5\beta = 1.65$ mm. [½]

(III) In water λ becomes λ/n_w, so the fringe width shrinks by the factor 4/3: $\beta' = 1.1 \times 3/4 \approx 0.83$ mm; the fringes come closer together. [1]

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