

ISC Class 12 Physics Specimen Paper 1

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Maximum Marks: 70 | Time Allowed: Three hours | Reading Time: 15 minutes

Paper 1 (Theory) carries 70 marks. All four Sections are compulsory.

General Instructions

Write your answers on the separate answer paper provided. The first 15 minutes are for reading the paper, and you may not write during that time. All four Sections are compulsory, and you must attempt every question. Marks for each question, or part of a question, are shown in brackets. All working for numerical questions must be shown on the same sheet as the answer, and the final answer must carry its unit. Every physical constant you need is given inside the question that needs it. Circuit diagrams and ray diagrams are not printed in this paper, and where a question describes an arrangement you are expected to draw it yourself in pencil and label it. This paper carries 70 of the 100 marks for the subject, the remaining 30 being for the practical work and the project.

SECTION A (16 Marks)

Attempt all parts of Question 1.

Question 1 [16]

Each part carries 1 mark. For the parts that offer four choices, write only the option you choose. For the rest, answer in a single sentence.

- (i) Three capacitors, each of $3\ \mu\text{F}$, are joined end to end in series. The capacitance of the combination is:
(a) $9\ \mu\text{F}$ (b) $3\ \mu\text{F}$ (c) $1\ \mu\text{F}$ (d) $0.33\ \mu\text{F}$
- (ii) State the value of the electric field at a point lying inside the hollow space of a charged metal sphere.
- (iii) In a metre bridge an unknown resistance is placed in the left gap and a $6\ \Omega$ resistance in the right gap. The balance point is found $40\ \text{cm}$ from the left end. The unknown resistance is:
(a) $4\ \Omega$ (b) $6\ \Omega$ (c) $9\ \Omega$ (d) $2.4\ \Omega$
- (iv) Define the drift velocity of the free electrons in a metallic conductor.
- (v) A cyclotron cannot be used to accelerate a:
(a) proton (b) deuteron (c) alpha particle (d) neutron
- (vi) State how the magnetic susceptibility of a diamagnetic substance compares with zero.
- (vii) A coil develops an induced emf of $2\ \text{V}$ when the current through it changes at the rate of $4\ \text{A s}^{-1}$. Its self inductance is:
(a) $8\ \text{H}$ (b) $0.5\ \text{H}$ (c) $2\ \text{H}$ (d) $0.25\ \text{H}$
- (viii) Name the condition under which the average power drawn by an a.c. circuit over one full cycle is zero.
- (ix) Of the following members of the electromagnetic spectrum, the one with the shortest wavelength is:
(a) microwaves (b) ultraviolet rays (c) gamma rays (d) infrared rays
- (x) State the SI unit of the power of a lens.
- (xi) Light reflected from a plane glass surface is completely plane polarised when the angle of incidence is equal to:
(a) the critical angle (b) 90° (c) zero (d) the polarising angle
- (xii) The critical angle for a medium of refractive index $\sqrt{2}$ with respect to air is:
(a) 30° (b) 45° (c) 60° (d) 90°
- (xiii) In a photoelectric experiment the stopping potential depends upon:

- (a) the frequency of the incident light and the work function of the metal
 - (b) the intensity of the incident light alone
 - (c) the area of the emitting surface (d) the distance of the source from the metal
- (xiv) State what the scattering of a few alpha particles through very large angles told Rutherford about the structure of the atom.
- (xv) When a nucleus undergoes beta minus decay, its mass number:
- (a) rises by one (b) falls by one
 - (c) remains unchanged (d) falls by four
- (xvi) A Zener diode working as a voltage regulator is joined:
- (a) in forward bias and in series with the load
 - (b) in reverse bias and in parallel with the load
 - (c) in forward bias and in parallel with the load
 - (d) in reverse bias and in series with the load

SECTION B (14 Marks)

Attempt all parts of Question 2.

Question 2 [14]

- (i) Define an equipotential surface and explain why no work is done in carrying a charge from one point to another along such a surface. [2]
- (ii) A cell of emf 2 V and internal resistance 0.5 ohm is joined to an external resistance of 3.5 ohm. Calculate the current drawn from the cell and the potential difference across its terminals. [2]
- (iii) A coil of 500 turns, each of area $2 \times 10^{-2} \text{ m}^2$, is held with its plane at right angles to a magnetic field. The field falls steadily from 0.4 T to zero in 0.1 s. Calculate the emf induced in the coil. [2]
- (iv) State any two properties of electromagnetic waves, and name the term that Maxwell added to Ampere's circuital law. [2]
- (v) An object is placed 15 cm from a converging lens of focal length 10 cm. Calculate the distance of the image from the lens and its magnification. [2]
- (vi) An electron is accelerated from rest through a potential difference of 100 V. Calculate the de Broglie wavelength associated with it. Take $h = 6.63 \times 10^{-34} \text{ J s}$, mass of electron = $9.1 \times 10^{-31} \text{ kg}$ and charge of electron = $1.6 \times 10^{-19} \text{ C}$. [2]
- (vii) Explain why an audio signal is not radiated directly from an antenna, giving two separate reasons. [2]

SECTION C (15 Marks)

Attempt all parts of Question 3.

Question 3 [15]

- (i) Capacitors of 2 μF , 3 μF and 6 μF are joined in parallel across a 10 V battery. Calculate the capacitance of the combination, the total charge drawn from the battery and the energy stored in the combination. [3]
- (ii) Two long straight parallel wires, held 20 cm apart in air, carry currents of 5 A and 10 A in the same direction. Calculate the magnetic flux density produced by the 5 A wire at a point 10 cm from it, calculate the force per unit length between the wires, and state whether the force is one of attraction or of repulsion. Take $\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$. [3]
- (iii) In Young's experiment two narrow slits 0.3 mm apart are lit by light of wavelength 600 nm, and the fringes are received on a screen 1.5 m away. Calculate the fringe width and the distance of the third bright fringe from the centre of the pattern, and state what happens to the fringe width if the screen is moved further away. [3]

- (iv) Calculate the mass defect, the binding energy and the binding energy per nucleon of a helium nucleus, ${}^4_2\text{He}$. Take the mass of a proton as 1.00728 u, the mass of a neutron as 1.00866 u, the mass of the helium nucleus as 4.00151 u and 1 u as equivalent to 931.5 MeV. [3]
- (v) Explain what is meant by the forward bias and the reverse bias of a p-n junction diode. Sketch the shape of the current against voltage graph you would obtain for such a diode in both biases, and state what the knee voltage of the diode means. [3]

SECTION D (25 Marks)

Attempt all five questions from this Section. Each question carries 5 marks.

Question 4 [5]

- (a) Derive an expression for the electric field intensity at a point on the axis of a short electric dipole, the point lying at a distance r from the centre of the dipole on the side of the positive charge. State the direction of the field. [3]
- (b) An electric dipole of moment $2 \times 10^{-8} \text{ C m}$ is held in a uniform electric field of $5 \times 10^4 \text{ N C}^{-1}$ with its axis at 30 degrees to the field. Calculate the torque acting on the dipole, and state the position in which the torque would be the greatest. [2]

Question 5 [5]

- (a) State Kirchhoff's junction rule and Kirchhoff's loop rule, and name the conservation principle on which each of them rests. [2]
- (b) A cell of emf 10 V and internal resistance 2 ohm is joined in parallel with a cell of emf 8 V and internal resistance 4 ohm, like poles being connected together, and the combination sends current through an external resistance of 4 ohm. Draw the circuit from this description and calculate the current through the external resistance and the current supplied by each cell. [3]

Question 6 [5]

- (a) A resistance of 10 ohm, an inductance of 0.5 H and a capacitance of $8 \mu\text{F}$ are joined in series across a 220 V a.c. supply whose frequency can be varied. Draw the circuit from this description and calculate the frequency at which the circuit resonates, the current at resonance and the quality factor of the circuit. [3]
- (b) Explain why the circuit in part (a) behaves as a pure resistance at resonance, and explain what is meant by a wattless current. [2]

Question 7 [5]

- (a) A ray of light passes through a glass prism of refracting angle A . Using the path of the ray through the prism, derive the relation connecting the refractive index of the glass, the angle A and the angle of minimum deviation. State the condition that holds at minimum deviation. [3]
- (b) An equilateral glass prism has a refractive index of 1.5. Calculate the angle of minimum deviation for the prism and the angle of incidence at which it occurs. [2]

Question 8 [5]

- (a) Describe, with a circuit you draw from this description, a full wave rectifier that uses a centre tapped transformer and two junction diodes. Explain how the two diodes conduct in turn, and state the frequency of the ripple in the output when the input supply has a frequency of 50 Hz. [3]
- (b) Draw the truth table of a two input NAND gate, and show by means of the same gate how the action of a NOT gate may be obtained. [2]

ANSWER KEY AND MARKING SCHEME

Full working is given for every numerical, and every answer is quoted to three significant figures unless the figures work out exactly. Marks shown in italics are the step marks an examiner would award. Accept any correct alternative method that reaches the same answer, and accept a correctly labelled diagram drawn in any reasonable style.

Question 1 [16]

- (i) (c) $1\ \mu\text{F}$. For a series joining $1/C = 1/3 + 1/3 + 1/3 = 1$, so $C = 1\ \mu\text{F}$.
- (ii) The field there is zero, because all the charge given to a conductor settles on its outer surface and the fields of that charge cancel at every point inside the hollow.
- (iii) (a) $4\ \text{ohm}$. $R/6 = 40/60$, so $R = 6 \times 40/60 = 4\ \text{ohm}$.
- (iv) Drift velocity is the small steady average velocity, in the direction opposite to the applied field, that the free electrons acquire along the conductor when a potential difference is set up across it.
- (v) (d) neutron. A cyclotron works by acting on a charged particle with an electric and a magnetic field, and the neutron carries no charge.
- (vi) The susceptibility of a diamagnetic substance is small and negative, that is less than zero.
- (vii) (b) $0.5\ \text{H}$. $L = e/(dI/dt) = 2/4 = 0.5\ \text{H}$.
- (viii) The average power is zero when the phase difference between the voltage and the current is 90° degrees, that is when the circuit contains only a pure inductance or only a pure capacitance and the power factor is zero.
- (ix) (c) gamma rays.
- (x) The dioptre, which is one reciprocal metre.
- (xi) (d) the polarising angle. At that angle, given by Brewster's law, the reflected ray and the refracted ray are at right angles to each other.
- (xii) (b) 45° degrees. $\sin C = 1/\mu = 1/\sqrt{2}$, so $C = 45^\circ$ degrees.
- (xiii) (a) the frequency of the incident light and the work function of the metal. Raising the intensity raises the number of photoelectrons but not the maximum kinetic energy, so it does not alter the stopping potential.
- (xiv) It showed that the positive charge and almost the whole mass of the atom are packed into a very small central core, the nucleus, the rest of the atom being largely empty space.
- (xv) (c) remains unchanged. A neutron turns into a proton, so the atomic number rises by one while the total number of nucleons stays the same.
- (xvi) (b) in reverse bias and in parallel with the load.

1 mark for each correct part. No mark is deducted for a wrong option, and a one-line answer that carries the correct physics gains the mark even if it is loosely worded.

Question 2 [14]

- (i) An equipotential surface is a surface every point of which stands at the same electric potential. Because the potential difference between any two points on it is zero, the work done in moving a charge q between them is $W = qV = 0$. Put another way, the electric field is always at right angles to an equipotential surface, so the displacement has no component along the force and no work is done.

Definition 1. Reason, either by zero potential difference or by field normal to the surface 1.

- (ii) $I = E/(R + r) = 2/(3.5 + 0.5) = 2/4 = 0.5\ \text{A}$. Terminal potential difference $V = IR = 0.5 \times 3.5 = 1.75\ \text{V}$. The same figure follows from $V = E - Ir = 2 - 0.5 \times 0.5 = 1.75\ \text{V}$.

Current 0.5 A 1. Terminal pd 1.75 V 1.

- (iii) The induced emf is $e = N A (dB/dt) = 500 \times 2 \times 10^{-2} \times (0.4/0.1) = 500 \times 2 \times 10^{-2} \times 4 = 40\ \text{V}$.

Correct use of $e = NA(dB/dt)$ 1. Answer 40 V 1.

- (iv) Any two of the following: they are transverse waves in which the electric and the magnetic field vectors oscillate at right angles to each other and to the direction of travel; they need no material medium and travel through free space at $3 \times 10^8\ \text{m s}^{-1}$; they carry energy and momentum; they are not deflected by electric or

magnetic fields. The term Maxwell added to Ampere's law is the displacement current, which arises from a changing electric flux.

Two properties 1. Displacement current named 1.

- (v) Using $1/v - 1/u = 1/f$ with $u = -15$ cm and $f = +10$ cm, $1/v = 1/10 + 1/(-15) = (3 - 2)/30 = 1/30$, so $v = +30$ cm. The image lies 30 cm from the lens on the far side from the object, and it is real. Magnification $m = v/u = 30/(-15) = -2$, so the image is twice the size of the object and inverted.

Image distance 30 cm 1. Magnification -2 with the sense of the image 1.

- (vi) The kinetic energy gained is eV, so the momentum is $p = \sqrt{2meV}$. $p = \sqrt{(2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 100)} = \sqrt{(2.912 \times 10^{-47})} = 5.396 \times 10^{-24} \text{ kg m s}^{-1}$. $\lambda = h/p = 6.63 \times 10^{-34} / 5.396 \times 10^{-24} = 1.23 \times 10^{-10} \text{ m}$, that is about 1.23 angstrom units.

Momentum from $\sqrt{2meV}$ 1. Wavelength $1.23 \times 10^{-10} \text{ m}$ 1.

- (vii) First, an audio signal has a very low frequency, between about 20 Hz and 20 kHz, and a signal of that frequency radiates very poorly because the aerial needed would have to be some kilometres long, a quarter of the wavelength being of that order. Second, if every station radiated its audio signal directly, all the signals would occupy the same narrow band of frequencies and the receiver would have no way of separating one station from another. Modulation lifts each signal to a high carrier frequency and so solves both difficulties.

First reason, poor radiation or impossibly long aerial 1. Second reason, mixing of signals and no way to separate stations 1.

Question 3 [15]

- (i) In parallel the capacitances add, so $C = 2 + 3 + 6 = 11 \text{ } \mu\text{F} = 1.1 \times 10^{-5} \text{ F}$. Total charge $Q = CV = 11 \times 10^{-6} \times 10 = 1.1 \times 10^{-4} \text{ C}$, that is 110 μC . Energy stored $U = \frac{1}{2}CV^2 = \frac{1}{2} \times 11 \times 10^{-6} \times 10^2 = 5.5 \times 10^{-4} \text{ J}$.

Capacitance $11 \text{ } \mu\text{F}$ 1. Charge $110 \text{ } \mu\text{C}$ 1. Energy $5.5 \times 10^{-4} \text{ J}$ 1.

- (ii) For a long straight wire $B = \mu_0 I / 2\pi r = (4\pi \times 10^{-7} \times 5) / (2\pi \times 0.10) = 1.0 \times 10^{-5} \text{ T}$. The force per unit length between the two wires is $F/l = \mu_0 I_1 I_2 / 2\pi d = (4\pi \times 10^{-7} \times 5 \times 10) / (2\pi \times 0.20) = 5.0 \times 10^{-5} \text{ N m}^{-1}$. Because the two currents run the same way the wires attract each other.

Flux density $1.0 \times 10^{-5} \text{ T}$ 1. Force per unit length $5.0 \times 10^{-5} \text{ N m}^{-1}$ 1. Attraction 1.

- (iii) Fringe width $\beta = \lambda D/d = (600 \times 10^{-9} \times 1.5) / (0.3 \times 10^{-3}) = 3.0 \times 10^{-3} \text{ m} = 3.0 \text{ mm}$. The third bright fringe lies at a distance 3β from the centre, that is $3 \times 3.0 = 9.0 \text{ mm}$. Since β is directly proportional to D , moving the screen further away widens the fringes.

Fringe width 3.0 mm 1. Third bright fringe at 9.0 mm 1. Fringe width increases with D 1.

- (iv) The helium nucleus holds 2 protons and 2 neutrons. Mass of the separate nucleons $= 2 \times 1.00728 + 2 \times 1.00866 = 2.01456 + 2.01732 = 4.03188 \text{ u}$. Mass defect $\Delta m = 4.03188 - 4.00151 = 0.03037 \text{ u}$. Binding energy $= 0.03037 \times 931.5 = 28.29 \text{ MeV}$, that is 28.3 MeV to three significant figures. Binding energy per nucleon $= 28.29/4 = 7.07 \text{ MeV}$.

Mass defect 0.03037 u 1. Binding energy 28.3 MeV 1. Binding energy per nucleon 7.07 MeV 1.

- (v) A junction is forward biased when the p side is joined to the positive terminal of the battery and the n side to the negative terminal. The applied voltage then opposes the barrier potential, the depletion layer narrows and a large current, of the order of milliamperes, flows. The junction is reverse biased when the p side goes to the negative terminal and the n side to the positive terminal. The applied voltage now adds to the barrier potential, the depletion layer widens and only a very small leakage current, of the order of microamperes, flows. The graph should show the current plotted upward against forward voltage to the right, staying almost flat along the voltage axis until the knee is reached and then rising very steeply, while in the third quadrant, for reverse voltage, it runs as a small nearly constant current until the breakdown voltage is met, where it plunges. The knee voltage is the forward voltage at which the diode current begins to rise sharply, roughly 0.3 V for germanium and 0.7 V for silicon.

Forward bias with narrowed depletion layer and large current 1. Reverse bias with widened layer and small leakage current 1. Correctly shaped characteristic with the knee voltage explained 1.

Question 4 [5]

- (a) Let the dipole be made of charges $-q$ at A and $+q$ at B, separated by $2a$, with centre O, so that the dipole moment is $p = q \times 2a$ directed from $-q$ to $+q$. Take the point P on the axis at a distance r from O on the side of $+q$. The field at P due to $+q$ acts along OP and has magnitude $E_1 = q/[4\pi\epsilon_0(r-a)^2]$. The field due to $-q$ acts along PO and has magnitude $E_2 = q/[4\pi\epsilon_0(r+a)^2]$. The two are opposite in direction, so the resultant along OP is $E = (q/4\pi\epsilon_0)[1/(r-a)^2 - 1/(r+a)^2] = (q/4\pi\epsilon_0) \times 4ar/(r^2 - a^2)^2 = 2pr/[4\pi\epsilon_0(r^2 - a^2)^2]$. For a short dipole a is far smaller than r , so a^2 may be dropped beside r^2 and $E = 2p/(4\pi\epsilon_0 r^3)$. The field is directed along the axis, from the negative charge towards the positive charge, that is away from the dipole on this side.

Fields of the two charges with their distances $r - a$ and $r + a$ 1. Resultant obtained by subtraction and simplified 1. Short dipole result $E = 2p/4\pi\epsilon_0 r^3$ with its direction 1.

- (b) Torque $\tau = pE \sin \theta = 2 \times 10^{-8} \times 5 \times 10^4 \times \sin 30^\circ = 2 \times 10^{-8} \times 5 \times 10^4 \times 0.5 = 5 \times 10^{-4} \text{ N m}$. The torque is greatest when the axis of the dipole lies at right angles to the field, since $\sin \theta$ is then 1, and it would be $1 \times 10^{-3} \text{ N m}$ in that position.

Substitution in $\tau = pE \sin \theta$ with the answer $5 \times 10^{-4} \text{ N m}$ 1. Greatest torque when the dipole is at right angles to the field 1.

Question 5 [5]

- (a) Junction rule: the algebraic sum of the currents meeting at any junction in a network is zero, so that the current flowing into a junction equals the current flowing out of it. It rests on the conservation of charge, since charge cannot pile up at a junction. Loop rule: the algebraic sum of the changes in potential met on going once round any closed loop of a network is zero. It rests on the conservation of energy, since a charge taken round a closed loop and brought back to its starting point must return to the same potential.

Junction rule with conservation of charge 1. Loop rule with conservation of energy 1.

- (b) The circuit shows the two cells side by side between the same pair of points, positive to positive, with the 4 ohm resistance across those points. Let V be the potential difference across the parallel combination, which is also the potential difference across the 4 ohm resistance. Taking the two cells together, the equivalent emf is $E = (E_1/r_1 + E_2/r_2)/(1/r_1 + 1/r_2) = (10/2 + 8/4)/(1/2 + 1/4) = (5 + 2)/0.75 = 9.33 \text{ V}$, and the equivalent internal resistance is $r = r_1 r_2 / (r_1 + r_2) = (2 \times 4)/6 = 1.33 \text{ ohm}$. Current through the external resistance $I = E/(r + R) = 9.33/(1.33 + 4) = 9.33/5.33 = 1.75 \text{ A}$. Hence $V = IR = 1.75 \times 4 = 7 \text{ V}$. Current from the first cell $I_1 = (E_1 - V)/r_1 = (10 - 7)/2 = 1.5 \text{ A}$, and from the second cell $I_2 = (E_2 - V)/r_2 = (8 - 7)/4 = 0.25 \text{ A}$. As a check, $1.5 + 0.25 = 1.75 \text{ A}$, which agrees with the current through the 4 ohm resistance.

Correct circuit with the two cells in parallel across the 4 ohm resistance 1. Current through the external resistance 1.75 A 1. Cell currents 1.5 A and 0.25 A 1.

Question 6 [5]

- (a) The circuit shows the 10 ohm resistance, the 0.5 H inductor and the $8 \mu\text{F}$ capacitor joined one after another in a single loop across the 220 V variable frequency supply, with an a.c. ammeter in the loop. At resonance the inductive and capacitive reactances are equal, so $\omega_0 = 1/\sqrt{LC} = 1/\sqrt{0.5 \times 8 \times 10^{-6}} = 1/\sqrt{4 \times 10^{-6}} = 1/(2 \times 10^{-3}) = 500 \text{ rad s}^{-1}$. Hence $f_0 = \omega_0/2\pi = 500/6.283 = 79.6 \text{ Hz}$. At resonance the impedance is simply R , so the current $I = V/R = 220/10 = 22.0 \text{ A}$. Quality factor $Q = (1/R)\sqrt{L/C} = (1/10) \times \sqrt{(0.5/8 \times 10^{-6})} = (1/10) \times \sqrt{62500} = (1/10) \times 250 = 25.0$. The same value follows from $Q = \omega_0 L/R = 500 \times 0.5/10 = 25.0$.

Resonant frequency 79.6 Hz 1. Current 22.0 A 1. Quality factor 25.0 1.

- (b) At resonance $X_L = X_C$, both being 250 ohm here, and because the voltage across the inductor leads the current by 90 degrees while the voltage across the capacitor lags it by 90 degrees, these two voltages are equal and exactly opposite and cancel out. Only the voltage across the resistance is left, so the applied voltage and the current are in step, the impedance is $Z = R$ and the circuit behaves as a pure resistance. A wattless current is an alternating current that flows in a circuit without any net power being drawn over a full cycle. It arises when the phase difference between the voltage and the current is 90 degrees, so that $\cos \phi$ is zero and $P = V_{\text{rms}} I_{\text{rms}} \cos \phi = 0$, as in a circuit holding only a pure inductance or only a pure capacitance.

Cancellation of the two reactive voltages leaving $Z = R$ 1. Wattless current explained with $\cos \phi = 0$ 1.

Question 7 [5]

- (a) Let the ray strike the first face at angle of incidence i , refract into the prism at angle r_1 , travel to the second face where it meets the normal at r_2 , and leave at angle of emergence e . In the quadrilateral formed by the two faces and the two normals the angles at the normals are each 90 degrees, so A + angle between the normals = 180 degrees, and in the triangle inside the prism $r_1 + r_2 + (180 \text{ degrees} - A) = 180 \text{ degrees}$. Hence $r_1 + r_2 = A$. The deviation produced at the first face is $i - r_1$ and at the second face $e - r_2$, so the total deviation is $d = (i - r_1) + (e - r_2) = i + e - A$. At minimum deviation the ray passes symmetrically through the prism, so $e = i$ and $r_2 = r_1 = r$. Then $A = 2r$, giving $r = A/2$, and $D = 2i - A$, giving $i = (A + D)/2$. Snell's law at the first face gives $\mu = \sin i / \sin r$, so $\mu = \sin[(A + D)/2] / \sin(A/2)$. The condition at minimum deviation is that the refracted ray inside the prism runs parallel to the base, the angle of incidence being equal to the angle of emergence.

*$r_1 + r_2 = A$ and $d = i + e - A$ established 1. Symmetry at minimum deviation used to get $r = A/2$ and $i = (A + D)/2$
1. Final relation with the stated condition 1.*

- (b) For an equilateral prism $A = 60$ degrees, so $A/2 = 30$ degrees and $\sin(A/2) = 0.5$. From $\mu = \sin[(A + D)/2] / \sin(A/2)$, $\sin[(60 + D)/2] = 1.5 \times 0.5 = 0.75$, so $(60 + D)/2 = 48.59$ degrees and $60 + D = 97.18$ degrees. Hence $D = 37.2$ degrees. The angle of incidence at which this occurs is $i = (A + D)/2 = 48.6$ degrees.

Minimum deviation 37.2 degrees 1. Angle of incidence 48.6 degrees 1.

Question 8 [5]

- (a) The circuit shows the a.c. mains feeding the primary of a transformer whose secondary is tapped at its midpoint. The two ends of the secondary go to the p sides of the two diodes, the n sides of both diodes are joined together, and the load resistance is connected between that common point and the centre tap, the output being taken across the load. During the half cycle in which the upper end of the secondary is positive with respect to the centre tap, the first diode is forward biased and conducts while the second is reverse biased and blocks, so current passes through the load from the common point towards the centre tap. During the next half cycle the polarity of the secondary reverses, the lower end becomes positive, the second diode conducts and the first blocks, but the current through the load still runs in the same direction as before. The load therefore receives a unidirectional current on both half cycles, which is why the arrangement is a full wave rectifier. Since there is one pulse in the output for each half cycle of the input, the ripple frequency is twice the supply frequency, that is $2 \times 50 = 100$ Hz.

Correct circuit with centre tapped secondary, two diodes and the load 1. Explanation of the two diodes conducting in turn with the load current keeping one direction 1. Ripple frequency 100 Hz 1.

- (b) For a two input NAND gate with inputs A and B and output $Y = \text{NOT}(A \text{ AND } B)$, the output is 1 for the input pairs 0 and 0, 0 and 1, and 1 and 0, and it is 0 only for the pair 1 and 1. The table should be set out in four rows showing exactly those values. To obtain the action of a NOT gate, join the two inputs of the NAND gate together and feed the single input A to both. Then $Y = \text{NOT}(A \text{ AND } A) = \text{NOT } A$, so an input of 0 gives an output of 1 and an input of 1 gives an output of 0, which is the behaviour of a NOT gate.

Correct four row truth table 1. Both inputs shorted together to give $Y = \text{NOT } A$ 1.