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CBSE Class 12 Physics Board Paper 2026 (55/2/1) with Solutions

PREVIOUS YEAR PAPER · CLASS XII · PHYSICS (042) · BOARD EXAM 2026 · Q.P. CODE 55/2/1

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. Question paper is divided into FIVE sections – Sections A, B, C, D and E.
3. In Section A : Question numbers 1 to 16 are Multiple Choice (MCQ) type questions. Each question carries 1 mark.
4. In Section B : Question numbers 17 to 21 are Very Short Answer (VSA) type questions. Each question carries 2 marks.
5. In Section C : Question numbers 22 to 28 are Short Answer (SA) type questions. Each question carries 3 marks.
6. In Section D : Question numbers 29 & 30 are Case Study-Based questions. Each question carries 4 marks.
7. In Section E : Question numbers 31 to 33 are Long Answer (LA) 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 calculator 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; $1/(4\pi\varepsilon_0) = 9 \times 10^{9}$ 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 55/2/1). 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 55/2/1, 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. Three point charges 2q, −2q and q are kept at the vertices of an equilateral triangle of side *l*. The potential energy of the system is 1

(A) zero

(B) $\frac{-2q^2}{\pi\varepsilon_0 l}$

(C) $\frac{q^2}{2\pi\varepsilon_0 l}$

(D) $\frac{-q^2}{\pi\varepsilon_0 l}$

2. Two metal spheres of radii r_1 and r_2 ($> r_1$) having charges q_1 and q_2 respectively kept in air, are brought in contact. Which of the following statements is <u>not</u> correct ? 1

(A) The total charge of the two spheres is conserved.

(B) Both spheres attain the same potential.

(C) The final potential of the system equals $\frac{1}{4\pi\varepsilon_0}\frac{(q_1+q_2)}{(r_1+r_2)}$

(D) The final potential of the system equals $\frac{1}{4\pi\varepsilon_0}\frac{(q_1+q_2)(r_1+r_2)}{r_1 r_2}$

3. The maximum kinetic energy of the electrons emitted from a photo sensitive surface depends on 1

(A) work function of the surface 'φ_0' only.

(B) frequency of the incident radiation 'ν' only.

(C) intensity of the incident radiation 'I' only.

(D) Both φ_0 and ν.

4. In Bohr model of hydrogen atom, for large values of n, the distance between the consecutive orbits is proportional to 1

(A) $\sqrt{n}$

(B) n

(C) n^2

(D) n^3

5. A straight long wire lying along y-axis, carries a current of 1 A along –y direction. The magnetic field due to the conductor at a point (50 cm, 0, 0) will point along. 1

(A) z-axis

(B) –z-axis

(C) *x*-axis

(D) –*x*-axis

6. Which of the following materials has positive and small value of magnetic susceptibility ? 1

(A) Cu

(B) A*l*

(C) Bi

(D) Ni

7. A galvanometer of resistance 27 Ω is converted into an ammeter of range (0 – 10 mA) using a resistance of 3 Ω. The galvanometer will show full scale deflection for a current of about – 1

(A) 10 mA

(B) 100 mA

(C) 1 mA

(D) 3 mA

8. The magnetic flux φ (in Wb) linked with a coil is related to time t (in s) as 1

$\varphi = 5\ At^2 + Bt - 2C$

The SI units of A and B are respectively

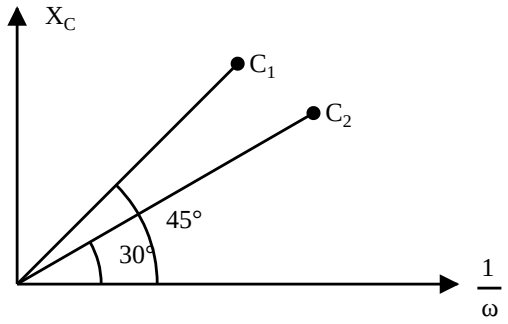
(A) Wbs^2, Wbs

(B) Wb s^{-1}, Wb

(C) Wbs^{-2}, Wbs^{-1}

(D) Wbs^{-1}, Wbs^{-2}

9. The figure shows the variation of capacitive reactance (X_C) of two ideal capacitors of capacitances C_1 & C_2 with the reciprocal of angular frequency ($1/\omega$) of ac source. The value of C_1/C_2 is 1



(A) $\frac{1}{2}$

(B) 2

(C) $\sqrt{3}$

(D) $\frac{1}{\sqrt{3}}$

10. A magnet held vertically, with its north pole down is dropped along the axis of a closed solenoid placed vertically on a table. If the observer looks down from the top, 1

(A) the induced current will flow in the anticlockwise direction.

(B) the induced current will flow in the clockwise direction.

(C) no induced current will flow in the solenoid.

(D) the magnet will fall with a constant velocity.

11. An electromagnetic wave is propagating along x-axis. At any instant, the phase difference (in radian) between the electric field (**E**) and the magnetic field (**B**) associated with the wave is 1

(A) zero

(B) $\frac{\pi}{4}$

(C) $\frac{\pi}{2}$

(D) π

12. In Bohr model of hydrogen atom, the electron makes a transition from n = 5 to n = 1 state. As a result, a photon of wavelength λ is emitted in the process. The wavelength of the photon emitted when an electron makes a transition from energy level n = 5 to n = 2 will be 1

(A) $\frac{8}{7}\lambda$

(B) $\frac{24}{7}\lambda$

(C) $\frac{16}{7}\lambda$

(D) $\frac{32}{7}\lambda$

13. **Assertion (A) :** On increasing the intensity of incident light of frequency $\nu(> \nu_0)$ on a photosensitive surface, the photocurrent increases. 1

Reason (R) : The stopping potential for a photosensitive surface increases with increase of frequency $\nu(> \nu_0)$ of incident light.

(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) :** On forward biasing a p-n junction diode, the height of the barrier potential increases. 1

Reason (R) : In forward biasing of a p-n junction diode, the direction of the applied voltage is in the same direction as the built-in potential.

(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) :** Light added to light can produce darkness. 1

Reason (R) : When two coherent light waves interfere, there is darkness at position of destructive interference.

(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) :** Two electric heaters of power P_1 and P_2 $(> P_1)$ are joined in series across a dc source of voltage V. The power consumed by the combination will be less than that consumed by P_1 when connected across the same source. 1

Reason (R) : The power consumed by a electric device when connected to a dc source of voltage V is proportional to its resistance.

(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. Write two points of difference between intrinsic and extrinsic semiconductors. 2

18. Find ratio (λ_a/λ_p) of the de Broglie wavelength λ_a and λ_p associated respectively with an alpha particle and a proton, 2

(i) if they are moving with the same kinetic energy.

(ii) just after they are accelerated through the same potential difference.

19. A ray of light in air is incident at angle ∠i on a face of an equilateral glass prism and is refracted through the prism. As ∠i is varied, it is observed that the ray undergoes minimum deviation, when the ∠i is three-fourth of the angle of the prism. Calculate the speed of light in the prism. 2

20. A heating element using nichrome is connected to a 220 V supply. Initially it draws a current of 2.9 A. After some time, the current attains a steady value of 2.5 A. Find the steady temperature of the heating element if the room temperature is 27 °C. The temperature coefficient of resistance of nichrome is $1.7 \times 10^{-4}\ °C^{-1}$. 2

21. (a) A 5 cm long pencil is placed along the principal axis of a concave mirror of focal length 20 cm such that its nearest end is at a distance of 25 cm from the mirror. Calculate the length of the image of the pencil. 2

OR

(b) In a Young's double-slit experiment, a beam of light consisting of two wavelengths 500 nm and 600 nm is used. The interference fringes are observed at a screen placed 1.8 m away from the plane of slits (slit separation 0.3 mm). Calculate the least distance from the central maximum where the bright fringes due to both the wavelengths coincide.

SECTION C

Short answer (SA) questions of 3 marks each.

22. (a) Consider the following nuclides : 3

$^{12}_{6}C$, $^{198}_{80}Hg$, $^{14}_{6}C$, $^{197}_{79}Au$

Group them into isotopes and isotones.

(b) How does the size of a nucleus depend on its mass number A ? Hence prove that the density of nucleus is a constant, independent of A, for all nuclei.

23. (a) An electric field $\mathbf{E} = E_0\,\hat{i}$ exists in a region of space. Draw three equipotential surfaces in the region. 3

(b) Two point charges –q and +q are located at points (–a, 0, 0) and (a, 0, 0) respectively. Find the electrostatic potential at point (x, 0, 0) where $x >> a$.

24. Name the electromagnetic waves which are used for 3

(i) detection of fractures in bones

(ii) physiotherapy

(iii) radar systems

Also write their wavelength range.

25. (a) (i) Define mutual inductance of a pair of coils. Write its SI unit. 3

(ii) A long solenoid of radius R and length L has n turns per unit length. A circular loop of radius r(<R) is placed inside at the centre of the solenoid such that its axis coincides with the axis of the solenoid. Obtain the mutual inductance of the solenoid and the loop.

OR

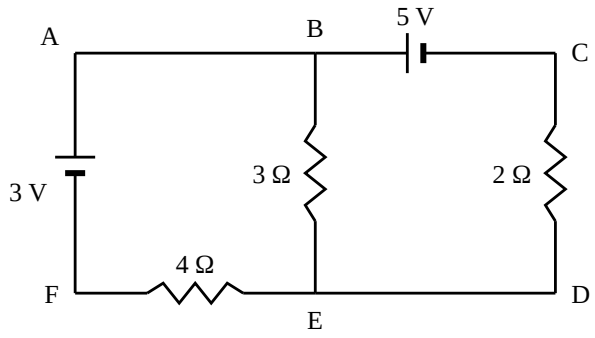
(b) Two long straight parallel conductors A and B carrying steady currents I_a and I_b in the same direction are separated by a distance d. Deduce the expressions for the force acting on length L of conductor B due to conductor A and show it in figure. Write the expression for the force acting on length L of conductor A due to conductor B and show that it follows Newton's third law.

26. (a) State Bohr's second postulate and mention its significance. 3

(b) Prove that, in Bohr model of hydrogen atom as principal quantum number n becomes large, the energy levels get closer and closer.

27. (a) Explain the statement : "Current is a scalar although we represent current with an arrow". 3

(b) Use Kirchhoff's rules to find the current through 3 Ω resistor in the circuit shown in the figure :



28. Derive an expression for the magnetic field **B**, due to a circular coil of N turns, each of radius r carrying current I, at a distance '*x*' from the centre along its axis. 3

SECTION D

Case study based questions of 4 marks each.

29. A p-type or n-type semiconductor can be converted into a p-n junction by doping it with suitable impurity. The motion of majority charge carriers causes diffusion current across the junction while the barrier electric field causes motion of minority carriers for drift current. In case of unbiased diode, the diffusion and drift currents are equal. This equilibrium is disturbed by the biasing batteries. Diodes, therefore, allow currents in one direction. This property of diode is used in making rectifiers.

(i) Silicon is doped with which of the following to obtain p-type semiconductor ?
(A) Phosphorus (B) Arsenic (C) Boron (D) Antimony [1]

(ii) A semiconductor has an electron concentration of $5 \times 10^{22}\ m^{-3}$. The concentration of holes is (given $n_i = 1.5 \times 10^{16}\ m^{-3}$)

(A) $5 \times 10^{22}\ m^{-3}$ (B) $1.5 \times 10^{6}\ m^{-3}$ (C) $9 \times 10^{8}\ m^{-3}$ (D) $4.5 \times 10^{9}\ m^{-3}$ [1]

(iii) During forward biasing of a p-n junction diode, the
(A) current is mainly due to drifting of majority carriers. (B) current is mainly due to drifting of minority carriers. (C) diffusion and drift currents are equal. (D) current is of the order of 1 A. [1]

(iv) The threshold voltage for silicon diode is about
(A) 0.2 V (B) 0.5 V (C) 0.7 V (D) 1.5 V [1]

OR

(iv) When we dope Ge with a pentavalent element, four of its electrons bond with four germanium neighbours but fifth electron remains weakly bound. The ionisation energy for this electron is about
(A) 0.01 eV (B) 0.05 eV (C) 0.1 eV (D) 0.15 eV [1]

30. In an experiment with convex lens of focal length f, the screen is fixed at a distance D from the object. A student slowly moves the lens away from the object towards the screen and finds that she is able to form sharp image of the object for two positions of the lens. The distance between these two positions of the lens is d.

(i) The value of d is
(A) $\sqrt{D(D-4f)}$ (B) $\sqrt{D(D-2f)}$ (C) $2\sqrt{Df}$ (D) $\sqrt{D(D-f)}$ [1]

(ii) Compared to the size of the object, the images formed in the two positions of the lens are respectively
(A) reduced, enlarged (B) reduced, reduced (C) enlarged, enlarged (D) enlarged, reduced [1]

(iii) If the distance between object and screen is 80.00 cm and the lens forms sharp images at two positions separated by 20.00 cm., the focal length of convex lens is
(A) 15.50 cm (B) 18.75 cm (C) 20.50 cm (D) 22.75 cm [1]

(iv) Consider a convex lens of focal length 15 cms. For which of the following values of object-screen distance, two positions of the object can be found to obtain sharp image on the screen ?
(A) 45 cm (B) 50 cm (C) 55 cm (D) 65 cm [1]

OR

(iv) A thin convex lens of focal length 10 cm and another thin lens of focal length ‘f ’ are placed coaxially in contact. If the power of their combination is $\frac{10}{3}$ D, the value of ‘f ’ is

(A) –15 cm (B) –10 cm (C) –20 cm (D) –30 cm [1]

SECTION E

Long answer (LA) questions of 5 marks each.

31. (a) (a) What are coherent sources ? Why they are necessary for observing stable interference pattern ? Draw a graph showing the variation of intensity of light with the position on the screen in Young's double-slit experiment. 5

(b) Find the intensity of light at a point on the screen when two interfering waves of the same intensity (I_0) have a path difference of (i) $\frac{\lambda}{4}$ and (ii) $\frac{\lambda}{3}$.

OR

(b) (a) Draw a labelled ray diagram of a refracting telescope when it forms image of a distant object at infinity. Derive expression for its magnifying power.

(b) (i) In a telescope the objective has much larger aperture than the eye piece. Why ?

(ii) Write two advantages of reflecting telescope over refracting telescope.

32. (a) (a) Derive an expression for the capacitance of a parallel plate capacitor of plate area A and plate separation d with air present between the plates. 5

(b) Two air-filled capacitors of capacitances C_1 and C_2 are connected in parallel with a dc battery. After the capacitors are fully charged, a slab of dielectric constant K is inserted between the plates of each capacitor. How will the (i) charge on each capacitor and (ii) energy stored in the capacitor affected after the slab is introduced.

OR

(b) (a) An electric field **E** is established across the ends of a cylindrical conductor of length L and area of cross-section A. Discuss how electrons attain an average velocity, independent of time. Hence, obtain a relation between current in the conductor and this 'average velocity' of electrons.

(b) (i) This 'average velocity' is found be few mm/s for currents in range of a few amperes. How then is current established almost the instant a circuit is closed ?

(ii) Two copper wires having their radii in the ratio of 3 : 2 are connected in series across a battery. Find the ratio of the drift velocities of the electrons in the wires.

33. (a) (a) A series combination of L, C and R is connected to an a.c. source. Using a phasor diagram, derive an expression for the impedance of the circuit and phase difference between V and I. 5

(b) Under what conditions the

(i) impedance of the circuit is minimum ?

(ii) Wattless current flows in the circuit ?

OR

(b) (i) With the help of a labelled diagram, explain the principle, construction and working of an a.c. generator.

(ii) Deduce an expression for the induced emf in the coil of the generator.

(iii) If T is the time period of the rotation of the coil, at what values of T in a cycle, the emf generator is maximum ?

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
(D)	(D)	(D)	(B)	(A)	(B)	(C)	(C)	(D)	(A)	(A)	(D)	(B)	(D)	(A)	(C)

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 (D). $U = k(q_1q_2 + q_2q_3 + q_3q_1)/l = k(-4q^2 - 2q^2 + 2q^2)/l = -4kq^2/l = -4q^2/(4\pi\varepsilon_0 l) = -q^2/(\pi\varepsilon_0 l)$.

Q2. Answer (D). Charge is conserved and the spheres reach a common potential V. Charges $Q_1 = 4\pi\varepsilon_0 r_1 V$ and $Q_2 = 4\pi\varepsilon_0 r_2 V$ add to $q_1 + q_2$, so $V = (q_1 + q_2)/[4\pi\varepsilon_0(r_1 + r_2)]$: (C) is correct and (D) is not.

Q3. Answer (D). $K_{max} = h\nu - \varphi_0$: it depends on the frequency and the work function, not on the intensity.

Q4. Answer (B). $r_n = n^2 a_0$, so $r_{n+1} - r_n = (2n + 1)a_0 \approx 2n\, a_0$ for large n: proportional to n.

Q5. Answer (A). B is along $I\, d\mathbf{l} \times \mathbf{r} = (-\hat{j}) \times (\hat{i}) = +\hat{k}$: along the z-axis (right-hand rule).

Q6. Answer (B). Small positive susceptibility means paramagnetic: aluminium. Cu and Bi are diamagnetic (negative); Ni is ferromagnetic (large positive).

Q7. Answer (C). The shunt and galvanometer share the voltage: $I_g \times 27 = (10 - I_g) \times 3$, so $30\, I_g = 30$ mA and $I_g = 1$ mA.

Q8. Answer (C). Each term is in Wb: At^2 gives A in Wb s^{-2}, Bt gives B in Wb s^{-1}.

Q9. Answer (D). $X_C = (1/C)(1/\omega)$, so the slope of each line is 1/C. $\tan 45° = 1/C_1$ and $\tan 30° = 1/C_2$: $C_1 = 1$, $C_2 = \sqrt{3}$, so $C_1/C_2 = 1/\sqrt{3}$.

Q10. Answer (A). By Lenz's law the top of the solenoid becomes a north pole to oppose the approaching N pole. A north face is seen with current anticlockwise.

Q11. Answer (A). In an electromagnetic wave E and B oscillate in phase (E = cB at every instant): phase difference zero.

Q12. Answer (D). $1/\lambda \propto (1 - 1/25) = 24/25$ and $1/\lambda' \propto (1/4 - 1/25) = 21/100$. $\lambda'/\lambda = (24/25)/(21/100) = 32/7$.

Q13. Answer (B). More intensity means more photons and more photoelectrons per second: A is true. $eV_0 = h\nu - \varphi_0$, so V_0 rises with frequency: R is true. But R concerns frequency, not intensity, so it does not explain A. Answer (B).

Q14. Answer (D). In forward bias the applied voltage opposes the built-in potential, so the barrier height decreases. Both A and R are false. Answer (D).

Q15. Answer (A). Dark fringes in interference show light added to light giving darkness, and destructive interference of coherent waves is exactly the reason. Answer (A).

Q16. Answer (C). In series $P = P_1P_2/(P_1 + P_2)$, which is less than P_1: A is true. At fixed V, $P = V^2/R$ is inversely proportional to R: R is false. Answer (C).

Q17. (2 marks) Answer: pure vs doped; $n_e = n_h$ vs $n_e \neq n_h$ (low vs higher conductivity).
(i) An intrinsic semiconductor is pure; an extrinsic semiconductor is doped with a small amount of a trivalent or pentavalent impurity. [1]
(ii) In an intrinsic semiconductor $n_e = n_h = n_i$ and the conductivity is very low; in an extrinsic semiconductor $n_e \neq n_h$ and the conductivity is much higher and can be controlled by the doping. [1]

Q18. (2 marks) Answer: (i) 1 : 2; (ii) 1 : 2√2.
λ = h/√(2mK). (i) Same K: λ_a/λ_p = √(m_p/m_α) = √(1/4) = 1/2. [1]
(ii) K = qV, so λ = h/√(2mqV): λ_a/λ_p = √(m_p e/(4m_p × 2e)) = 1/(2√2). [1]

Q19. (2 marks) Answer: ≈ 2.12 × 10^8 m/s.
A = 60°, so i = ¾ × 60° = 45°. At minimum deviation r = A/2 = 30°. [½]
n = sin 45°/sin 30° = (1/√2)/(1/2) = √2. [1]
v = c/n = 3 × 10^8/√2 ≈ 2.12 × 10^8 m/s. [½]

Q20. (2 marks) Answer: ≈ 968 °C.
At 27 °C: R_1 = 220/2.9 = 75.9 Ω. At the steady temperature: R_2 = 220/2.5 = 88.0 Ω. [1]
$R_2 = R_1[1 + \alpha(T_2 - T_1)]$: $T_2 - T_1$ = (88.0 − 75.9)/(75.9 × 1.7 × 10^{-4}) ≈ 941 °C, so T_2 ≈ 941 + 27 ≈ 968 °C. [1]

Q21. (2 marks) Answer: (a) 40 cm; (b) 18 mm.
(a) f = −20 cm. Near end u = −25 cm: 1/v = 1/f − 1/u = −1/20 + 1/25 = −1/100, v = −100 cm. [½]
Far end u = −30 cm: 1/v = −1/20 + 1/30 = −1/60, v = −60 cm. [½]
Length of the image = 100 − 60 = 40 cm. [1]
OR (b) Bright fringes at y = nλD/d. They coincide when n_1(500) = n_2(600): least n_1 = 6, n_2 = 5 (3000 nm). [1]
y = 3000 × 10^{-9} × 1.8/(0.3 × 10^{-3}) = 1.8 × 10^{-2} m = 18 mm. [1]

Q22. (3 marks) Answer: isotopes: C-12, C-14; isotones: Hg-198, Au-197; R = R_0A^(1/3), ρ = 3m/(4πR_0^3).
(a) Isotopes (same Z): $^{12}_{6}$C and $^{14}_{6}$C. Isotones (same N): $^{198}_{80}$Hg (N = 118) and $^{197}_{79}$Au (N = 118). [1]
(b) R = R_0A^(1/3), with R_0 ≈ 1.2 fm. [1]
Density ρ = mass/volume = Am/[(4/3)πR_0^3A] = 3m/(4πR_0^3), where m is the mass of a nucleon: independent of A (about 2.3 × 10^{17} kg m^{-3}). [1]

Q23. (3 marks) Answer: planes x = constant; V = 2qa/(4π$\varepsilon_0 x^2$).
(a) Equipotential surfaces are perpendicular to the field: three equally spaced planes parallel to the y-z plane (x = constant), with the potential falling along +x. [1]
(b) V = k[q/(x − a) − q/(x + a)] = 2kqa/(x^2 − a^2). [1]
For x ≫ a: V ≈ 2qa/(4π$\varepsilon_0 x^2$) = p/(4π$\varepsilon_0 x^2$), where p = 2qa. [1]

Q24. (3 marks) Answer: X-rays; infrared; microwaves.
(i) X-rays: about 10 nm to 10^{-3} nm (10^{-8} m to 10^{-12} m). [1]
(ii) Infrared: about 1 mm to 700 nm. [1]
(iii) Microwaves: about 0.1 m to 1 mm. [1]

Q25. (3 marks) Answer: (a) M = $\mu_0 n\pi r^2$ (henry); (b) F = μ_0I_aI_bL/(2πd), attractive, equal and opposite.
(a) (i) Mutual inductance M is the flux linked with one coil per unit current in the other: $\Phi_2 = MI_1$ (equivalently $\varepsilon_2 = -M\, dI_1/dt$). SI unit: henry (H). [1]
(ii) The solenoid field B = μ_0nI is uniform inside and along the axis. Flux through the loop Φ = μ_0nI × πr^2. [1]
M = Φ/I = $\mu_0 n\pi r^2$. [1]
OR (b) Field of A at B: B_a = μ_0I_a/(2πd), perpendicular to B. Force on length L of B: F_ba = I_bLB_a = μ_0I_aI_bL/(2πd), directed towards A (figure: two parallel wires, the forces on each pointing towards the other). [2]
Similarly F_ab = μ_0I_aI_bL/(2πd) on A, directed towards B. The two forces are equal in magnitude and opposite in direction: F_ab = −F_ba, as Newton's third law requires (currents in the same direction attract). [1]

Q26. (3 marks) Answer: mvr = nh/2π; ΔE ≈ 27.2/n^3 eV → 0.
(a) The electron revolves only in those orbits for which its angular momentum is an integral multiple of h/2π: mvr = nh/2π. Significance: it quantises the orbits (and hence the energies), so only certain stable orbits are allowed. [1]
(b) $E_n = -13.6/n^2$ eV. $E_{n+1} - E_n = 13.6[1/n^2 - 1/(n+1)^2] = 13.6(2n+1)/[n^2(n+1)^2]$ eV. [1]
For large n this is ≈ 27.2/n^3 eV, which tends to zero as n grows: the levels get closer and closer. [1]

Q27. (3 marks) Answer: 1 A (B to E).

(a) The arrow shows only the sense of flow of charge along the wire. Currents add algebraically (Kirchhoff's junction rule), not by the law of vector addition, so current is a scalar. [1]

(b) Take E (joined to D) at 0 V and A, B at potential x. With the cells as drawn: $V_F = x - 3$ and $V_C = x - 5$. Junction rule at B: $x/3 + (x - 5)/2 + (x - 3)/4 = 0$. [1]

$13x = 39$, $x = 3$ V. Current through 3 Ω = 3/3 = 1 A, from B to E (the 2 Ω carries 1 A from D to C and the 4 Ω carries none). [1]

Q28. (3 marks) Answer: $B = \mu_0 N I r^2/[2(x^2 + r^2)^{(3/2)}]$.

Biot–Savart: an element dl at distance $\sqrt{(x^2 + r^2)}$ from P gives $dB = \mu_0 I\, dl/[4\pi(x^2 + r^2)]$, perpendicular to the line joining it to P. [1]

By symmetry the components perpendicular to the axis cancel; the axial components add: $dB \cos\theta$, with $\cos\theta = r/\sqrt{(x^2 + r^2)}$. [1]

$B = [\mu_0 I\, r/(4\pi(x^2 + r^2)^{(3/2)})] \times 2\pi r$ for one turn; for N turns $B = \mu_0 N I r^2/[2(x^2 + r^2)^{(3/2)}]$, along the axis. [1]

Q29. (4 marks) Answer: (i) C; (ii) D; (iii) A; (iv) C (OR: A).

(i) (C) Boron, a trivalent impurity, gives p-type silicon. [1]

(ii) (D) $n_h = n_i^2/n_e = (1.5 \times 10^{16})^2/(5 \times 10^{22}) = 4.5 \times 10^9\ m^{-3}$. [1]

(iii) (A) In forward bias the current is carried mainly by the majority carriers (it is in the mA range, and the drift current of minority carriers is negligible), so (A) is the intended answer. Strictly, the majority carriers cross the junction by diffusion, not drift; none of the printed options says this exactly. [1]

(iv) (C) about 0.7 V for silicon. [1]

OR (iv) (A) about 0.01 eV for Ge (about 0.05 eV for Si). [1]

Q30. (4 marks) Answer: (i) A; (ii) D; (iii) B; (iv) D (OR: A).

(i) (A) With object distance u and image distance D − u: $1/(D - u) + 1/u = 1/f$ gives $u^2 - Du + Df = 0$. The two roots differ by $d = \sqrt{(D^2 - 4Df)} = \sqrt{(D(D - 4f))}$. [1]

(ii) (D) In the first position (lens nearer the object) u < v: the image is enlarged; in the second the distances swap: reduced. [1]

(iii) (B) $f = (D^2 - d^2)/(4D) = (6400 - 400)/320 = 18.75$ cm. [1]

(iv) (D) Two positions need D > 4f = 60 cm: only 65 cm. [1]

OR (iv) (A) P = 10/3 D, $P_1 = 1/0.10$ m = 10 D, so $P_2 = 10/3 - 10 = -20/3$ D and f = −3/20 m = −15 cm. [1]

Q31. (5 marks) Answer: (a) $2I_0$ and I_0; (b) $m = f_0/f_e$.

(a) (a) Coherent sources emit waves of the same frequency with a constant (time-independent) phase difference. [1]

Only then is the phase difference at each point of the screen fixed in time, so the bright and dark fringes stay in place; with incoherent sources the pattern shifts rapidly and averages to uniform illumination. [1]

Graph: intensity against position, equally spaced maxima of $4I_0$ and zeros, with fringe width $\beta = \lambda D/d$. [1]

(b) $I = 4I_0 \cos^2(\varphi/2)$, $\varphi = (2\pi/\lambda) \times$ path difference. (i) $\varphi = \pi/2$: $I = 4I_0 \times ½ = 2I_0$. (ii) $\varphi = 2\pi/3$: $I = 4I_0 \times ¼ = I_0$. [1 + 1]

OR (b) (a) Diagram: parallel rays from the distant object form a real, inverted image at the focus of the objective, which is also the focus of the eyepiece; the final image is at infinity. [1½]

Magnifying power $m = \beta/\alpha$. With the intermediate image of height h: $\alpha \approx h/f_0$ and $\beta \approx h/f_e$, so $m = f_0/f_e$. [1½]

(b) (i) A large aperture collects more light (a brighter image of faint objects) and gives a higher resolving power. [1] (ii) No chromatic aberration (and a parabolic mirror has no spherical aberration); a mirror needs only one polished surface and can be supported over its whole back, so large ones are easier and cheaper to make. [1]

Q32. (5 marks) Answer: (a) $C = \varepsilon_0 A/d$; charge and energy each become K times; (b) $I = neAv_d$; 4 : 9.

(a) (a) Plates carry ±Q, surface density $\sigma = Q/A$. Between the plates $E = \sigma/\varepsilon_0$ (outside it is zero). [1]

$V = Ed = Qd/(\varepsilon_0 A)$, so $C = Q/V = \varepsilon_0 A/d$. [2]

(b) The battery stays connected, so the voltage V across each capacitor is fixed. (i) C becomes KC, so each charge becomes KC_1V and KC_2V: K times larger (the battery supplies the extra charge). [1] (ii) $U = \frac{1}{2}CV^2$ also becomes K times larger for each. [1]

OR (b) (a) The field accelerates each electron ($a = -eE/m$) between collisions with the ions; each collision randomises its velocity. Averaged over the electrons, the random velocities give zero and the gain is $-eE\tau/m$, where τ is the mean time between collisions: $v_d = -eE\tau/m$, independent of time. [1½]

In time Δt, the electrons in a length $v_d\Delta t$ cross a section: charge $neAv_d\Delta t$, so $I = neAv_d$. [1½]

(b) (i) Closing the circuit sets up the electric field throughout the conductor almost at once (it travels at nearly the speed of light), so the free electrons everywhere start drifting together. [1] (ii) In series the current is the same: $v_d \propto 1/A \propto 1/r^2$, so $v_1 : v_2 = 2^2 : 3^2 = 4 : 9$. [1]

Q33. (5 marks) Answer: (a) $Z = \sqrt{[R^2 + (X_C - X_L)^2]}$; resonance; $R = 0$ ($\varphi = 90°$); (b) $\varepsilon = NBA\omega \sin \omega t$; T/4 and 3T/4.

(a) (a) The same current $i = i_m \sin \omega t$ flows through all three. Phasors: V_R in phase with I, V_L ahead by 90°, V_C behind by 90°. [1]

$V^2 = V_R^2 + (V_C - V_L)^2$; with $V_R = IR$, $V_L = IX_L$, $V_C = IX_C$: $Z = \sqrt{[R^2 + (X_C - X_L)^2]}$. [1½]

$\tan \varphi = (X_C - X_L)/R$ (or $(X_L - X_C)/R$ for the lead of V over I). [½]

(b) (i) Z is minimum (= R) when $X_L = X_C$, that is at resonance, $\omega = 1/\sqrt{(LC)}$. [1] (ii) Wattless current flows when the average power VI cos φ is zero: $\varphi = 90°$, for a purely inductive or purely capacitive circuit ($R = 0$). [1]

OR (b) (i) Principle: electromagnetic induction; a coil rotated in a magnetic field has a changing flux linkage. Construction: armature coil on an axle between the poles of a magnet, slip rings and brushes. Working: as the coil turns, the flux through it changes periodically and an alternating emf is induced. [2]

(ii) $\Phi = NBA \cos \omega t$, so $\varepsilon = -d\Phi/dt = NBA\omega \sin \omega t$, with peak $\varepsilon_0 = NBA\omega$. [2]

(iii) ε is maximum when $\sin \omega t = \pm 1$: $t = T/4$ and $3T/4$ (the plane of the coil parallel to the field). [1]

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