CBSE Class 12 Physics

Sample Paper – 4

Duration: 180 Minutes **Maximum Marks: 70**

General Instructions

- This question paper contains **33 questions**. **All questions are compulsory**.
- The paper is divided into **five sections** – A, B, C, D and E.
- **Section A** (Q1–Q16) carries **1 mark** each: Q1–Q12 are multiple choice questions and Q13–Q16 are Assertion–Reason questions.
- **Section B** (Q17–Q21) carries **2 marks** each (Very Short Answer).
- **Section C** (Q22–Q28) carries **3 marks** each (Short Answer).
- **Section D** (Q29–Q30) carries **4 marks** each (case study based, with sub-parts).
- **Section E** (Q31–Q33) carries **5 marks** each (Long Answer).
- There is **no overall choice**, but an **internal choice** has been provided in some questions. Attempt only one of the alternatives in such questions.
- There is **no negative marking**. Use of a **calculator is not permitted**. 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 as required.

Section A (Q1–Q16) – 1 Mark Each

Q1. A flat surface of area $2\ \text{m}^2$ is placed in a uniform electric field of magnitude 100 N/C such that the normal to the surface makes an angle of $60°$ with the field. The electric flux through the surface is:

(A) $50\ \text{N m}^2/\text{C}$

(B) $200\ \text{N m}^2/\text{C}$

(C) $100\ \text{N m}^2/\text{C}$

(D) $0\,\mathrm{N\,m^2/C}$

Q2. Two cells of emf 2 V and 4 V, each of internal resistance $1\,\Omega$, are connected in series so that their emfs aid each other. This combination drives a current through an external resistance of $10\,\Omega$. The net emf and the current are:

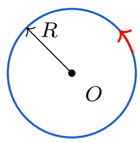
(A) 6 V, 0.5 A

(B) 2 V, 0.5 A

(C) 6 V, 1 A

(D) 8 V, 0.5 A

Q3. A circular loop of radius R carries a steady current I, as shown. The magnitude of the magnetic field at the centre O of the loop is:



current I

(A) $\dfrac{\mu_0 I}{2R}$

(B) $\dfrac{\mu_0 I}{2\pi R}$

(C) $\dfrac{\mu_0 I}{4\pi R}$

(D) $\dfrac{\mu_0 I}{R}$

Q4. Two coils are placed close to each other with a mutual inductance of 0.5 H. When the current in the primary coil changes from 0 to 4 A in 0.2 s, the magnitude of the emf induced in the secondary coil is:

(A) 5 V

(B) 10 V

(C) 20 V

(D) 2 V

Q5. In an AC circuit, the power factor $\cos\varphi$ represents:

(A) the ratio of apparent power to true power

(B) the product of the rms voltage and rms current

(C) the reciprocal of the impedance of the circuit

(D) the ratio of true power to apparent power, equal to $\frac{R}{Z}$

Q6. For a plane electromagnetic wave travelling in vacuum, the amplitudes E_0 and B_0 of the electric and magnetic fields are related by:

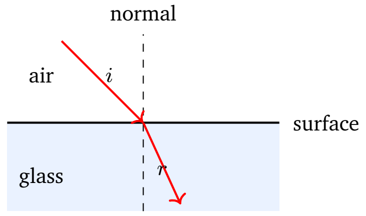
(A) $B_0 = cE_0$

(B) $E_0 = B_0$

(C) $E_0 = c^2 B_0$

(D) $E_0 = cB_0$

Q7. A ray of light travelling in air enters a denser medium (glass) at the interface, as shown. According to Snell's law, the refracted ray bends:



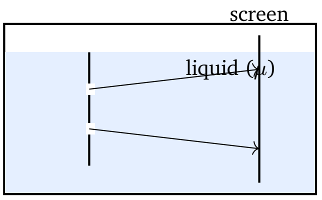
(A) away from the normal

(B) towards the normal

(C) along the same straight path, undeviated

(D) back along the incident ray

Q8. In Young's double-slit experiment the fringe width in air is β. If the entire apparatus is immersed in a transparent liquid of refractive index μ, the new fringe width becomes:



(A) $\mu\beta$

(B) β (unchanged)

(C) $\dfrac{\beta}{\mu}$

(D) $\mu^2\beta$

Q9. For a given metal illuminated by light of frequency above its threshold, the saturation photoelectric current is directly proportional to:

(A) the frequency of the incident light

(B) the work function of the metal

(C) the intensity of the incident light

(D) the wavelength of the incident light

Q10. When a nucleus ${}^{A}_{Z}X$ undergoes alpha decay, the mass number and the atomic number of the daughter nucleus become respectively:

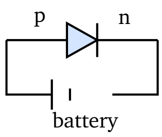
(A) $A-2,\ Z-4$

(B) $A-4,\ Z-2$

(C) $A-4,\ Z-1$

(D) $A-2,\ Z-2$

Q11. The p-n junction diode shown below conducts appreciable current only when it is connected in:



(A) forward bias

(B) reverse bias

(C) zero bias

(D) both forward and reverse bias equally

Q12. A $2\,\mu$F capacitor charged to 100 V and a $3\,\mu$F capacitor charged to 50 V are connected together, plates of like sign joined. The common potential of the combination is:

(A) 50 V

(B) 100 V

(C) 150 V

(D) 70 V

Q13. **Assertion (A):** The drift velocity of free electrons in a conductor is only of the order of 10^{-4} m/s, yet a bulb glows almost instantly when the switch is closed.
Reason (R): On closing the switch, an electric field is established throughout the circuit with a speed close to that of light, setting all the free electrons in motion almost simultaneously.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Q14. **Assertion (A):** The core of a transformer is built up of thin laminated sheets to reduce eddy-current losses.
Reason (R): Eddy currents can be induced only in a material that conducts electricity.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Q15. **Assertion (A):** The focal length of a glass lens increases when it is immersed in water.
Reason (R): The refractive index of glass with respect to water is greater than the refractive index of glass with respect to air.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Q16. Assertion (A): For the same speed, a heavier particle has a longer de Broglie wavelength than a lighter one.

Reason (R): The de Broglie wavelength of a particle is inversely proportional to its momentum.

(A) Both A and R are true and R is the correct explanation of A.

(B) Both A and R are true but R is *not* the correct explanation of A.

(C) A is true but R is false.

(D) A is false but R is true.

Section B (Q17–Q21) – 2 Marks Each

Q17. A parallel-plate capacitor has plates of area 100 cm^2 separated by 1 mm. The gap is completely filled with a dielectric of constant $K = 5$. Find its capacitance. (Take $\varepsilon_0 = 8.85 \times 10^{-12}$ F/m.) **[2]**

Q18. An electric bulb is rated "100 W, 220 V". Calculate the resistance of its filament at the operating voltage. **[2]**

Q19. An inductor of self-inductance 2 H carries a steady current of 3 A. Calculate the energy stored in its magnetic field. **[2]**

OR

The peak value of an alternating current is 4 A. Find its root-mean-square (rms) value.

Q20. The refractive index of a glass slab is 1.5. Calculate the critical angle for the glass-air interface. (Take $\sin^{-1}(0.667) \approx 42°$.) **[2]**

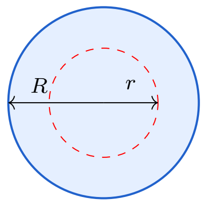
Q21. The work function of a metal is 2 eV. Calculate the threshold wavelength for photoelectric emission from this metal. (Take $hc = 1.989 \times 10^{-25}$ J m, 1 eV$= 1.6 \times 10^{-19}$ J.) **[2]**

OR

In a nuclear reaction the mass defect is 0.002 u. Calculate the energy released. (Take 1 u$= 931.5$ MeV/c^2.)

Section C (Q22–Q28) – 3 Marks Each

Q22. Using Gauss's law, derive an expression for the electric field at a point inside ($r < R$) a uniformly charged non-conducting solid sphere of radius R carrying total charge Q distributed uniformly through its volume.

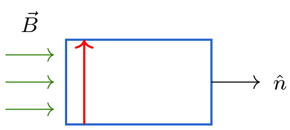


charge density ρ

[3]

Q23. State the balance condition of a Wheatstone bridge. In a balanced bridge the four arms are $P = 2\,\Omega$, $Q = 3\,\Omega$, $R = 4\,\Omega$ and an unknown resistance S. Find the value of S. **[3]**

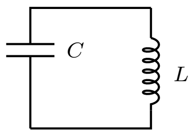
Q24. Derive an expression for the torque acting on a rectangular current-carrying loop of N turns placed in a uniform magnetic field B, with its plane parallel to the field.



loop of N turns, current I

[3]

Q25. An inductor $L = 2$ H and a capacitor $C = 8\,\mu$F form an ideal LC circuit that undergoes free electrical oscillations. Find the frequency of oscillation. (Take $\pi = 3.14$.)

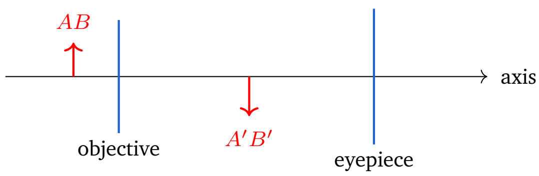


[3]

OR

For a sinusoidal alternating current $i = i_0 \sin \omega t$ of peak value i_0, write the expressions for its rms value and its average value over a positive half-cycle, and evaluate the ratio of the two.

Q26. Draw a labelled ray diagram of a compound microscope forming a magnified virtual image, and write the expression for its magnifying power in normal use.



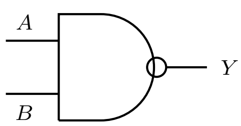
[3]

OR

Light passes from air ($n_1 = 1$) into glass ($n_2 = 1.5$) through a convex spherical refracting surface of radius of curvature $R = +10$ cm. A point object lies on the axis in air at 30 cm from the surface. Using $\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}$, find the position of the image.

Q27. The mass defect of a helium nucleus ${}^4_2\text{He}$ is 0.0304 u. Calculate its total binding energy and the binding energy per nucleon. (Take 1 u$=$ 931.5 MeV/c^2.) **[3]**

Q28. Show that the NAND gate is a universal gate by explaining, with truth tables, how it can be used to realise (i) a NOT gate and (ii) an AND gate.



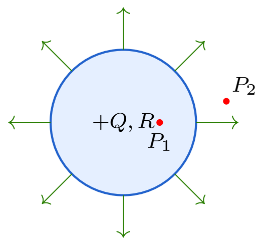
NAND

[3]

Section D (Q29–Q30) – 4 Marks Each (Case Study)

Q29. Case Study – Field and Potential of a Charged Sphere.

A solid non-conducting sphere of radius $R = 0.1$ m carries a total charge $Q = 10$ nC spread uniformly through its volume. The field is radial everywhere, and its behaviour differs inside and outside the sphere.



Based on the above, answer the following (take $\frac{1}{4\pi\varepsilon_0} = 9\times10^9$ N m^2/C^2):

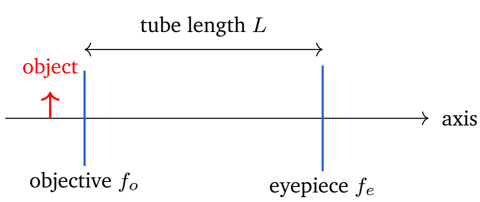
(i) Write the expression for the electric field at an interior point P_1 at distance $r < R$. (1)

(ii) Find the electric field just outside the surface of the sphere. (1)

(iii) Find the electric potential at the surface of the sphere. (2)

Q30. Case Study – Compound Microscope.

In a compound microscope the objective has focal length $f_o = 1$ cm and the eyepiece has focal length $f_e = 5$ cm. A tiny object is placed 1.25 cm in front of the objective, and the final image is viewed at the least distance of distinct vision $D = 25$ cm.



Based on the above, answer the following:

(i) Find the linear magnification produced by the objective. (1)

(ii) Find the angular magnification of the eyepiece (final image at D). (1)

(iii) Find the total magnifying power and the tube length L of the microscope. (2)

Section E (Q31–Q33) – 5 Marks Each

Q31. (a) Derive an expression for the electric potential at a point due to a system of point charges, and hence obtain the work done in assembling two point charges q_1 and q_2 separated by a distance r.

(b) Two point charges $q_1 = 2\,\mu$C and $q_2 = 3\,\mu$C are held 0.1 m apart in vacuum. Find the work done in bringing them from infinity to this configuration. (Take $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \mathrm{N\,m^2/C^2}$.) **[5]**

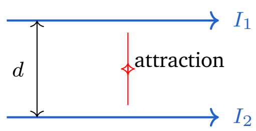
OR

(a) Describe the principle and working of a potentiometer, and explain with a circuit how it is used to measure the internal resistance of a cell.

(b) In such a measurement the balancing length is 80 cm with the cell on open circuit and 60 cm when a $4\,\Omega$ resistance is connected across the cell. Find the internal resistance of the cell.

Q32. (a) Derive the expression for the force per unit length between two long straight parallel conductors carrying currents I_1 and I_2 separated by a distance d, and use it to define the ampere.

(b) Two long parallel wires 1 m apart carry currents of 5 A and 10 A in the same direction. Find the force per unit length between them. (Take $\mu_0 = 4\pi \times 10^{-7}\ \mathrm{T\,m/A}$.)



[5]

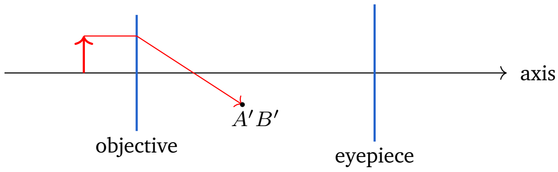
OR

(a) A capacitor C is charged through a resistor R from a battery of emf $\mathcal{E}$. Derive the expression for the growth of charge $q(t)$ on the capacitor, and define the time constant of the circuit.

(b) For $R = 1$ kΩ and $C = 1\,\mu$F, find the time constant, and state the fraction of the final charge acquired after one time constant.

Q33. (a) With a labelled ray diagram, derive the expression for the magnifying power of a compound microscope when the final image is formed at the least distance of distinct vision.

(b) A compound microscope has an objective of focal length 1 cm and an eyepiece of focal length 5 cm. If the tube length (image distance of the objective) is 20 cm and $D = 25$ cm, find its magnifying power.



[5]

OR

(a) Explain the dispersion of white light by a glass prism, and define the dispersive power of the prism material.

(b) For a certain glass, $\mu_v = 1.52$, $\mu_r = 1.50$ and $\mu_y = 1.51$. Calculate its dispersive power.

Detailed Solutions

Q1.

Solution

Concept — Electric flux through a flat surface: For a uniform field $\vec{E}$ through a flat area A, the flux is $\Phi = EA\cos\theta$, where θ is the angle between the field and the outward normal.

Step 1 — Write the formula:

$$\Phi = E\,A\cos\theta.$$

Step 2 — Substitute the given values:

$$\Phi = (100)(2)\cos 60^\circ.$$

Step 3 — Use $\cos 60^\circ = 0.5$:

$$\Phi = (100)(2)(0.5).$$

$$= 100\ \mathrm{N\,m^2/C}.$$

Why other options are wrong: (A) 50 uses an extra half; (B) 200 omits the $\cos 60^\circ$ factor; (D) 0 would need $\theta = 90^\circ$.

Final Answer: $\Phi = 100\ \mathrm{N\,m^2/C} \Rightarrow \boxed{\text{C}}$

Answer: (C) **Go Back to Q1**

Q2.

Solution

Concept — Cells in series aiding: The net emf is the sum of the individual emfs, and the total resistance is the sum of the external and the internal resistances.

Step 1 — Net emf:

$$\varepsilon = \varepsilon_1 + \varepsilon_2 = 2 + 4 = 6\ \mathrm{V}.$$

Step 2 — Total resistance:

$$R_{\text{total}} = R + r_1 + r_2 = 10 + 1 + 1 = 12\ \Omega.$$

Step 3 — Current from Ohm's law:

$$I = \frac{\varepsilon}{R_{\text{total}}} = \frac{6}{12}.$$

$$= 0.5 \text{ A}.$$

Why other options are wrong: (B) 2 V takes a difference of emfs; (C) 1 A ignores the internal resistances; (D) 8 V is not a valid sum.

Final Answer: Net emf 6 V, current 0.5 A $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept — Field at the centre of a circular loop: By the Biot–Savart law, every current element is at the same distance R from the centre and contributes a field along the same axis, giving $B = \frac{\mu_0 I}{2R}$.

Step 1 — Biot–Savart contribution: Each element $I\,dl$ at distance R gives

$$dB = \frac{\mu_0}{4\pi}\frac{I\,dl}{R^2}.$$

Step 2 — Integrate around the loop: The total length is $2\pi R$, so

$$B = \frac{\mu_0}{4\pi}\frac{I}{R^2}(2\pi R).$$

$$= \frac{\mu_0 I}{2R}.$$

Why other options are wrong: (B) and (C) are the forms for a straight wire ($\propto 1/\pi R$); (D) drops the factor of 2.

Final Answer: $B = \frac{\mu_0 I}{2R} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q3

Q4.

Solution

Concept — Mutual inductance: The emf induced in the secondary is $\varepsilon = M\dfrac{dI}{dt}$, where M is the mutual inductance.

Step 1 — Rate of change of primary current:

$$\frac{dI}{dt} = \frac{4-0}{0.2} = 20\ \text{A/s}.$$

Step 2 — Induced emf:

$$\varepsilon = M\frac{dI}{dt} = (0.5)(20).$$
$$= 10\ \text{V}.$$

Why other options are wrong: (A) 5 V halves the rate; (C) 20 V drops the factor M; (D) 2 V uses a wrong time interval.

Final Answer: $\varepsilon = 10\ \text{V} \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept — Power factor: The average (true) power in an AC circuit is $P = V_{\text{rms}} I_{\text{rms}} \cos\varphi$, while the apparent power is $V_{\text{rms}} I_{\text{rms}}$. Their ratio is the power factor.

Step 1 — Form the ratio:

$$\cos\varphi = \frac{\text{true power}}{\text{apparent power}} = \frac{V_{\text{rms}} I_{\text{rms}} \cos\varphi}{V_{\text{rms}} I_{\text{rms}}}.$$

Step 2 — Express through the impedance triangle: Since $R = Z\cos\varphi$,

$$\cos\varphi = \frac{R}{Z}.$$

Why other options are wrong: (A) inverts the ratio; (B) is the apparent power itself; (C) has the wrong dimensions.

Final Answer: $\cos\varphi = \dfrac{\text{true power}}{\text{apparent power}} = \dfrac{R}{Z} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept — EM wave field amplitudes: In a plane electromagnetic wave the electric and magnetic fields are in phase, and the speed of light equals the ratio of their amplitudes, $c = \frac{E_0}{B_0}$.

Step 1 — Write the defining relation:

$$c = \frac{E_0}{B_0}.$$

Step 2 — Rearrange for E_0:

$$E_0 = c\,B_0.$$

Why other options are wrong: (A) inverts the roles of E_0, B_0; (B) ignores the factor c; (C) uses c^2, which is dimensionally wrong.

Final Answer: $E_0 = cB_0 \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q6

Q7.

Solution

Concept — Snell's law: $n_1 \sin i = n_2 \sin r$. When light enters a denser medium ($n_2 > n_1$), the angle of refraction is smaller than the angle of incidence, so the ray bends towards the normal.

Step 1 — Apply Snell's law:

$$n_1 \sin i = n_2 \sin r.$$

Step 2 — Compare the angles: Since $n_2 > n_1$,

$$\sin r = \frac{n_1}{n_2} \sin i < \sin i \;\Rightarrow\; r < i.$$

Step 3 — Conclusion: A smaller refraction angle means the ray is deflected towards the normal.

Why other options are wrong: (A) bending away happens only into a rarer medium; (C) undeviated needs equal indices; (D) describes reflection, not refraction.

Final Answer: Towards the normal $\Rightarrow$ B

Answer: (B) Go Back to Q7

Q8.

Solution

Concept — Fringe width in a medium: The fringe width is $\beta = \dfrac{\lambda D}{d}$. Inside a medium of index μ the wavelength shortens to $\lambda_m = \dfrac{\lambda}{\mu}$, so the fringe width changes accordingly.

Step 1 — Fringe width in air:

$$\beta = \frac{\lambda D}{d}.$$

Step 2 — Wavelength in the liquid:

$$\lambda_m = \frac{\lambda}{\mu}.$$

Step 3 — New fringe width:

$$\beta_m = \frac{\lambda_m D}{d} = \frac{\lambda D}{\mu d} = \frac{\beta}{\mu}.$$

Why other options are wrong: (A) $\mu\beta$ has the effect reversed; (B) unchanged ignores the medium; (D) $\mu^2\beta$ has the wrong power.

Final Answer: $\beta_m = \dfrac{\beta}{\mu} \Rightarrow$ C

Answer: (C) Go Back to Q8

Q9.

Solution

Concept — Photoelectric current and intensity: Once the frequency exceeds the threshold, each photon can eject one electron. Raising the intensity raises the number of photons per second, hence the number of ejected electrons per second.

Step 1 — Relate current to electrons: The saturation photocurrent equals the charge of all emitted electrons per second, $I_{\text{ph}} = n_e\, e$.

Step 2 — Relate electrons to intensity: The photon arrival rate, and so n_e, is proportional to the intensity, giving $I_{\text{ph}} \propto$ intensity.

Why other options are wrong: (A) frequency and (D) wavelength set the stopping potential and $K_{\max}$, not the current; (B) work function is a property of the metal.

Final Answer: Photocurrent $\propto$ intensity $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q9

Q10.

Solution

Concept — Alpha decay: An α-particle is a helium nucleus ${}^4_2\text{He}$. Emitting it lowers the mass number by 4 and the atomic number by 2.

Step 1 — Write the decay:

$$ {}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\text{He}. $$

Step 2 — Read off the daughter values:

$$ A' = A - 4, \qquad Z' = Z - 2. $$

Why other options are wrong: (A) swaps the changes; (C) uses $Z - 1$ (that is beta decay behaviour); (D) uses the wrong mass loss.

Final Answer: $A - 4,\ Z - 2 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept — Diode conduction: A p-n junction conducts a large current only when the p-side is at higher potential (forward bias), which lowers the potential barrier and shrinks the depletion region.

Step 1 — Forward bias: With p connected to the positive terminal, the barrier is reduced and majority carriers cross the junction, giving a large current.

Step 2 — Reverse bias: With the polarity reversed, the barrier widens and only a tiny leakage current flows.

Why other options are wrong: (B) reverse bias gives negligible current; (C) zero bias gives no net current; (D) the two biases are not equivalent.

Final Answer: Forward bias $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q11

Q12.

Solution

Concept — Common potential: When two charged capacitors are joined, charge redistributes until both reach a common potential $V = \dfrac{C_1V_1 + C_2V_2}{C_1 + C_2}$ (total charge conserved).

Step 1 — Total charge before joining:

$$Q_{\text{total}} = C_1V_1 + C_2V_2 = (2)(100) + (3)(50).$$

$$= 200 + 150 = 350\ \mu\text{C}.$$

Step 2 — Total capacitance in parallel:

$$C_{\text{total}} = C_1 + C_2 = 2 + 3 = 5\ \mu\text{F}.$$

Step 3 — Common potential:

$$V = \frac{350}{5} = 70\ \text{V}.$$

Why other options are wrong: (A) 50 and (B) 100 pick a single original voltage; (C) 150 adds the voltages.

Final Answer: $V = 70\ \text{V} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q12

Q13.

Solution

Concept — Assertion–Reason on conduction: Judge each statement, then test whether R explains A.

Step 1 — Assertion: The drift speed is indeed only $\sim 10^{-4}$ m/s, yet the bulb lights up at once. So A is **true**.

Step 2 — Reason: On closing the switch the electric field propagates through the wire almost at the speed of light, so every electron everywhere starts drifting nearly simultaneously. So R is **true**.

Step 3 — Does R explain A? The near-instant glow is precisely because the field, not the slow electrons, travels almost instantly and starts the current everywhere at once. So R correctly explains A.

Why other options are wrong: (B) denies a real causal link; (C),(D) misjudge a truth value.

Final Answer: Both true, R explains A $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept — Laminated core: Judge each statement, then test whether R explains A.

Step 1 — Assertion: A transformer core is laminated (thin insulated sheets) to cut down eddy-current heating. So A is **true**.

Step 2 — Reason: Eddy currents are indeed induced only in conducting material, since a current needs free charge carriers. So R is **true**.

Step 3 — Does R explain A? Lamination works by *breaking the conducting paths* and raising resistance to the eddy currents; merely stating that eddy currents need a conductor does not by itself explain why thin sheets reduce the loss. So R is true but is **not** the correct explanation of A.

Why other options are wrong: (A) claims a direct explanation that is missing; (C),(D) misjudge a truth value.

Final Answer: Both true, R does not explain A $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

Concept — Lens focal length in a medium: By the lens maker's formula $\frac{1}{f} = ({}_m n_g - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$, the focal length depends on the refractive index of the lens *relative to* the surrounding medium.

Step 1 — Assertion: Since ${}_w n_g = \frac{1.5}{1.33} \approx 1.13 < 1.5$, the factor $({}_m n_g - 1)$ becomes much smaller in water, so f *increases*. Thus A is **true**.

Step 2 — Reason: The refractive index of glass with respect to water (≈ 1.13) is *smaller*, not greater, than that with respect to air (1.5). So the stated R is **false**.

Step 3 — Combine: A is true but R is false.

Why other options are wrong: (A),(B) require R true; (D) requires A false.

Final Answer: A true, R false $\Rightarrow$ C

Answer: (C) Go Back to Q15

Q16.

Solution

Concept — de Broglie wavelength: $\lambda = \frac{h}{p} = \frac{h}{mv}$; for a fixed speed, $\lambda \propto \frac{1}{m}$.

Step 1 — Assertion: At the same speed a *heavier* particle has larger momentum $p = mv$, hence a *shorter* wavelength. The claim that it has a longer wavelength is **false**.

Step 2 — Reason: $\lambda = \frac{h}{p}$, so the wavelength is genuinely inversely proportional to momentum. So R is **true**.

Step 3 — Combine: A is false and R is true.

Why other options are wrong: (A),(B) require A true; (C) requires R false.

Final Answer: A false, R true $\Rightarrow$ D

Answer: (D) Go Back to Q16

Q17.

Solution

Concept — Dielectric-filled capacitor: $C = \frac{K\varepsilon_0 A}{d}$.

Step 1 — Convert to SI units:

$$A = 100\ \text{cm}^2 = 100 \times 10^{-4}\ \text{m}^2 = 1 \times 10^{-2}\ \text{m}^2.$$

$$d = 1\ \text{mm} = 1 \times 10^{-3}\ \text{m}.$$

Step 2 — Substitute into the formula:

$$C = \frac{(5)(8.85 \times 10^{-12})(1 \times 10^{-2})}{1 \times 10^{-3}}.$$

Step 3 — Simplify the numerator:

$$(5)(8.85 \times 10^{-12}) = 4.425 \times 10^{-11}.$$

$$(4.425 \times 10^{-11})(1 \times 10^{-2}) = 4.425 \times 10^{-13}.$$

Step 4 — Divide by d:

$$C = \frac{4.425 \times 10^{-13}}{1 \times 10^{-3}} = 4.425 \times 10^{-10}\ \text{F}.$$

Final Answer: $C \approx 4.43 \times 10^{-10}\ \text{F} = 442\ \text{pF}$. Go Back to Q17

Q18.

Solution

Concept — Power rating of a bulb: At the rated voltage, $P = \frac{V^2}{R}$, so $R = \frac{V^2}{P}$.

Step 1 — Write the working formula:

$$R = \frac{V^2}{P}.$$

Step 2 — Substitute the rated values:

$$R = \frac{(220)^2}{100}.$$

Step 3 — Evaluate the square:

$$(220)^2 = 48400.$$

Step 4 — Divide:

$$R = \frac{48400}{100} = 484\ \Omega.$$

Final Answer: Resistance of the filament $= 484\,\Omega$. Go Back to Q18

Q19.

Solution

Concept — Energy stored in an inductor: $U = \frac{1}{2}LI^2$.

Step 1 — Substitute the values:

$$U = \frac{1}{2}(2)(3)^2.$$

Step 2 — Square the current:

$$(3)^2 = 9.$$

Step 3 — Multiply out:

$$U = \frac{1}{2}(2)(9) = \frac{1}{2}(18).$$
$$= 9 \text{ J}.$$

Final Answer: Energy stored $= 9$ J.

OR — rms value of the current:

Step 1 — Relation: $I_{\text{rms}} = \frac{i_0}{\sqrt{2}}$.

Step 2 — Substitute:

$$I_{\text{rms}} = \frac{4}{\sqrt{2}} = \frac{4}{1.414}.$$
$$= 2.83 \text{ A}.$$

Final Answer (OR): $I_{\text{rms}} \approx 2.83$ A. **Go Back to Q19**

Q20.

Solution

Concept — Critical angle: At the critical angle the refracted ray grazes the surface, so $\sin\theta_c = \frac{1}{\mu}$.

Step 1 — Write the relation:

$$\sin\theta_c = \frac{1}{\mu}.$$

Step 2 — Substitute $\mu = 1.5$:

$$\sin\theta_c = \frac{1}{1.5} = 0.667.$$

Step 3 — Take the inverse sine:

$$\theta_c = \sin^{-1}(0.667) \approx 42^\circ.$$

Final Answer: Critical angle $\theta_c \approx 42^\circ$. **Go Back to Q20**

Q21.

Solution

Concept — Threshold wavelength: Emission just begins when a photon's energy equals the work function, $\frac{hc}{\lambda_0} = W$, so $\lambda_0 = \frac{hc}{W}$.

Step 1 — Work function in joules:

$$W = 2\ \text{eV} = 2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}\ \text{J}.$$

Step 2 — Substitute into $\lambda_0 = \frac{hc}{W}$:

$$\lambda_0 = \frac{1.989 \times 10^{-25}}{3.2 \times 10^{-19}}.$$

Step 3 — Divide:

$$\lambda_0 = 6.22 \times 10^{-7}\ \text{m}.$$

Final Answer: $\lambda_0 \approx 6.22 \times 10^{-7}\ \text{m} = 622\ \text{nm}$.

OR — Energy from mass defect:

Step 1 — Use $E = \Delta m\, c^2$ in MeV units:

$$E = (0.002)(931.5)\ \text{MeV}.$$

Step 2 — Multiply:

$$E = 1.863\ \text{MeV}.$$

Final Answer (OR): Energy released ≈ 1.86 MeV. **Go Back to Q21**

Q22.

Solution

Concept — Gauss's law inside a uniform charge: $\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\varepsilon_0}$; for $r < R$ only the charge within radius r is enclosed.

Step 1 — Volume charge density:

$$\rho = \frac{Q}{\frac{4}{3}\pi R^3}.$$

Step 2 — Charge enclosed within radius r:

$$q_{\text{enc}} = \rho\left(\tfrac{4}{3}\pi r^3\right) = Q\frac{r^3}{R^3}.$$

Step 3 — Flux through a Gaussian sphere of radius r:

$$\oint \vec{E} \cdot d\vec{A} = E\,(4\pi r^2).$$

Step 4 — Apply Gauss's law:

$$E\,(4\pi r^2) = \frac{1}{\varepsilon_0}\,Q\frac{r^3}{R^3}.$$

Step 5 — Solve for E:

$$E = \frac{1}{4\pi\varepsilon_0}\frac{Q\,r}{R^3}.$$

Final Answer: Inside the sphere $E = \frac{1}{4\pi\varepsilon_0}\frac{Qr}{R^3}$, i.e. $E \propto r$, rising linearly from the centre. **Go Back to Q22**

Q23.

Solution

Concept — Wheatstone bridge balance: When no current flows through the galvanometer, the ratios of the arms are equal, $\frac{P}{Q} = \frac{R}{S}$.

Step 1 — Write the balance condition:

$$\frac{P}{Q} = \frac{R}{S}.$$

Step 2 — Rearrange for S:

$$S = \frac{Q\,R}{P}.$$

Step 3 — Substitute the values:

$$S = \frac{(3)(4)}{2}.$$

Step 4 — Evaluate:

$$S = \frac{12}{2} = 6\,\Omega.$$

Final Answer: Unknown resistance $S = 6\,\Omega$. **Go Back to Q23**

Q24.

Solution

Concept — Torque on a current loop: Opposite sides of the loop carry currents in opposite directions, so the forces on them form a couple that tends to rotate the loop.

Step 1 — Force on one side of length ℓ: A side carrying current I in field B feels

$$F = BI\ell.$$

Step 2 — The two sides of length ℓ: These carry current in opposite senses, so the forces F are equal and opposite, separated by the breadth b, forming a couple.

Step 3 — Torque of the couple (plane parallel to B):

$$\tau = F \times b = (BI\ell)\,b.$$

Step 4 — Introduce area and turns: With $A = \ell b$ and N turns,

$$\tau = NBI\,(\ell b) = NBIA.$$

Final Answer: $\tau = NBIA$ (maximum, since the plane is parallel to B); in general $\tau = NBIA\sin\theta$. **Go Back to Q24**

Q25.

Solution

Concept — LC oscillations: Energy sloshes between the capacitor and the inductor at the natural frequency $f = \dfrac{1}{2\pi\sqrt{LC}}$.

Step 1 — Product LC:

$$LC = (2)(8 \times 10^{-6}) = 16 \times 10^{-6}.$$

Step 2 — Square root:

$$\sqrt{LC} = \sqrt{16 \times 10^{-6}} = 4 \times 10^{-3}.$$

Step 3 — Apply the formula:

$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2(3.14)(4 \times 10^{-3})}.$$

Step 4 — Evaluate the denominator and divide:

$$2(3.14)(4 \times 10^{-3}) = 2.512 \times 10^{-2}.$$

$$f = \frac{1}{2.512 \times 10^{-2}} \approx 39.8 \text{ Hz}.$$

Final Answer: $f \approx 39.8$ Hz.

OR — rms and average values of AC:

Step 1 — rms value over a full cycle:

$$i_{\text{rms}} = \frac{i_0}{\sqrt{2}} = 0.707\, i_0.$$

Step 2 — Average value over a positive half-cycle:

$$i_{\text{avg}} = \frac{2i_0}{\pi} = 0.637\, i_0.$$

Step 3 — Ratio (form factor):

$$\frac{i_{\text{rms}}}{i_{\text{avg}}} = \frac{i_0/\sqrt{2}}{2i_0/\pi} = \frac{\pi}{2\sqrt{2}} \approx 1.11.$$

Final Answer (OR): $i_{\rm rms} = \dfrac{i_0}{\sqrt{2}}$, $i_{\rm avg} = \dfrac{2i_0}{\pi}$, ratio ≈ 1.11. Go Back to Q25

Q26.

Solution

Concept — Compound microscope: The objective forms a real, magnified image inside the tube; the eyepiece then acts as a magnifier of this image. The overall magnifying power is the product of the two stage magnifications.

Step 1 — Objective and eyepiece action: A small object just beyond the objective's focus gives a real inverted image $A'B'$; the eyepiece, used as a simple microscope, magnifies $A'B'$ into the final virtual image.

Step 2 — Magnifying power (normal use, image at D):

$$M = m_o \times m_e = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right),$$

where L is the tube length, f_o and f_e the focal lengths and D the least distance of distinct vision.

Final Answer: $M = \dfrac{L}{f_o}\left(1 + \dfrac{D}{f_e}\right)$ (product of objective and eyepiece magnifications).

OR — Refraction at a spherical surface:

Step 1 — Assign values (real-object sign convention): $n_1 = 1$, $n_2 = 1.5$, $R = +10$ cm, $u = -30$ cm.

Step 2 — Write the refraction relation:

$$\frac{n_2}{v} - \frac{n_1}{u} = \frac{n_2 - n_1}{R}.$$

Step 3 — Substitute:

$$\frac{1.5}{v} - \frac{1}{-30} = \frac{1.5 - 1}{10}.$$

Step 4 — Simplify each term:

$$\frac{1.5}{v} + \frac{1}{30} = \frac{0.5}{10} = 0.05.$$

$$\frac{1.5}{v} = 0.05 - 0.0333 = 0.01667.$$

Step 5 — Solve for v:

$$v = \frac{1.5}{0.01667} = 90 \text{ cm}.$$

Final Answer (OR): The image forms 90 cm from the surface, inside the glass (real). Go Back to Q26

Q27.

Solution

Concept — Binding energy: The energy equivalent of the mass defect is the binding energy, $BE = \Delta m \times 931.5$ MeV (with Δm in u).

Step 1 — Total binding energy:

$$BE = (0.0304)(931.5) \text{ MeV}.$$

Step 2 — Multiply:

$$BE = 28.32 \text{ MeV}.$$

Step 3 — Binding energy per nucleon: Helium-4 has $A = 4$ nucleons, so

$$\frac{BE}{A} = \frac{28.32}{4}.$$

$$= 7.08 \text{ MeV/nucleon}.$$

Final Answer: $BE \approx 28.3$ MeV; binding energy per nucleon ≈ 7.08 MeV. Go Back to Q27

Q28.

Solution

Concept — Universal gate: A NAND gate gives $Y = \overline{A \cdot B}$. By wiring its inputs suitably, it can reproduce NOT and AND, so it is called universal.

Step 1 — NAND as a NOT gate: Tie both inputs together ($A = B$):

$$Y = \overline{A \cdot A} = \overline{A}.$$

A	$Y = \overline{A}$
0	1
1	0

Step 2 — NAND as an AND gate: Take a NAND, then invert its output with a second NAND (used as NOT):

$$Y = \overline{\overline{A \cdot B}} = A \cdot B.$$

A	B	$Y = A \cdot B$
0	0	0
0	1	0
1	0	0
1	1	1

Final Answer: A single NAND with joined inputs gives NOT; two NANDs in cascade give AND, proving NAND is a universal gate. Go Back to Q28

Q29.

Solution

Concept — Uniformly charged sphere: Inside, E grows linearly ($E \propto r$); outside and at the surface, the sphere behaves like a point charge at its centre.

(i) Field at an interior point $r < R$:

$$E_{\text{in}} = \frac{1}{4\pi\varepsilon_0} \frac{Q\,r}{R^3}.$$

(ii) Field just outside the surface ($r = R$):

$$E_{\text{out}} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{R^2} = \frac{(9 \times 10^9)(10 \times 10^{-9})}{(0.1)^2}.$$

$$= \frac{(9 \times 10^9)(1 \times 10^{-8})}{0.01} = \frac{90}{0.01} = 9000 \text{ N/C}.$$

(iii) Potential at the surface:

$$V = \frac{1}{4\pi\varepsilon_0} \frac{Q}{R} = \frac{(9 \times 10^9)(10 \times 10^{-9})}{0.1}.$$

$$= \frac{90}{0.1} = 900 \text{ V}.$$

Final Answer: $E_{\text{in}} = \dfrac{1}{4\pi\varepsilon_0} \dfrac{Qr}{R^3}$; $E_{\text{out}} = 9000$ N/C; $V_{\text{surface}} = 900$ V. Go Back to Q29

Q30.

Solution

Concept — Compound microscope magnification: The objective gives a linear magnification $m_o = \dfrac{v_o}{u_o}$; the eyepiece (final image at D) gives $m_e = 1 + \dfrac{D}{f_e}$; total $M = m_o \times m_e$.

(i) Objective magnification: First locate the image using $\frac{1}{v_o} - \frac{1}{u_o} = \frac{1}{f_o}$ with $u_o = -1.25$ cm, $f_o = 1$ cm:

$$\frac{1}{v_o} = \frac{1}{1} + \frac{1}{-1.25} = 1 - 0.8 = 0.2.$$

$$v_o = 5 \text{ cm}.$$

$$m_o = \frac{v_o}{u_o} = \frac{5}{-1.25} = -4.$$

(ii) Eyepiece magnification (image at $D = 25$ cm):

$$m_e = 1 + \frac{D}{f_e} = 1 + \frac{25}{5} = 1 + 5 = 6.$$

(iii) Total magnifying power and tube length:

$$M = m_o \times m_e = (-4)(6) = -24.$$

For the eyepiece, $\frac{1}{-25} - \frac{1}{u_e} = \frac{1}{5} \Rightarrow u_e = -\frac{25}{6} \approx -4.17$ cm, so

$$L = v_o + |u_e| = 5 + 4.17 = 9.17 \text{ cm}.$$

Final Answer: $m_o = -4$, $m_e = 6$, $M = -24$ (magnitude 24); tube length $L \approx 9.2$ cm. **Go Back to Q30**

Q31.

Solution

Concept — Potential of point charges and assembly work: Potentials add algebraically; the work to assemble charges equals the electrostatic potential energy of the final configuration.

(a) Potential due to a system of point charges: The potential at a point due to charges $q_1, q_2, \ldots$ at distances $r_1, r_2, \ldots$ is the scalar sum

$$V = \frac{1}{4\pi\varepsilon_0} \sum_i \frac{q_i}{r_i}.$$

To assemble two charges, bring q_1 in first (no work, empty space). Then q_2 is brought to distance r against the potential $V_1 = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{r}$ of q_1:

$$W = q_2 V_1 = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r}.$$

(b) Numerical work done:

$$W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = (9\times10^9)\frac{(2\times10^{-6})(3\times10^{-6})}{0.1}.$$

$$= (9\times10^9)\frac{6\times10^{-12}}{0.1}.$$

$$= (9\times10^9)(6\times10^{-11}) = 0.54\text{ J}.$$

Final Answer: $W = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r} = 0.54$ J.

OR — Potentiometer and internal resistance:

(a) A potentiometer works on the principle that the potential drop across a uniform wire is proportional to its length ($V \propto \ell$) for a steady current. To find a cell's internal resistance r, the cell is balanced first on open circuit (length ℓ_1), then with a known resistance R across it (length ℓ_2). Since $\ell_1 \propto \mathcal{E}$ and $\ell_2 \propto V$ (terminal voltage),

$$r = R\left(\frac{\ell_1 - \ell_2}{\ell_2}\right).$$

(b) With $\ell_1 = 80$ cm, $\ell_2 = 60$ cm, $R = 4\,\Omega$:

$$r = 4\left(\frac{80-60}{60}\right) = 4\left(\frac{20}{60}\right) = 4\times\frac{1}{3}.$$

$$= 1.33\ \Omega.$$

Final Answer (OR): Internal resistance $r \approx 1.33\,\Omega$. **Go Back to Q31**

Q32.

Solution

Concept — Force between parallel currents: Each wire sits in the magnetic field of the other; the mutual force per unit length is $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}$, attractive for like directions.

(a) Derivation and definition of the ampere: Wire 1 produces a field at wire 2:

$$B_1 = \frac{\mu_0 I_1}{2\pi d}.$$

The force on length L of wire 2 (current I_2) is

$$F = B_1 I_2 L = \frac{\mu_0 I_1 I_2 L}{2\pi d}.$$

So the force per unit length is
$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d}.$$
Definition of the ampere: one ampere is the steady current which, flowing in each of two infinitely long parallel wires 1 m apart in vacuum, produces a force of 2×10^{-7} N per metre of length between them.

(b) Numerical force per unit length:

$$\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d} = \frac{(4\pi \times 10^{-7})(5)(10)}{2\pi(1)}.$$
$$= \frac{(2 \times 10^{-7})(5)(10)}{1}.$$
$$= (2 \times 10^{-7})(50) = 1 \times 10^{-5}\ \text{N/m}.$$

Final Answer: $\frac{F}{L} = \frac{\mu_0 I_1 I_2}{2\pi d} = 1 \times 10^{-5}$ N/m (attractive).

OR — Charging a capacitor through a resistor:

(a) With the loop equation $\mathcal{E} = \frac{q}{C} + R\frac{dq}{dt}$, separating variables and integrating from 0 to t gives the growth of charge

$$q(t) = C\mathcal{E}\left(1 - e^{-t/RC}\right).$$

The *time constant* $\tau = RC$ is the time in which the charge rises to $\left(1 - \frac{1}{e}\right)$ of its final value.

(b) With $R = 1\ \text{k}\Omega = 10^3\ \Omega$ and $C = 1\ \mu\text{F} = 10^{-6}$ F,

$$\tau = RC = (10^3)(10^{-6}) = 10^{-3}\ \text{s} = 1\ \text{ms}.$$

After one time constant the charge reaches $\left(1 - \frac{1}{e}\right) \approx 0.63$, i.e. about 63% of the final charge.

Final Answer (OR): $q(t) = C\mathcal{E}(1 - e^{-t/RC})$; $\tau = 1$ ms; $\approx 63\%$ after one τ. **Go Back to Q32**

Q33.

Solution

Concept — Magnifying power of a compound microscope: The objective magnifies the object, and the eyepiece angularly magnifies that intermediate image; the total is the product.

(a) Derivation (final image at D): The objective forms a real image of linear magnification

$$m_o = \frac{L}{f_o},$$

where L is the image distance (tube length). The eyepiece, acting as a simple magnifier with the final image at the near point D, gives angular magnification

$$m_e = 1 + \frac{D}{f_e}.$$

The total magnifying power is the product

$$M = m_o \times m_e = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right).$$

(b) Numerical value: With $L = 20$ cm, $f_o = 1$ cm, $f_e = 5$ cm, $D = 25$ cm:

$$m_o = \frac{L}{f_o} = \frac{20}{1} = 20.$$

$$m_e = 1 + \frac{25}{5} = 1 + 5 = 6.$$

$$M = (20)(6) = 120.$$

Final Answer: $M = \frac{L}{f_o}\left(1 + \frac{D}{f_e}\right) = 120.$

OR — Dispersion and dispersive power:

(a) A prism bends violet light more than red because the refractive index of glass is larger for shorter wavelengths. White light therefore spreads into its constituent colours, an effect called dispersion. The *dispersive power* is the ratio of the angular dispersion (between violet and red) to the mean deviation:

$$\omega = \frac{\delta_v - \delta_r}{\delta_y} = \frac{\mu_v - \mu_r}{\mu_y - 1}.$$

(b) With $\mu_v = 1.52$, $\mu_r = 1.50$, $\mu_y = 1.51$:

$$\omega = \frac{1.52 - 1.50}{1.51 - 1} = \frac{0.02}{0.51}.$$

$$= 0.039.$$

Final Answer (OR): $\omega = \dfrac{\mu_v - \mu_r}{\mu_y - 1} \approx 0.039$. **Go Back to Q33**

Answer Key – Section A (Q1–Q16)

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	C	2	A	3	A	4	B	5	D
6	D	7	B	8	C	9	C	10	B
11	A	12	D	13	A	14	B	15	C
16	D								

Sections B–E are descriptive; refer to the Detailed Solutions above for full model answers and step marking.