CBSE Class 12 Physics Board Paper 2026 (55/5/1) with Solutions

PREVIOUS YEAR PAPER · CLASS XII · PHYSICS (042) · BOARD EXAM 2026 · Q.P. CODE 55/5/1

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 55/5/1). 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 55/5/1, 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. Two small identical metallic balls having charges q and – 2q are kept far at a separation r. They are brought in contact and then separated at distance $\frac{r}{2}$. Compared to the initial force F, they will now : 1

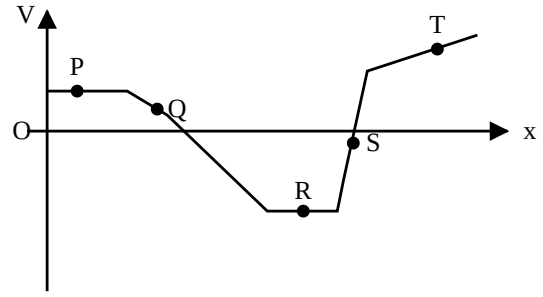
(A) attract with a force $\frac{F}{2}$

(B) repel with a force $\frac{F}{2}$

(C) repel with a force F

(D) attract with a force F

2. The figure represents the variation of the electric potential V at a point in a region of space as a function of its position along the x-axis. A charged particle will experience the maximum force at : 1



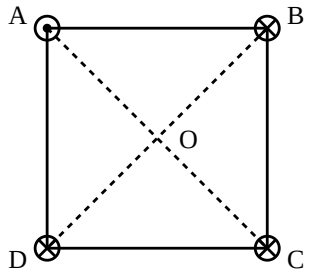
(A) P

(B) Q

(C) R

(D) S

3. Four long straight thin wires are held vertically at the corners A, B, C and D of a square of side ‘a’, kept on a table and carry equal current ‘I’. The wire at A carries current in upward direction whereas the current in the remaining wires flows in downward direction. The net magnetic field at the centre of the square will have the magnitude : 1



(A) $\frac{\mu_0 I}{\pi a}$ and directed along OC

(B) $\frac{\mu_0 I}{\pi a \sqrt{2}}$ and directed along OD

(C) $\frac{\mu_0 I \sqrt{2}}{\pi a}$ and directed along OB

(D) $\frac{2\mu_0 I}{\pi a}$ and directed along OA

4. The magnetic flux through a loop placed in a magnetic field can be changed by changing : 1

(A) area of the loop only

(B) the value of magnetic field only

(C) orientation of the loop in the magnetic field only

(D) any one or more of the factors given in (A), (B) and (C)

5. Which of the following statements is ***not*** true for electric energy in ac form compared to that in dc form ? 1

(A) Production of ac is economical.

(B) ac can be easily and efficiently converted from one voltage to the other.

(C) ac can be transmitted economically over long distances.

(D) ac is less dangerous.

6. The magnetic field in a plane electromagnetic wave travelling in glass (n = 1·5) is given by 1

$B_y = (2 \times 10^{-7}\ T) \sin(\alpha x + 1{\cdot}5 \times 10^{11}\ t)$

where x is in metres and t is in seconds. The value of α is :

(A) $0{\cdot}5 \times 10^{3}\ m^{-1}$

(B) $6{\cdot}0 \times 10^{2}\ m^{-1}$

(C) $7{\cdot}5 \times 10^{2}\ m^{-1}$

(D) $1{\cdot}5 \times 10^{3}\ m^{-1}$

7. Light of which of the following colours will have the maximum energy in a photon associated with it ? 1

(A) Red light

(B) Yellow light

(C) Green light

(D) Blue light

8. Nuclides with the same number of neutrons are called : 1

(A) Isobars

(B) Isotones

(C) Isotopes

(D) Isomers

9. The radius of a nucleus of mass number 125 is 1

(A) 6·0 fm

(B) 30 fm

(C) 72 fm

(D) 150 fm

10. The energy of an electron in an orbit in hydrogen atom is − 3·4 eV. Its angular momentum in the orbit will be : 1

(A) $\frac{3h}{2\pi}$

(B) $\frac{2h}{\pi}$

(C) $\frac{h}{\pi}$

(D) $\frac{h}{2\pi}$

11. A good diode checked by a multimeter should indicate : 1

(A) high resistance in reverse bias and a low resistance in forward bias

(B) high resistance in both forward bias and reverse bias

(C) low resistance in both reverse bias and forward bias

(D) high resistance in forward bias and low resistance in reverse bias

12. The rms and the average value of an ac voltage $V = V_0 \sin \omega t$ volt over a cycle respectively will be : 1

(A) $\frac{V_0}{2}, \frac{V_0}{\sqrt{2}}$

(B) $\frac{V_0}{\pi}, \frac{V_0}{2}$

(C) $\frac{V_0}{\sqrt{2}}, 0$

(D) $V_0, \frac{V_0}{\sqrt{2}}$

13. **Assertion (A) :** Induced emf produced in a coil will be more when the magnetic flux linked with the coil is more. 1

Reason (R) : Induced emf produced is directly proportional to the magnetic flux.

(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) :** In Young's double-slit experiment, the fringe width for dark and bright fringes is the same. 1

Reason (R) : Fringe width is given by $\beta = \frac{\lambda D}{d}$, where symbols have their usual meanings.

(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) :** Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion. 1

Reason (R) : For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei, it decreases with increasing Z.

(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) :** Photoelectric effect is a spontaneous phenomenon. 1

Reason (R) : According to the wave picture of radiation, an electron would take hours/days to absorb sufficient energy to overcome the work function and come out from a metal surface.

(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) An electric iron rated 2·2 kW, 220 V is operated at 110 V supply. Find : 2
(i) its resistance, and
(ii) heat produced by it in 10 minutes.

OR

(b) A current of 4·0 A flows through a wire of length 1 m and cross-sectional area 1·0 mm^2, when potential difference of 2 V is applied across its ends. Calculate the resistivity of the material of the wire.

18. A plane circular coil is rotated about its vertical diameter with a constant angular speed ω in a uniform horizontal magnetic field. Initially the plane of the coil is parallel to the magnetic field. Draw plots showing the variation of the following physical quantities as the function of ωt, where t represents time elapsed : 2
(a) Magnetic flux φ linked with the coil, and
(b) emf induced in the coil.

19. A tank is filled with a liquid to a height of 12·5 m. The apparent depth of a needle lying at the bottom of the tank is measured to be 9·0 m. Calculate the speed of light in the liquid. 2

20. Two thin lenses of focal length f_1 and f_2 are placed in contact with each other coaxially. Prove that the focal length f of the combination is given by $f = \frac{f_1 f_2}{f_1 + f_2}$. 2

21. Suppose a pure Si crystal has 5×10^{28} atoms per m^3. It is doped with 5×10^{22} atoms per m^3 of Arsenic. Calculate the majority and minority carrier concentration in the doped silicon. (Given : $n_i = 1{\cdot}5 \times 10^{16}\ m^{-3}$) 2

SECTION C

Short answer (SA) questions of 3 marks each.

22. Two parallel plate capacitors X and Y are connected in series to a 6 V battery. They have the same plate area and same plate separation but capacitor X has air between its plates, whereas capacitor Y contains a material of dielectric constant 4. 3
(a) Calculate the capacitances of X and Y, if the equivalent capacitance of the combination is 4 μF.
(b) Calculate the potential difference across the plates of X and Y.

23. Write the expression for the magnetic field due to a current element in vector form. Consider a 1 cm segment of a wire, centered at the origin, carrying a current of 10 A in positive x-direction. Calculate the magnetic field **B** at a point (1 m, 1 m, 0). 3

24. A long solenoid of length L and radius r_1 having N_1 turns is surrounded symmetrically by a coil of radius r_2 ($> r_1$) having N_2 turns ($N_2 << N_1$) around its mid-point. Derive an expression for the mutual inductance of solenoid and coil. Is $M_{12} = M_{21}$ valid in this case ? 3

25. What is displacement current (i_d) ? Considering the case of charging of a capacitor, show that $i_d = \varepsilon_0 \frac{d\varphi_E}{dt}$. What is the value of i_d for a conductor across which a constant voltage is applied ? 3

26. (a) (i) Write any two features of nuclear forces. 3

(ii) If both the number of protons and the neutrons are conserved in each nuclear reaction, in what way is mass converted into energy (or vice versa) in a nuclear reaction ? Explain.

OR

(b) (i) Draw the number of scattered particles versus the scattering angle graph for scattering of alpha particles by a thin foil. Write two important conclusions that can be drawn from this plot.

(ii) If Bohr's quantization postulate (angular momentum = $\frac{nh}{2\pi}$) is a basic law of nature, it should be equally valid for the case of planetary motion also. Why, then, do we never speak of quantization of orbits of planets around the Sun ? Explain.

27. Photoemission of electrons occurs from a metal ($\varphi_0 = 1{\cdot}96$ eV) when light of frequency $6{\cdot}4 \times 10^{14}$ Hz is incident on it. Calculate : 3

(a) Energy of a photon in the incident light,

(b) The maximum kinetic energy of the emitted electrons, and

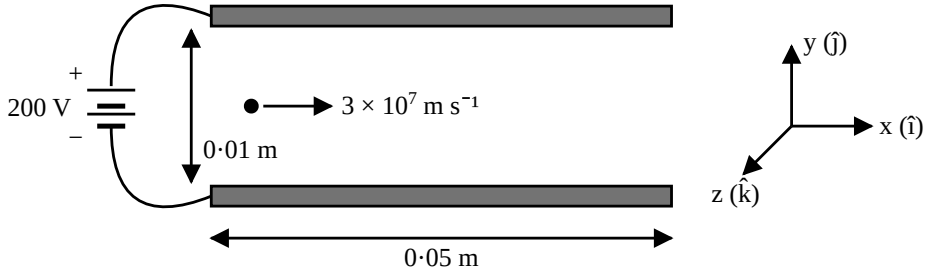
(c) The stopping potential.

28. Draw a circuit diagram of a full-wave rectifier using p-n junction diodes. Explain its working and show the input-output waveforms. 3

SECTION D

Case study based questions of 4 marks each.

29. The electric potential (V) and electric field (E) are closely related concepts in electrostatics. The electric field is a vector quantity that represents the force per unit charge at a given point in space, whereas electric potential is a scalar quantity that represents the potential energy per unit charge at a given point in space. Electric field and electric potential are related by the equations $E_r = -\frac{dV}{dr}$ and $\mathbf{E} = E_r \hat{r}$, i.e., electric field is the negative gradient of the electric potential. This means that electric field points in the direction of decreasing potential and its magnitude is the rate of change of potential with distance. The electric field is the force that drives a unit charge to move from higher potential region to lower potential region and electric potential difference between the two points determines the work done in moving a unit charge from one point to the other point.



A pair of square conducting plates having sides of length 0·05 m are arranged parallel to each other in x-y plane. They are 0·01 m apart along z-axis and are connected to a 200 V power supply as shown in the figure. An electron enters with a speed of 3×10^7 ms^{-1} horizontally and symmetrically in the space between the two plates. Neglect the effect of gravity on the electron.

(i) The electric field **E** in the region between the plates is :

(A) $(2 \times 10^2$ V/m) $\hat{k}$ (B) $-(2 \times 10^2$ V/m) $\hat{k}$ (C) $(2 \times 10^4$ V/m) $\hat{k}$ (D) $-(2 \times 10^4$ V/m) $\hat{k}$ [1]

(ii) In the region between the plates, the electron moves with an acceleration **a** given by :

(A) $-(3{\cdot}5 \times 10^{15}$ ms^{-2}) $\hat{k}$ (B) $(3{\cdot}5 \times 10^{15}$ ms^{-2}) $\hat{k}$ (C) $(3{\cdot}5 \times 10^{13}$ ms^{-2}) $\hat{i}$ (D) $-(3{\cdot}5 \times 10^{13}$ ms^{-2}) $\hat{i}$ [1]

(iii) Time interval during which an electron moves through the region between the plates is :

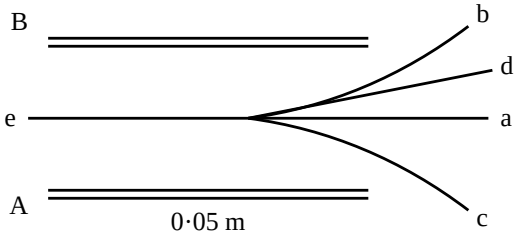
(A) $9{\cdot}0 \times 10^{-9}$ s (B) $1{\cdot}67 \times 10^{-8}$ s (C) $1{\cdot}67 \times 10^{-9}$ s (D) $2{\cdot}17 \times 10^{-9}$ s [1]

OR

(iii) The vertical displacement of the electron which travels through the region between the plates is :

(A) 10 mm (B) 4·9 mm (C) 5·9 mm (D) 3·0 mm [1]

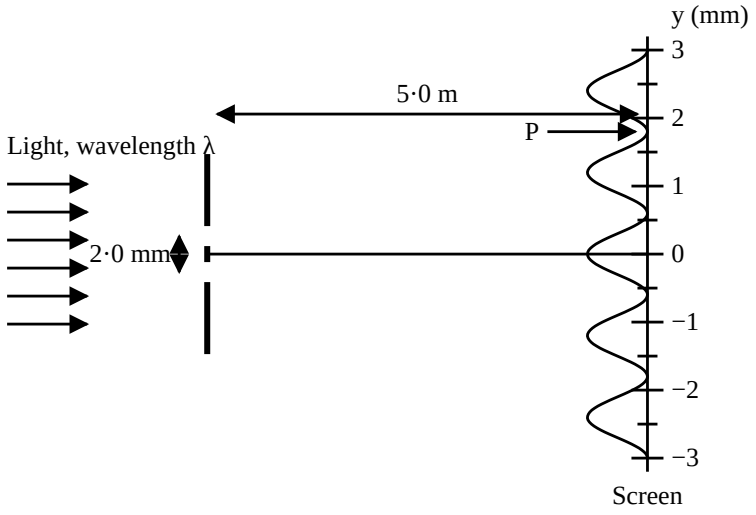
(iv) Which one of the following is the path traced by the electron in between the two plates ?



(A) a (B) b (C) c (D) d [1]

30. In a Young's double-slit experiment, the two slits behave as coherent sources. When coherent light waves superpose over each other they create an interference pattern of successive bright and dark regions due to constructive and destructive interference.

Two slits 2 mm apart are illuminated by a source of monochromatic light and the interference pattern is observed on a screen 5·0 m away from the slits as shown in the figure.



(i) What property of light does this interference experiment demonstrate ?

(A) Wave nature of light (B) Particle nature of light (C) Transverse nature of light (D) Both wave nature and transverse nature of light [1]

(ii) The wavelength of light used in this experiment is :

(A) 720 nm (B) 590 nm (C) 480 nm (D) 364 nm [1]

OR

(ii) The fringe width in the interference pattern formed on the screen is :

(A) 1·2 mm (B) 0·2 mm (C) 4·2 mm (D) 6·8 mm [1]

(iii) The path difference between the two waves meeting at point P, where there is a minimum in the interference pattern is :

(A) $8{\cdot}1 \times 10^{-7}$ m (B) $7{\cdot}2 \times 10^{-7}$ m (C) $6{\cdot}5 \times 10^{-7}$ m (D) $6{\cdot}0 \times 10^{-7}$ m [1]

(iv) When the experiment is performed in a liquid of refractive index greater than 1, then fringe pattern will :

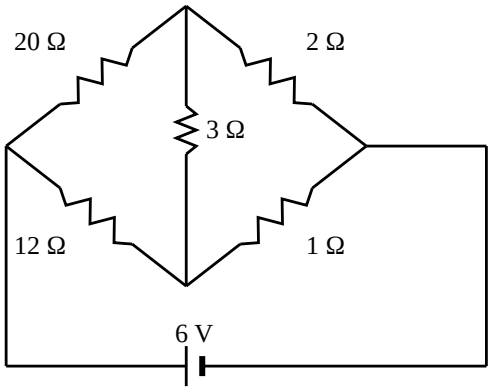
(A) disappear (B) become blurred (C) be widened (D) be compressed [1]

SECTION E

Long answer (LA) questions of 5 marks each.

31. (a) (i) Derive the condition for which a Wheatstone Bridge is balanced. 5

(ii) Determine the current in 3 Ω branch of a Wheatstone Bridge in the circuit shown in the figure.



OR

(b) (i) Consider a cylindrical conductor of length *l* and area of cross-section A. Current I is maintained in the conductor and electrons drift with velocity $\mathbf{v}_d$ ($|\mathbf{v}_d| = \frac{e|E|}{m}\tau$), (where symbols have their usual meanings). Show that the conductivity σ of the material of the conductor is given by $\sigma = \frac{ne^2}{m}\tau$.

(ii) The resistance of a metal wire at 20°C is 1·05 Ω and at 100°C is 1·38 Ω. Determine the temperature coefficient of resistivity of this metal.

32. (a) (i) A rectangular loop of sides a and b carrying current I is placed in a magnetic field **B** such that its area vector **A** makes an angle θ with **B**. With the help of a suitable diagram, show that the torque **τ** acting on the loop is given by **τ** = **m** × **B**, where **m** (= I **A**) is the magnetic dipole moment of the loop. 5

(ii) A circular coil of 100 turns and radius $\left(\frac{10}{\sqrt{\pi}}\right)$ cm carrying current of 5·0 A is suspended vertically in a uniform horizontal magnetic field of 2·0 T. The field makes an angle 30° with the normal to the coil. Calculate :

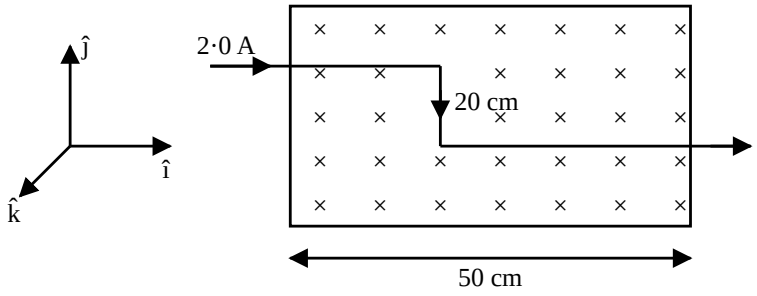
(I) the magnetic dipole moment of the coil, and

(II) the magnitude of the counter torque that must be applied to prevent the coil from turning.

OR

(b) (i) Derive an expression for the force **F** acting on a conductor of length L and area of cross-section A carrying current I and placed in a magnetic field **B**.

(ii) A part of a wire carrying 2·0 A current and bent at 90° at two points is placed in a region of uniform magnetic field $\mathbf{B} = -(0{\cdot}50\ \text{T})\ \hat{k}$, as shown in the figure. Calculate the magnitude of the net force acting on the wire.



33. (a) (i) A parallel beam of monochromatic light falls normally on a single slit of width ‘a’ and a diffraction pattern is observed on a screen placed at distance D from the slits. Explain : 5

(I) the formation of maxima and minima in the diffraction pattern, and

(II) why the maxima go on becoming weaker and weaker with its increasing number (n).

(ii) Write any two points of difference between interference pattern due to double-slit and diffraction pattern due to single-slit.

OR

(b) (i) With the help of a ray diagram, describe the construction and working of a compound microscope.

(ii) (I) The real image of an object placed between f and 2f from a convex lens can be seen on a screen placed at the image location. If the screen is removed, is the image still there ? Explain.

(II) Plane and convex mirrors produce virtual images of objects. Can they produce real images under some circumstances ? Explain.

END OF THE QUESTION PAPER

ANSWER KEY — SECTION A

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
(B)	(D)	(C)	(D)	(D)	(C)	(D)	(B)	(A)	(C)	(A)	(C)	(D)	(A)	(C)	(B)

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). Initially $F = k(2q^2)/r^2$, attractive. On contact the total $-q$ is shared: $-q/2$ each. At $r/2$: $k(q^2/4)/(r^2/4) = kq^2/r^2 = F/2$, and like charges repel.

Q2. Answer (D). $E = -dV/dx$: the force is largest where the V–x graph is steepest, at S.

Q3. Answer (C). Each wire is $a/\sqrt{2}$ from O and gives $B_0 = \mu_0 I/(2\pi \cdot a/\sqrt{2}) = \mu_0 I/(\sqrt{2}\pi a)$. Seen from above, the fields of B and D (both downward currents, opposite corners) cancel; those of A (upward) and C (downward) both point along OB. Net $B = 2B_0 = \sqrt{2}\mu_0 I/(\pi a)$, along OB.

Q4. Answer (D). $\Phi = BA\cos\theta$: changing B, A or θ (any one or more) changes the flux.

Q5. Answer (D). ac at the same voltage is more dangerous than dc (its peak is $\sqrt{2}$ times the rms value and it can cause muscle spasm). The other three are advantages of ac.

Q6. Answer (C). $v = c/n = 2 \times 10^8$ m $s^{-1} = \omega/\alpha$, so $\alpha = 1.5 \times 10^{11}/(2 \times 10^8) = 7.5 \times 10^2$ m^{-1}.

Q7. Answer (D). $E = hc/\lambda$: blue has the shortest wavelength of the four, so the most energetic photons.

Q8. Answer (B). Same N: isotones (same Z: isotopes; same A: isobars).

Q9. Answer (A). $R = R_0 A^{\wedge}(1/3) = 1.2$ fm $\times 5 = 6.0$ fm.

Q10. Answer (C). $E_n = -13.6/n^2 = -3.4$ eV gives n = 2. $L = nh/2\pi = 2h/2\pi = h/\pi$.

Q11. Answer (A). A working diode conducts one way: low resistance in forward bias, high in reverse bias.

Q12. Answer (C). $V_rms = V_0/\sqrt{2}$; the average of a sine over a full cycle is 0.

Q13. Answer (D). $\varepsilon = -d\Phi/dt$ depends on the rate of change of flux, not on the flux itself: a large steady flux induces nothing. Both A and R are false. Answer (D).

Q14. Answer (A). Bright fringes are at $n\lambda D/d$ and dark ones at $(n + \tfrac{1}{2})\lambda D/d$: both are spaced $\lambda D/d$ apart. R gives this common width and explains A. Answer (A).

Q15. Answer (C). A is true. R has the trend the wrong way round: binding energy per nucleon decreases with mass number for heavy nuclei and increases for light nuclei, which is why both fission and fusion release energy. Answer (C).

Q16. Answer (B). Emission is instantaneous (A is true). R correctly states what the wave picture predicts, but that prediction fails; the instant emission is explained by photons, not by R. Answer (B).

Q17. (2 marks) Answer: (a) 22 Ω, 3.3×10^5 J; (b) 5×10^{-7} Ω m.
(a) (i) $R = V^2/P = 220^2/2200 = 22$ Ω. [1]
(ii) At 110 V: $P = 110^2/22 = 550$ W; $H = Pt = 550 \times 600 = 3.3 \times 10^5$ J. [1]
OR (b) $R = V/I = 2/4.0 = 0.5$ Ω. [1]
$\rho = RA/l = 0.5 \times 1.0 \times 10^{-6}/1 = 5 \times 10^{-7}$ Ω m. [1]

Q18. (2 marks) Answer: $\varphi = NBA \sin \omega t$; $\varepsilon = -NBA\omega \cos \omega t$.
At t = 0 the plane is parallel to B, so the flux is zero: $\varphi = NBA \sin \omega t$, a sine curve starting from 0 with peaks NBA at $\omega t = \pi/2, 3\pi/2$. [1]
$\varepsilon = -d\varphi/dt = -NBA\omega \cos \omega t$: a (negative) cosine curve, maximum in magnitude ($NBA\omega$) when $\varphi = 0$ and zero when φ is maximum. [1]

Q19. (2 marks) Answer: 2.16×10^8 m/s.
n = real depth/apparent depth = 12.5/9.0 ≈ 1.39. [1]
$v = c/n = 3 \times 10^8 \times 9.0/12.5 = 2.16 \times 10^8$ m s^{-1}. [1]

Q20. (2 marks) Answer: $1/f = 1/f_1 + 1/f_2$.
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: $1/v - 1/v_1 = 1/f_2$. [1]
Adding: $1/v - 1/u = 1/f_1 + 1/f_2 = 1/f$, so $f = f_1f_2/(f_1 + f_2)$. [1]

Q21. (2 marks) Answer: electrons 5×10^{22} m^{-3}; holes 4.5×10^9 m^{-3}.
Each As atom gives one free electron: majority carriers (electrons) $n_e \approx 5 \times 10^{22}$ m^{-3}. [1]
Minority carriers (holes) $n_h = n_i^2/n_e = (1.5 \times 10^{16})^2/(5 \times 10^{22}) = 4.5 \times 10^9$ m^{-3}. [1]

Q22. (3 marks) Answer: 5 μF, 20 μF; 4.8 V, 1.2 V.
(a) C_X = C, C_Y = 4C. In series: C·4C/(5C) = 4C/5 = 4 μF, so C = 5 μF: C_X = 5 μF, C_Y = 20 μF. [1½]
(b) Q = 4 μF × 6 V = 24 μC on each. V_X = 24/5 = 4.8 V, V_Y = 24/20 = 1.2 V. [1½]

Q23. (3 marks) Answer: ≈ 3.5×10^{-9} T along +z.
Biot–Savart law: $dB = (\mu_0/4\pi)\, I\, (dl \times r)/r^3$. [1]
$dl = 0.01\ \hat{i}$ m, $r = \hat{i} + \hat{j}$ m, $r = \sqrt{2}$ m; $dl \times r = 0.01\ (\hat{i} \times \hat{j}) = 0.01\ \hat{k}$. [1]
$dB = 10^{-7} \times 10 \times 0.01\ \hat{k}/(\sqrt{2})^3 = 10^{-8}/2.83\ \hat{k} \approx 3.5 \times 10^{-9}$ T $\hat{k}$ (along +z). [1]

Q24. (3 marks) Answer: $M = \mu_0 N_1 N_2 \pi r_1^2/L$; yes.
A current I_1 in the solenoid gives $B = \mu_0 N_1 I_1/L$ inside it and (ideally) zero outside, so the flux through each turn of the outer coil is $B \times \pi r_1^2$ (only the solenoid's cross-section). [1]
$N_2\Phi_2 = N_2(\mu_0 N_1 I_1/L)\pi r_1^2 = M\, I_1$, so $M = \mu_0 N_1 N_2 \pi r_1^2/L$. [1]
Yes: $M_{12} = M_{21}$ holds for any pair of coils (reciprocity); the same M is obtained by passing current through the outer coil. [1]

Q25. (3 marks) Answer: $i_d = \varepsilon_0\, d\varphi_E/dt$; zero.
Displacement current is the current associated with a changing electric field (flux); it makes the current continuous through regions where no charge flows, such as the gap of a charging capacitor. [1]
In the gap $E = q/(\varepsilon_0 A)$, so $\varphi_E = EA = q/\varepsilon_0$ and $\varepsilon_0\, d\varphi_E/dt = dq/dt = i$: the displacement current in the gap equals the conduction current in the wires: $i_d = \varepsilon_0\, d\varphi_E/dt$. [1½]
With a constant voltage the field is steady ($d\varphi_E/dt = 0$), so $i_d = 0$. [½]

Q26. (3 marks) Answer: (a) $Q = \Delta m\, c^2$ from the change in binding energy; (b) n is enormous for planets.
(a) (i) Nuclear forces are much stronger than the Coulomb force; they are short-ranged (negligible beyond a few fm); they are charge-independent (n–n, p–p, n–p alike); they are attractive above about 0.8 fm and repulsive below it. [1]
(ii) The total binding energies of the nuclei before and after the reaction differ. The mass defects differ by Δm, and this difference appears as energy $Q = \Delta m\, c^2$: the masses of the nuclei (not the number of nucleons) change. [2]
OR (b) (i) Graph: N very large at small θ and falling steeply ($\propto 1/\sin^4(\theta/2)$); very few particles near 180°. Conclusions: most of the atom is empty space; the positive charge and nearly all the mass are concentrated in a tiny nucleus. [1½]
(ii) For the Earth the angular momentum is about 10^{40} J s, so $n \approx 10^{74}$. The spacing between allowed orbits and energies is then so small compared with the values that they form a continuum; quantisation cannot be noticed. [1½]

Q27. (3 marks) Answer: ≈ 2.65 eV; ≈ 0.69 eV; ≈ 0.69 V.
(a) $E = h\nu = 6.63 \times 10^{-34} \times 6.4 \times 10^{14} = 4.24 \times 10^{-19}$ J ≈ 2.65 eV. [1]
(b) K_max = 2.65 − 1.96 ≈ 0.69 eV (≈ 1.1×10^{-19} J). [1]
(c) V_0 = K_max/e ≈ 0.69 V. [1]

Q28. (3 marks) Answer: both half-cycles rectified.
Circuit: centre-tapped transformer secondary; diode D_1 from one end and D_2 from the other, both to the load R_L, which returns to the centre tap. [1]
When end A is positive D_1 conducts (D_2 reverse biased); in the next half-cycle B is positive and D_2 conducts. The current through R_L is in the same direction in both half-cycles. [1]
Waveforms: sine input; output a train of positive half-sine pulses, one per half-cycle. [1]

Q29. (4 marks) Answer: (i) D; (ii) B; (iii) C (OR: B); (iv) B.
(i) (D) $E = V/d = 200/0.01 = 2 \times 10^4$ V/m, pointing from the positive (upper) plate to the negative plate. Taking the upper plate at the larger z, as the key does, $E = -(2 \times 10^4 \text{ V/m})\,\hat{k}$. (The text puts the separation along z but the figure shows it vertical; with the positive plate at the lower z the answers to (i) and (ii) would be (C) and (A).) [1]
(ii) (B) $a = eE/m = 1.6 \times 10^{-19} \times 2 \times 10^4/(9.1 \times 10^{-31}) \approx 3.5 \times 10^{15}$ m s^{-2}, opposite to E (towards the positive plate): $+\hat{k}$. [1]
(iii) (C) $t = 0.05/(3 \times 10^7) = 1.67 \times 10^{-9}$ s. [1]
OR (iii) (B) $y = \tfrac{1}{2}at^2 = \tfrac{1}{2} \times 3.5 \times 10^{15} \times (1.67 \times 10^{-9})^2 \approx 4.9 \times 10^{-3}$ m = 4.9 mm (just less than the 5 mm half-gap, so it comes out). [1]
(iv) (B) Between the plates the force is constant and towards the positive plate (B, the upper one), so the path is a parabola curving towards it: b. [1]

Q30. (4 marks) Answer: (i) A; (ii) C (OR: A); (iii) B; (iv) D.
From the screen scale: central maximum at 0, minima at ±0.6 mm and ±1.8 mm, maxima at ±1.2 mm and ±2.4 mm: the fringe width is 1.2 mm and P (1.8 mm) is the second minimum.
(i) (A) interference shows the wave nature of light (it says nothing about transverse waves). [1]
(ii) (C) $\lambda = \beta d/D = 1.2 \times 10^{-3} \times 2 \times 10^{-3}/5.0 = 4.8 \times 10^{-7}$ m = 480 nm. [1]
OR (ii) (A) β = 1.2 mm. [1]
(iii) (B) At the second minimum the path difference is $3\lambda/2$ = 720 nm = 7.2×10^{-7} m. [1]
(iv) (D) In the liquid λ becomes λ/n, so $\beta = \lambda D/d$ shrinks: the fringes are compressed. [1]

Q31. (5 marks) Answer: (a) P/Q = R/S; 12/821 A ≈ 14.6 mA; (b) $\sigma = ne^2\tau/m$; $\alpha \approx 3.9 \times 10^{-3}$ °C^{-1}.
(a) (i) Bridge of arms P, Q, R, S with a galvanometer between B and D. At balance I_g = 0, so B and D are at the same potential and the same current I_1 flows in P and Q, I_2 in R and S. [1]
Loop rule: $I_1P = I_2R$ and $I_1Q = I_2S$. Dividing: P/Q = R/S. [1]
(ii) Here 20/2 = 10 ≠ 12/1 = 12, so the bridge is not balanced and current flows in 3 Ω. Take the right junction at 0 V and the left at +6 V (the positive plate of the cell faces left); top node x, bottom node y. [1]
Top: $(6 - x)/20 = x/2 + (x - y)/3$, that is $53x - 20y = 18$. Bottom: $(6 - y)/12 + (x - y)/3 = y/1$, that is $4x - 17y = -6$. So x = 426/821 V, y = 390/821 V. [1]
Current in 3 Ω = (x − y)/3 = 12/821 A ≈ 0.0146 A (about 14.6 mA), from the top junction to the bottom junction. [1]
OR (b) (i) $I = neAv_d = neA(eE/m)\tau = (ne^2\tau/m)AE$. [1½]
With E = V/l: $I = (ne^2\tau/m)(A/l)V$, so $R = V/I = (m/(ne^2\tau))(l/A) = \rho l/A$, $\rho = m/(ne^2\tau)$ and $\sigma = 1/\rho = ne^2\tau/m$. [1½]
(ii) $\alpha = (R_2 - R_1)/[R_1(T_2 - T_1)] = (1.38 - 1.05)/(1.05 \times 80) = 0.33/84 \approx 3.9 \times 10^{-3}$ °C^{-1}. [2]

Q32. (5 marks) Answer: (a) m = 5 A m², τ = 5 N m; (b) F = IL × B, ≈ 0.54 N.

(a) (i) Diagram: loop with sides a (perpendicular to B) and b, normal at angle θ to B. The forces on the two sides of length b are equal, opposite and collinear (they cancel). The forces on the sides of length a are each IaB, equal and opposite but separated by b sin θ: a couple. [1½]

τ = IaB × b sin θ = IAB sin θ = mB sin θ, directed so that τ = m × B with m = IA. [1½]

(ii) A = πr² = π × (0.1/√π)² = 0.01 m². (I) m = NIA = 100 × 5.0 × 0.01 = 5 A m². [1] (II) τ = mB sin 30° = 5 × 2.0 × 0.5 = 5 N m. [1]

OR (b) (i) Each electron (drift velocity v_d) feels $-e(v_d \times B)$. The conductor holds nAL of them: $F = nAL(-e)(v_d \times B)$. With I = neA$v_d$ and L along the current: F = I L × B (magnitude ILB sin θ). [2]

(ii) In a uniform field the force on a bent wire equals that on a straight wire joining its ends. Inside the field the wire goes 50 cm along +x and 20 cm along −y: $L_{eff} = (0.50\,\hat{i} - 0.20\,\hat{j})$ m, $|L_{eff}| = \sqrt{0.29} \approx 0.54$ m. [1½]

F = I$|L_{eff}|$B (L_{eff} is perpendicular to B) = 2.0 × 0.54 × 0.50 ≈ 0.54 N. [1½]

Q33. (5 marks) Answer: see the model answers.

(a) (i) (I) Divide the slit into parts. At θ = 0 all secondary wavelets arrive in phase: central maximum. At a sin θ = nλ the slit can be split into 2n parts whose contributions cancel pairwise: minima. At a sin θ = (n + ½)λ one part is left uncancelled: secondary maxima. [2]

(II) For the nth secondary maximum only 1/(2n + 1) of the slit contributes uncancelled, so the intensity falls as n increases. [1]

(ii) Interference fringes are (nearly) equally spaced and equally bright; diffraction has a central maximum twice as wide as the others and maxima of rapidly decreasing intensity. Interference results from two coherent sources; diffraction from wavelets from different points of one wavefront. [2]

OR (b) (i) Diagram: objective (short f_0) forms a real, inverted, magnified image A′B′ of an object just beyond its focus; the eyepiece, acting as a magnifier, forms a virtual magnified final image (at the near point or at infinity). $m = m_0 m_e \approx (L/f_0)(D/f_e)$. [3]

(ii) (I) Yes. The rays still converge at that position and diverge from it; the screen only scatters the light so that we can see it. An eye placed beyond the image can see it in air. [1] (II) Yes: if rays converging towards a point behind the mirror (a virtual object) fall on it, a plane or convex mirror can bring them to a real image in front of it. [1]

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