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

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

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; $\mu_0 = 4\pi \times 10^{-7}$ 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 55/1/1). 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 55/1/1, 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. In a region, the electric potential varies as V = 10 − 50*x*, where V is in volts and *x* in meters. The electric field in the region is 1

(A) 10 N/C along +*x*

(B) 10 N/C along −*x*

(C) 50 N/C along +*x*

(D) 50 N/C along −*x*

2. A conducting wire connects two charged metallic spheres A and B of radii r_1 and r_2 respectively. The distance between the spheres is very large compared to their radii. The ratio of electric fields, (E_A/E_B) at the surfaces of spheres A and B will be 1

(A) $\frac{r_1}{r_2}$

(B) $\frac{r_2}{r_1}$

(C) $\frac{{r_1}^2}{{r_2}^2}$

(D) $\frac{{r_2}^2}{{r_1}^2}$

3. A long straight wire of circular cross-section (radius a) carries a steady current I. The current is uniformly distributed across this cross-section. The magnitude of the magnetic field produced at a point at a distance (a/2) from the axis of the wire will be 1

(A) Zero

(B) $\frac{\mu_0 I}{2\pi a}$

(C) $\frac{\mu_0 I}{4\pi a}$

(D) $\frac{\mu_0 I}{6\pi a}$

4. The shape of the interference fringes in Young's double-slit experiment, when the distance between the slit and the screen is very large as compared to the slit-separation, is nearly 1

(A) straight

(B) parabolic

(C) circular

(D) hyperbolic

5. An electromagnetic wave passes from vacuum into a dielectric medium with relative electrical permittivity (3/2) and relative magnetic permeability (8/3). Then, its 1

(A) wavelength is doubled and frequency remains unchanged.

(B) wavelength is doubled and frequency is halved.

(C) wavelength is halved and frequency remains unchanged.

(D) wavelength and frequency both will remain unchanged.

6. In a series LCR circuit, the voltage across the resistor, capacitor and inductor is 10 V each. If the capacitor is short circuited, the voltage across the inductor will be 1

(A) 10 V

(B) $5\sqrt{2}$ V

(C) $\frac{5}{\sqrt{2}}$ V

(D) $10\sqrt{2}$ V

7. Electromagnetic waves used in a diagnostic tool in medicine have a wavelength range 1

(A) 1 nm to 10^{-3} nm

(B) 400 nm to 1 nm

(C) 1 mm to 700 nm

(D) 0.1 m to 1 mm

8. The 'distance of closest approach' of an alpha-particle is 'd' when it moves with a velocity v head-on towards the target nucleus. If the velocity of alpha particle is halved, the new 'distance of closest approach' will be – 1

(A) $\frac{d}{2}$ (B) 2d

(C) $\frac{d}{4}$ (D) 4d

9. A concave lens of focal length 10 cm is cut into two identical plano-concave lenses. The focal length of each lens will be 1

(A) 20 cm (B) 30 cm

(C) 40 cm (D) 5 cm

10. Four independent waves are expressed as 1

(i) $y_1 = A_1 \sin \omega t$ (ii) $y_2 = A_2 \sin 2\omega t$

(iii) $y_3 = A_3 \cos \omega t$ (iv) $y_4 = A_4 \sin (\omega t + \pi/3)$

The interference between two of these waves is possible in

(A) (i) and (iii) only (B) (iii) and (iv) only

(C) (i), (iii) and (iv) only (D) All of them

11. Two heaters rated as (P_1, V) and (P_2, V) are connected in series across a dc source of $\frac{V}{2}$ volt. The power consumed by the combination will be – 1

(A) $(P_1 + P_2)$ (B) $\frac{P_1 + P_2}{2}$

(C) $\frac{P_1 P_2}{2(P_1 + P_2)}$ (D) $\frac{P_1 P_2}{4(P_1 + P_2)}$

12. In an unbiased p-n junction, at equilibrium, which of the following statements is <u>true</u> ? 1

(A) Diffusion current is zero but drift current exists.

(B) Diffusion current exists but drift current is zero.

(C) Diffusion and drift currents are equal and opposite.

(D) Both the diffusion and drift currents exist but are unequal.

13. **Assertion (A) :** All atoms have a net magnetic moment. 1

Reason (R) : A current loop does not always behave as a magnetic dipole.

(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) :** If accelerated electrons are passed through a narrow slit, a diffraction pattern is observed. 1

Reason (R) : Electrons behave as both particles and waves.

(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) :** The mass of a nucleus is less than the sum of the masses of the constituent nucleons. 1

Reason (R) : Energy is absorbed when the nucleons are bound together to form a nucleus.

(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) :** In Bohr model of hydrogen atom, the energy levels are discrete and quantised. 1

Reason (R) : In a hydrogen atom, the electrostatic force on the electron provides the necessary centripetal force to it to revolve around the nucleus.

(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. In a photoelectric experiment, the emitter plate is irradiated with radiation of 200 nm. The photocurrent becomes zero when the collector plate potential is − 0.80 V. Calculate the work function (in eV) of the emitter. 2

18. (a) A beam of light consisting of two wavelengths 400 nm and 600 nm is used to illuminate a single slit of width 1 mm. Find the least distance of the point from the central maximum where the dark fringes due to both wavelengths coincide on the screen placed 1.5 m from the slit. 2

OR

(b) In a Young's double-slit experimental set-up with slit separation 0.6 mm a beam of light consisting of two wavelengths 440 nm and 660 nm is used to obtain interference pattern on a screen kept 1.5 m in front of the slits. Find the least distance of the point from the central maximum where the bright fringes due to both the wavelengths coincide.

19. A wire of length L is bent round into (i) a square coil having N turns and (ii) a circular coil having N turns. The coil in both cases is free to turn about a vertical axis coinciding with the plane of the coil, in a uniform, horizontal magnetic field and carry the same currents. Find the ratio of the maximum value of the torque acting on the square coil to that on the circular coil. 2

20. What is the order of magnitude of drift velocity of electrons in a conductor ? Deduce the relation between the current flowing through a conductor and drift velocity of electrons in it. 2

21. Draw the plot of potential energy of a pair of nucleons as a function of their separation. Write two important conclusions that can be drawn from this plot. 2

SECTION C

Short answer (SA) questions of 3 marks each.

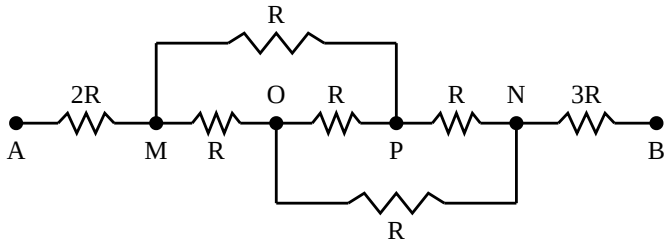
22. (a) (a) Using Gauss's law, deduce an expression for electric field at a point due to a uniformly charged infinite plane thin sheet. 3

(b) Two large thin plane sheets, each having surface charge density σ, are held close and parallel to each other in air. What is the net electric field at a point (i) inside and (ii) outside, the sheets ?

OR

(b) (a) Obtain the condition of balance of a Wheatstone bridge.

(b) Find net resistance of the network of resistors connected between A and B, as shown in figure.



23. A parallel plate capacitor of capacitance C has a dielectric slab between its plates. It is charged to a potential difference V by connecting it across a battery. The battery is then disconnected. If the dielectric slab is now withdrawn from the capacitor, how will the following be affected ? 3

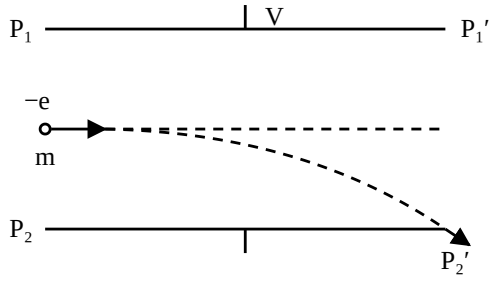
(a) Capacitance of the capacitor,

(b) Energy stored in the capacitor, and

(c) The potential difference between the plates of the capacitor.

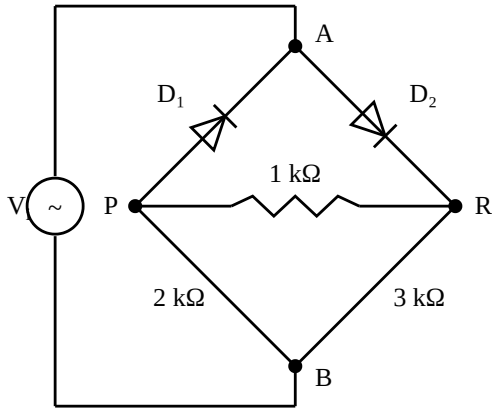
Justify your answer in each case.

24. Figure shows a narrow beam of electrons entering with a velocity of 3×10^7 m/s, symmetrically through the space between two parallel horizontal plates P_1P_1' and P_2P_2' kept 2 cm apart. 3



If each plate is 3 cm long, calculate the potential difference V applied between the plates so that the beam just strikes the end P_2'.

25. An ac voltage $V_i = 12 \sin (100 \pi t)V$ is applied between points A and B in a network of two ideal diodes and three resistors as shown in figure. 3



During the positive half-cycle of the input voltage V_i supplied to the network.

(a) Identify which of the two diodes will conduct and why ?

(b) Redraw an equivalent circuit diagram to show the flow of current.

(c) Calculate the output voltage drops V_0 across the three resistors when the input voltage attains its peak value.

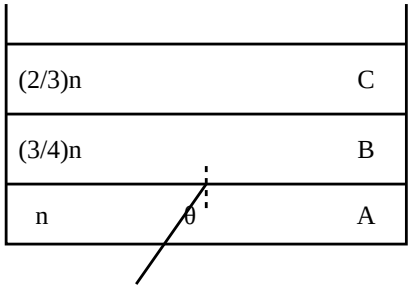
26. Briefly explain the two important processes that occur during the formation of a p-n junction. 3

27. (a) Draw the ray diagram to show the image formation by a refracting telescope and write the expression for angular magnification for the telescope in normal adjustment. 3

(b) Give two reasons to explain why a reflecting telescope is preferred over a refracting telescope.

28. (a) State the two conditions under which total internal reflection occurs. 3

(b) A transparent container contains layers of three immiscible transparent liquids A, B and C of refractive indices n, (3/4)n and (2/3)n, respectively. A laser beam is incident at the interface between A and B at an angle θ as shown in figure. Prove that the beam does not enter region C at all for sin θ ≥ 2/3.



SECTION D

Case study based questions of 4 marks each.

29. A galvanometer is used to detect or/and measure small currents in an electrical circuit. It essentially works on the fact that a current-carrying coil experiences a deflecting torque when placed in a magnetic field. This deflection in the coil can be measured and it is related to the current flowing in the coil, the number of turns in the coil, area of the coil and the magnetic field. A hair spring attached to the coil provides a counter torque and helps in measuring the deflection. A galvanometer can be converted to an ammeter or a voltmeter of desired range by using suitable resistances.

(I) The torque on the coil remains constant irrespective of the coil's orientation during rotation due to (A) use of soft iron core which increases the magnetic field. (B) radial magnetic field (C) hair spring which provides the counter torque (D) eddy current in the iron core which causes damping. [1]

(II) The best way to increase current sensitivity of a galvanometer is by
(A) increasing number of turns of the coil (B) increasing area of coil and magnitic field strength (C) decreasing area of coil and magnetic field strength (D) increasing torsional constant of the hair spring [1]

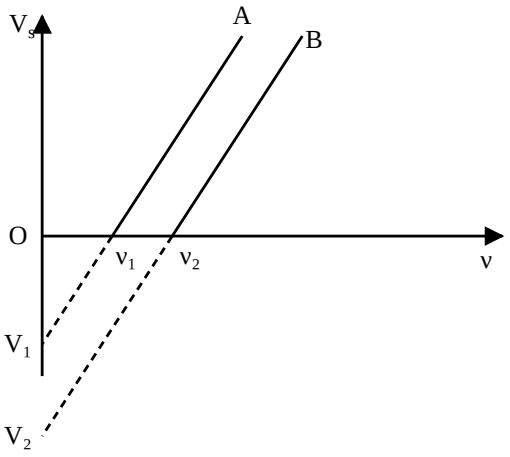
(III) A moving coil galvanometer has a coil with area of cross-section 4.0×10^{-3} m^2 and number of turns 50. The coil is rotating in a magnetic field of 0.25 T. The torque acting on the coil when a current of 5 A passes through it is
(A) 1.0 N m (B) 2.0 N m (C) 0.50 N m (D) 0.25 N m [1]

OR

(III) A galvanometer coil has a resistance of 15 Ω and the meter shows full scale deflection for a current of 3 mA. The value of resistance required to convert it into a voltmeter of range (0 − 12 V) is
(A) 4015 Ω (B) 3985 Ω (C) 415 Ω (D) 385 Ω [1]

(IV) A galvanometer with coil of resistance 20 Ω shows full scale deflection for a current of 5 mA. To convert it into an ammeter of range (0 − 10 A), a resistance of
(A) 0.05 Ω should be connected in series with it. (B) 0.05 Ω should be connected in parallel with it. (C) 0.01 Ω should be connected in parallel with it. (D) 0.01 Ω should be connected in series with it. [1]

30. A researcher performs an experiment on photo-electric effect using two metals A and B with unknown work functions. She illuminates the surfaces of A and B with monochromatic radiation of various frequencies and records the value of corresponding stopping potentials (V_s). The graph shows the variation of stopping potential (V_s) with the frequency of incident radiation (ν) for metals A and B.



Answer the following questions :

(I) From the graph, the work functions of A and B are (h is Planck's constant and e value of charge on an electron)

(A) ν_1 and ν_2 (B) V_1 and V_2 (C) $h\nu_1$ and $h\nu_2$ (D) $h\nu_1/e$ and $h\nu_2/e$ [1]

(II) For radiation of frequency $\nu > \nu_2$ incident on the surfaces of A and B, the maximum kinetic energy of ejected electron is

(A) greater for metal A because it has a smaller work function. (B) greater for metal B because it has a larger work function. (C) greater for metal B because it has higher threshold frequency. (D) the same for both metal A and metal B because it is independent of work functions of metals. [1]

(III) If the intensity of the incident radiation for both metals A and B, is doubled keeping its frequency constant, then

(A) the slope of the parallel lines will increase. (B) the slope of the parallel lines will decrease. (C) the threshold frequencies for both A and B will decrease. (D) the slope of the parallel lines will not change but more electrons will be emitted per second. [1]

(IV) The threshold frequency for a metal surface is ν_0. If the radiation of frequency $3\nu_0$ illuminates the surface, the maximum kinetic energy (KE) of photoelectrons is E_1. If the frequency were increased to $6\nu_0$, the maximum KE of the photoelectrons becomes E_2. Then (E_1/E_2) equals

(A) 1/3 (B) 1/2 (C) 2/5 (D) 3/4 [1]

OR

(IV) Let m be the slope of the graph line for metal B. If e is the value of electron charge, then Planck's constant 'h' is given by

(A) me (B) 1/(me) (C) m/e (D) e/m [1]

SECTION E

Long answer (LA) questions of 5 marks each.

31. (a) (a) An electric dipole consists of two point charges q and −q separated by a distance 2a. Derive an expression for the electric field **E** due to this dipole at a point distant r from the centre of the dipole on the equatorial plane. Write the expression for the electric field at a far off point, i.e. r >> a. 5

(b) A dipole is placed in x-y plane such that charges q and −q are located at x = a and x = b respectively. There exists an electric field **E** = 2 î N/C in the region. Calculate the force **F** and torque **τ** experienced by the dipole.

OR

(b) (a) Two cells of emf E_1 and E_2 with internal resistances r_1 and r_2 respectively, are connected in parallel by connecting their positive terminals together and negative terminals together. Deduce an expression for equivalent emf and equivalent internal resistance of the combination.

(b) A parallel combination, as stated in (a) above, of two cells of emfs E and 3E and internal resistances R each is connected across a resistance 2R. Find the current that flows through resistance 2R.

32. (a) (a) Using the relation for refraction at a curved spherical surface, derive the expression for lens maker's formula. 5

(b) Three lenses L_1, L_2 and L_3, each of focal length 40 cm, are placed coaxially. The distance between L_1 and L_2 and between L_2 and L_3 are 120 cm and 20 cm respectively. An object is kept at a distance of 80 cm to the left of lens L_1. Find the distance of the final image formed from the object.

OR

(b) (a) Draw a ray diagram to show the image formation by a concave mirror when the object is kept between its focus and the centre of curvature. Using this diagram, derive the mirror formula.

(b) A concave mirror produces a two times magnified virtual image of an object kept 10 cm in front of it. Calculate the focal length of the mirror.

33. (a) (a) State Faraday's law of electromagnetic induction. 5

(b) Derive an expression for the self-inductance of an air-filled long solenoid of length l and cross-sectional area A having N turns.

(c) A conducting rod of length 50 cm, with one end pivoted, is rotated with angular speed of 60 rpm in a uniform magnetic field of 4.0 mT directed perpendicular to the plane of rotation of rod. Find the emf induced in the rod.

OR

(b) (a) Draw a labelled diagram of a step-up transformer. State the principle on which it works and obtain the ratio of secondary voltage to primary voltage in terms of number of turns and currents in the two coils.

(b) The ratio of the number of turns in the primary to the secondary of an ideal transformer is 1 : 5. If 5 kW power at 200 V is supplied to the primary, find

(i) current in the primary, and

(ii) output voltage.

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
(C)	(B)	(C)	(A)	(C)	(B)	(A)	(D)	(A)	(C)	(D)	(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 (C). $E = -dV/dx = -(-50) = +50$ V/m: 50 N/C along +x (the field points the way the potential falls).

Q2. Answer (B). Connected spheres are at the same potential: $kq_1/r_1 = kq_2/r_2 = V$. The surface field $E = kq/r^2 = V/r$, so $E_A/E_B = r_2/r_1$.

Q3. Answer (C). Inside, Ampère's law with the enclosed current $I(r^2/a^2)$: $B(2\pi r) = \mu_0 I\, r^2/a^2$, so $B = \mu_0 I\, r/(2\pi a^2)$. At $r = a/2$, $B = \mu_0 I/(4\pi a)$.

Q4. Answer (A). The fringes are strictly hyperbolic, but when $D \gg d$ they are very nearly straight lines (equally spaced).

Q5. Answer (C). $n = \sqrt{(\varepsilon_r \mu_r)} = \sqrt{((3/2)(8/3))} = 2$. The frequency does not change on entering a medium; $v = c/2$, so $\lambda = v/f$ is halved.

Q6. Answer (B). $V_R = V_L = V_C$ means $R = X_L = X_C$ and the supply is 10 V (resonance). Without C: $Z = \sqrt{(R^2 + X_L^2)} = \sqrt{2}\,R$, $I = 10/(\sqrt{2}\,R)$, $V_L = I\,X_L = 10/\sqrt{2} = 5\sqrt{2}$ V.

Q7. Answer (A). X-rays, used as a diagnostic tool in medicine, have wavelengths from about 10 nm down to 10^{-4} nm; the range 1 nm to 10^{-3} nm lies in the X-ray band. 400 nm to 1 nm is ultraviolet, 1 mm to 700 nm infrared and 0.1 m to 1 mm microwaves.

Q8. Answer (D). $\tfrac{1}{2}mv^2 = kZe(2e)/d$, so $d \propto 1/v^2$. Halving v makes d four times: 4d.

Q9. Answer (A). $1/f = (\mu - 1)(1/R + 1/R) = 2(\mu - 1)/R$ for the whole lens. Each plano-concave half has one curved surface: $1/f' = (\mu - 1)/R$, so $f' = 2f = 20$ cm (in magnitude; it is still diverging).

Q10. Answer (C). Sustained interference needs the same frequency and a constant phase difference. (i), (iii) and (iv) all have angular frequency ω with fixed phase differences; (ii) has 2ω.

Q11. Answer (D). $R_1 = V^2/P_1$, $R_2 = V^2/P_2$. $P = (V/2)^2/(R_1 + R_2) = (V^2/4)/[V^2(P_1 + P_2)/(P_1P_2)] = P_1P_2/[4(P_1 + P_2)]$.

Q12. Answer (C). At equilibrium the diffusion current and the drift current are equal and opposite, so the net current is zero.

Q13. Answer (D). Atoms of diamagnetic substances have zero net magnetic moment: A is false. A current loop always behaves as a magnetic dipole ($m = IA$): R is false. Answer (D).

Q14. Answer (A). Electrons have a de Broglie wavelength $\lambda = h/p$ and show diffraction (Davisson–Germer): A is true, and the wave nature in R explains it. Answer (A).

Q15. Answer (C). The mass defect is real: A is true. Energy (the binding energy) is released, not absorbed, when nucleons bind: R is false. Answer (C).

Q16. Answer (B). Both are true. But the levels are discrete because of Bohr's quantisation condition ($mvr = nh/2\pi$), not because the Coulomb force provides the centripetal force. Answer (B).

Q17. (2 marks) Answer: ≈ 5.4 eV.
$E = hc/\lambda = (6.63 \times 10^{-34} \times 3 \times 10^{8})/(200 \times 10^{-9}) = 9.95 \times 10^{-19}$ J = 6.22 eV. [1]
Stopping potential 0.80 V: $K_{max} = 0.80$ eV, so $\varphi_0 = 6.22 - 0.80 \approx 5.4$ eV. [1]

Q18. (2 marks) Answer: (a) 1.8 mm; (b) 3.3 mm.
(a) Dark fringes at $y = n\lambda D/a$. They coincide when $n_1(400) = n_2(600)$: least $n_1 = 3$, $n_2 = 2$ (1200 nm). [1]
$y = 1200 \times 10^{-9} \times 1.5/10^{-3} = 1.8 \times 10^{-3}$ m = 1.8 mm. [1]
OR (b) Bright fringes at $y = n\lambda D/d$. $n_1(440) = n_2(660)$: least $n_1 = 3$, $n_2 = 2$ (1320 nm). [1]
$y = 1320 \times 10^{-9} \times 1.5/(0.6 \times 10^{-3}) = 3.3 \times 10^{-3}$ m = 3.3 mm. [1]

Q19. (2 marks) Answer: π : 4.
$\tau_{max} = NIAB$, so the ratio is A_{square}/A_{circle}. Square: side $L/(4N)$, $A = L^2/(16N^2)$. Circle: radius $L/(2\pi N)$, $A = L^2/(4\pi N^2)$. [1]
Ratio = $(L^2/16N^2)/(L^2/4\pi N^2) = \pi/4$. [1]

Q20. (2 marks) Answer: ~10^{-4} m/s; $I = neAv_d$.
Drift velocity is of the order of 10^{-4} m/s (a fraction of a mm per second). [½]
In time Δt, electrons in a length $v_d\Delta t$ of a conductor of area A cross a section: charge $\Delta q = n(A\, v_d\Delta t)e$, where n is the number density. [1]
$I = \Delta q/\Delta t = neAv_d$. [½]

Q21. (2 marks) Answer: see the model answer.
Plot: potential energy against separation r falls to a minimum (about −100 MeV) near $r_0 \approx 0.8$ fm, rises steeply below it and tends to zero beyond a few fm. [1]
Conclusions: the nuclear force is attractive for $r > 0.8$ fm and strongly repulsive for $r < 0.8$ fm; it is short-ranged, becoming negligible beyond a few femtometres. [½ + ½]

Q22. (3 marks) Answer: (a) $\sigma/2\varepsilon_0$; 0 inside, σ/ε_0 outside; (b) P/Q = R/S; 6R.
(a) (a) Take a cylindrical Gaussian surface of cross-section A through the sheet. The field is normal to the sheet, so flux passes only through the two ends: $2EA = \sigma A/\varepsilon_0$. [1]
$E = \sigma/(2\varepsilon_0)$, directed away from a positively charged sheet. [1]
(b) Each sheet gives $\sigma/2\varepsilon_0$. (i) Inside, the fields are opposite: E = 0. (ii) Outside, they add: $E = \sigma/\varepsilon_0$, directed away from the sheets. [½ + ½]
OR (b) (a) In the bridge P, Q, R, S with a galvanometer between B and D, balance means $I_g = 0$, so B and D are at the same potential. Kirchhoff's loop rule in the two loops gives $I_1P = I_2R$ and $I_1Q = I_2S$. [1]
Dividing: P/Q = R/S. [1]
(b) Between M and N: M–O and M–P are R each, O–N and P–N are R each, with R between O and P. By symmetry O and P are at the same potential, so no current flows in OP; the two paths of 2R in parallel give R. $R_{AB} = 2R + R + 3R = 6R$. [1]

Q23. (3 marks) Answer: C → C/K; U → KU; V → KV.
The battery is disconnected, so the charge Q = CV stays constant. Let K be the dielectric constant.
(a) $C = K\varepsilon_0A/d$ becomes ε_0A/d: it decreases to C/K. [1]
(b) $U = Q^2/2C$: with Q constant and C reduced K times, U increases K times (work is done in pulling out the slab). [1]
(c) V = Q/C: it increases to KV. [1]

Q24. (3 marks) Answer: ≈ 2.3 kV (2275 V).
Time between the plates $t = L/v = 0.03/(3 \times 10^7) = 10^{-9}$ s; to strike P_2' the beam is deflected y = 1 cm = 0.01 m. [1]
$y = \frac{1}{2}(eE/m)t^2$: $E = 2ym/(et^2) = 2 \times 0.01 \times 9.1 \times 10^{-31}/(1.6 \times 10^{-19} \times 10^{-18}) = 1.14 \times 10^5$ V/m. [1]
$V = Ed = 1.14 \times 10^5 \times 0.02 \approx 2.3 \times 10^3$ V. [1]

Q25. (3 marks) Answer: D_2 conducts; 3 kΩ: 12 V, 1 kΩ: 4 V, 2 kΩ: 8 V.
Taking A positive with respect to B in the positive half-cycle: (a) D_2 (anode at A) is forward biased and conducts; D_1 (cathode at A) is reverse biased and does not conduct. [1]
(b) Current flows A → D_2 → R, then through 3 kΩ (R to B) in parallel with 1 kΩ + 2 kΩ (R → P → B). [1]
(c) Both branches are 3 kΩ: equivalent 1.5 kΩ, peak current 12/1.5 kΩ = 8 mA, 4 mA in each branch. V(3 kΩ) = 12 V, V(1 kΩ) = 4 V, V(2 kΩ) = 8 V. [1]

Q26. (3 marks) Answer: diffusion and drift.
Diffusion: holes diffuse from the p-side (high concentration) to the n-side and electrons from the n-side to the p-side, leaving behind immobile ions near the junction: the depletion region with a barrier potential forms. [1½]
Drift: the electric field of this space-charge region drives minority carriers across the junction in the opposite direction (drift current). At equilibrium the drift current equals the diffusion current, and the net current is zero. [1½]

Q27. (3 marks) Answer: $m = f_0/f_e$.
(a) Diagram: parallel rays from a distant object pass through the objective (long f_0) and form a real, inverted image at its focus, which is also the focus of the eyepiece; the eyepiece gives a final image at infinity. [1]
Angular magnification in normal adjustment $m = f_0/f_e$. [1]
(b) A mirror has no chromatic aberration (and with a parabolic mirror no spherical aberration); a large mirror is easier and cheaper to make and support than a large lens, and gives greater light-gathering power and resolution. [½ + ½]

Q28. (3 marks) Answer: see the model answer.
(a) Light must travel from the optically denser to the rarer medium, and the angle of incidence must exceed the critical angle. [1]
(b) The interfaces are parallel, so n sin(angle) is the same in every layer: $n \sin\theta = (3/4)n \sin r_B = (2/3)n \sin r_C$. [1]
$\sin r_C = (3/2)\sin\theta$. For $\sin\theta \geq 2/3$ this would be ≥ 1, so there is no refracted ray into C: the beam is totally reflected (at the B–C interface, or already at A–B if $\sin\theta \geq 3/4$) and does not enter C. [1]

Q29. (4 marks) Answer: (I) B; (II) B; (III) D (OR: B); (IV) C.
(I) (B) radial magnetic field: the plane of the coil is always along the field, so $\tau = NIAB$ at every position. [1]
(II) (B) current sensitivity $\varphi/I = NAB/k$; increasing A and B raises it without raising the coil resistance as more turns would. [1]
(III) (D) $\tau = NIAB = 50 \times 5 \times 4.0 \times 10^{-3} \times 0.25 = 0.25$ N m. [1]
OR (III) (B) $R = V/I_g - G = 12/0.003 - 15 = 3985\ \Omega$, in series. [1]
(IV) (C) $S = I_gG/(I - I_g) = 0.005 \times 20/9.995 \approx 0.01\ \Omega$, in parallel (a shunt). [1]

Q30. (4 marks) Answer: (I) C; (II) A; (III) D; (IV) C (OR: A).
(I) (C) $\varphi_0 = h\nu_0$, so $h\nu_1$ and $h\nu_2$. [1]
(II) (A) $K_{max} = h\nu - \varphi_0$ is larger for A, which has the smaller work function. [1]
(III) (D) the stopping potential depends only on frequency; the slope h/e is unchanged, but more photons give more electrons per second. [1]
(IV) (C) $E_1 = 3h\nu_0 - h\nu_0 = 2h\nu_0$, $E_2 = 5h\nu_0$: $E_1/E_2 = 2/5$. [1]
OR (IV) (A) $eV_s = h\nu - \varphi_0$, so the slope $m = h/e$ and $h = me$. [1]

Q31. (5 marks) Answer: (a) $kp/(r^2 + a^2)^{(3/2)}$, kp/r^3; F = 0, τ = 0; (b) $E_{eq} = (E_1r_2 + E_2r_1)/(r_1 + r_2)$, $r_{eq} = r_1r_2/(r_1 + r_2)$; 4E/(5R).
(a) (a) Each charge is at distance $\sqrt{(r^2 + a^2)}$; each field has magnitude $kq/(r^2 + a^2)$. [1]
The components along the perpendicular bisector cancel; those parallel to the dipole axis add, opposite to p: $E = 2kq/(r^2 + a^2) \times a/\sqrt{(r^2 + a^2)} = kp/(r^2 + a^2)^{(3/2)}$, with $p = 2qa$. [1½]
For $r \gg a$: $E = -kp/r^3$ (opposite to p). [½]
(b) In a uniform field the net force is $F = qE - qE = 0$. [1] The dipole moment $p = q(a - b)\,\hat{\imath}$ is along the field (or opposite), so $\tau = p \times E = 0$ ($\hat{\imath} \times \hat{\imath} = 0$). [1]
OR (b) (a) With terminal voltage V: $I_1 = (E_1 - V)/r_1$, $I_2 = (E_2 - V)/r_2$, $I = I_1 + I_2$. [1]
$V = (E_1r_2 + E_2r_1)/(r_1 + r_2) - I\,r_1r_2/(r_1 + r_2)$, so $E_{eq} = (E_1r_2 + E_2r_1)/(r_1 + r_2)$ and $r_{eq} = r_1r_2/(r_1 + r_2)$. [2]
(b) $E_{eq} = (E \cdot R + 3E \cdot R)/(2R) = 2E$; $r_{eq} = R/2$. [1]
$I = 2E/(2R + R/2) = 4E/(5R)$. [1]

Q32. (5 marks) Answer: (a)(b) 260 cm from the object; (b)(b) f = −20 cm.

(a) (a) First surface ($n_1 \rightarrow n_2$, radius R_1): $n_2/v_1 - n_1/u = (n_2 - n_1)/R_1$. Second surface ($n_2 \rightarrow n_1$, radius R_2), with v_1 as its object: $n_1/v - n_2/v_1 = (n_1 - n_2)/R_2$. [1]

Adding: $n_1(1/v - 1/u) = (n_2 - n_1)(1/R_1 - 1/R_2)$. With u = ∞, v = f: $1/f = (n_{21} - 1)(1/R_1 - 1/R_2)$. [2]

(b) L_1: 1/v = 1/40 − 1/80, v = 80 cm, i.e. 40 cm before L_2. L_2: u = −40 cm = −f, so the rays leave parallel. L_3: the image is at its focus, 40 cm beyond L_3. [1½]

The final image is 120 + 20 + 40 = 180 cm from L_1, so 80 + 180 = 260 cm from the object. [½]

OR (b) (a) Diagram with AB between F and C, image A′B′ beyond C; similar triangles A′B′F ~ MPF and A′B′P ~ ABP give B′A′/BA = B′F/FP = B′P/BP. [1½]

With sign convention: (v − f)/f = v/u, which rearranges to 1/v + 1/u = 1/f. [1½]

(b) Virtual image, m = +2 = −v/u with u = −10 cm: v = +20 cm. [1]

1/f = 1/20 − 1/10 = −1/20: f = −20 cm (focal length 20 cm). [1]

Q33. (5 marks) Answer: (a) $L = \mu_0 N^2 A/l$; ≈ 3.14 mV; (b) 25 A, 1000 V.

(a) (a) The induced emf equals the rate of change of magnetic flux through the circuit: $\varepsilon = -d\Phi/dt$ (the minus sign is Lenz's law). [1]

(b) $B = \mu_0(N/l)I$ inside; total flux linkage $N\Phi = N \times \mu_0(N/l)I \times A = LI$, so $L = \mu_0 N^2 A/l$. [2]

(c) $\varepsilon = \tfrac{1}{2}B\omega L^2$ with $\omega = 2\pi \times 60/60 = 2\pi$ rad/s: $\varepsilon = \tfrac{1}{2} \times 4.0 \times 10^{-3} \times 2\pi \times (0.5)^2 = \pi \times 10^{-3}$ V ≈ 3.14 mV. [2]

OR (b) (a) Diagram: primary and secondary coils (more turns) on a laminated soft-iron core. Principle: mutual induction. [1½]

The same flux links each turn: $\varepsilon_s = -N_s\, d\Phi/dt$, $\varepsilon_p = -N_p\, d\Phi/dt$, so $V_s/V_p = N_s/N_p$; for an ideal transformer $V_pI_p = V_sI_s$, so $V_s/V_p = N_s/N_p = I_p/I_s$. [1½]

(b) (i) $I_p = P/V_p = 5000/200 = 25$ A. [1] (ii) $V_s = 5 \times 200 = 1000$ V. [1]

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