H2 PHYSICS

Exam papers with worked solutions

(Selected from Top JC)

SET B

PAPER 3

Answer

Compiled by

THE PHYSICS CAFE

1 (a) (i) Consider vertical motion: Take vectors downwards as positive,
$s_y = 0 + ½ a_y t^2$
$22.8 – 1.0 = ½ (9.81) t^2$ M1
$t = 2.1082 = 2.11$ s A1

(ii) Consider horizontal motion:
$s_x = u_x t$
$5.0 = u_x (2.1082)$ M1
$u_x = 2.3717 = 2.37$ m s^{-1} A1

(b) (i) Let x be the average depression of the net.
Total initial energy = Total final energy
$mgh + ½ m u_x^2 = mg(1.0 – x) + ½ k x^2$ [Take GPE = 0 at ground level.] M1
$(75)(9.81)(22.8) + ½ (75)(2.3717)^2 = (75)(9.81)(1.0 – x) + ½ (50 / 0.001) x^2$
$25000 x^2 – 735.75 x – 16250 = 0$
$x = 0.82108 = 0.821$ m A1

(ii) Total initial energy of victim = Total final energy of victim + Work done by net against the victim
$mgh + ½ m u_x^2 = mg(1.0 – 0.82108) + F \times \text{depression}$ M1
$(75)(9.81)(22.8) + ½ (75)(2.3717)^2 = (75)(9.81)(1.0 – 0.82108) + F \times 0.82108$
$F = 20.5 \times 10^3$ N A1

(c) Force on the person is too big for the person to withstand; hence the spring constant k of material must not be too big. B1
If k is too small, stretching is too big and victim may hit the floor. B1
Weight of the person and height of jump also need to be considered.

2 (a) Sum of the <u>microscopic kinetic and potential energies</u> B1
of <u>atoms/molecules</u> of the two gases are the same. B1

(b) (i) $V_1/T_1 = V_2/T_2$
$0.00322/300 = 0.00550/ T_2$ M1
$T_2 = 512.42$ K = 239 °C A1

(ii) $W = - p \times \Delta V$
$= - 1.0 \times 10^5 \times (0.00550 – 0.00322)$ M1
$= - 228$ J
Hence, work done by gas is 228 J. A1

(iii) $\Delta U = 3/2\ nR\Delta T = 3/2\ p\Delta V$ M1
$= 3/2 \times (1.0 \times 10^5) \times (0.00550 – 0.00322) = 342$ J A1

(iv) $\Delta U = Q + W$
$342 = Q + (-228)$ M1
$Q = 570$ J A1

3 (a) The main difference lies in the energy changes.

The potential difference between two points in a circuit is the amount of energy converted from electrical form to other forms of energy per unit charge that passes between the two points. A1

The electromotive force of a source of electrical energy is the amount of energy converted from other forms (such as chemical energy in a dry cell or mechanical energy in a dynamo) to electrical energy in driving a unit charge round a complete circuit. A1

The electromotive force of a source of electrical energy is equal to the potential difference across the terminals of the source when there is no current in the cell. A1

Additional:

Another difference lies in the roles they play in a circuit.

e.m.f. acts in a circuit so as to drive current around it by producing a potential difference between its terminals.

The p.d. across any part of a circuit outside the source acts so as to drive current through that part of circuit and supply energy to it. The energy supplied is derived from the source of e.m.f. There will be no p.d. without e.m.f.
e.m.f exists whether current flows of not. This is the case when a cell is left alone.

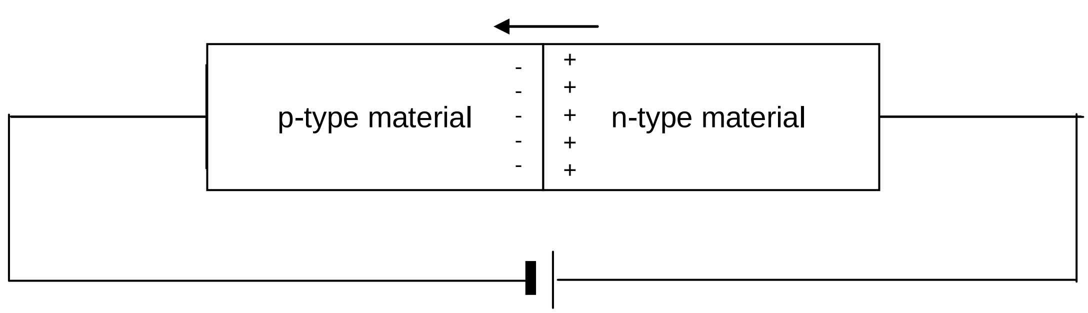
(b) (i) Potential difference across XZ = (100/100+30)(2.0) M1
= 1.54 V A1

(ii) XZ = (1.54/4.0)(100 cm) M1
= 38.5 cm A1

(iii) At null deflection, V_{XZ} = 2.0 V M1
New balance length = (2.0/4.0)(100 cm) A1
= 50 cm

(iv) I = 0 amperes A1

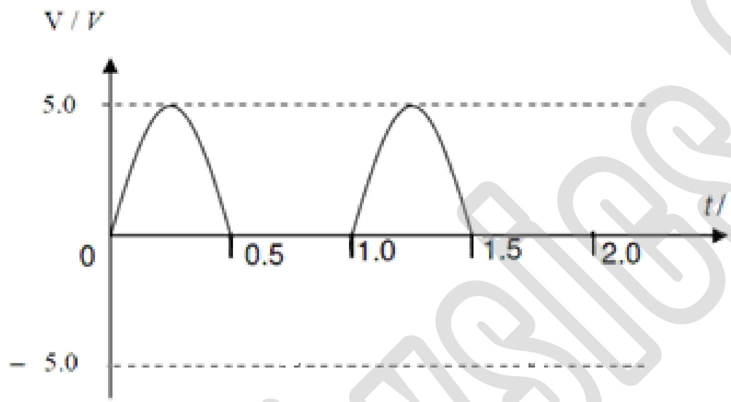
4 (a) / (c) B1 / B1



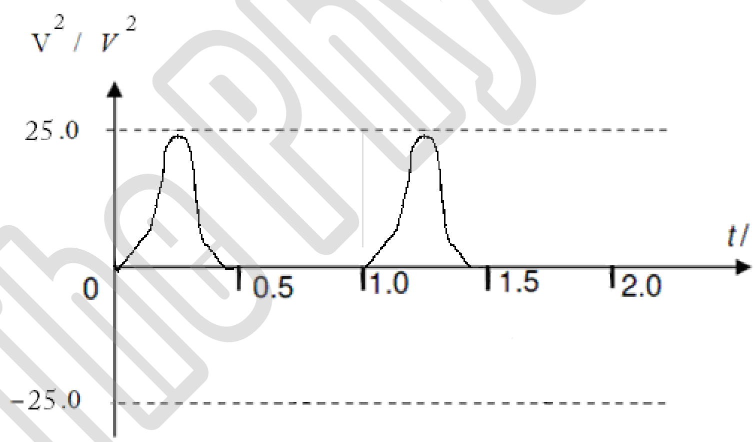
(b) 1. The p-type semiconductor contains a high concentration of holes, while the n-type semiconductor contains a high concentration of conduction electrons. Due to the concentration gradient, in the <u>narrow region</u> near the p-n junction, free B1 electrons from the n-type side tend to diffuse across the junction into the p-type side.

2. When free electrons move over to the p-type side, they combine with the holes there. The holes vanish and the electron is no longer mobile. The migration of mobile electrons across the junction, <u>and</u>, the combination of electrons and holes in the p region depletes the p region of holes and the n region of mobile electrons near the junction. B1
3. Immobile charge carriers in the form of dopants – negatively charged on p side (electron acceptors) and positively charged on n side (electron donators) cause an internal electric field to set up across the junction. This internal electric field prevents any further drift of mobile charge carriers across the depletion region. B1
4. The migration of electrons over from the n-side and recombination of electrons and holes on the p-side depletes the region near the p-n junction of all charge carriers, and hence the name "depletion region". B1

(d) (i) B1



(ii) B1



(iii) For $0<t<0.5$, $\langle V^2 \rangle = 25/2 = 12.5$ V
For $0.5<t<1.0$, $\langle V^2 \rangle = 0$ V
Hence over one complete cycle,
$\langle V^2 \rangle = (12.5 + 0) / 2 = 6.25$ V B1

(iv) $V_{rms} = \sqrt{\langle V^2 \rangle} = 2.5$ V B1

5 (a) (i) $T = 365(24)(3600)$ M1

$\omega = \frac{2\pi}{T} = 1.9924\times10^{-7} = 1.99\times10^{-7}\,rads^{-1}$ A1

(ii) $\frac{GMm}{r^2} = mr\omega^2$ M1

$r = \sqrt[3]{\frac{GM}{\omega^2}} = \sqrt[3]{\frac{(6.67\times10^{-11})(1.989\times10^{30})}{(1.9924\times10^{-7})^2}} = 1.4951\times10^{11} = 1.50\times10^{11}\,m$ A1

(iii) Orbit is a perfect circle. It is actually an ellipse. B1

(b) (i) $\Delta m = 2(1.007276) - (2.01410178 - 0.000549) - 0.000549$ M1

$= 4.5022\times10^{-4}\,u$ M1

$E = mc^2 = (4.5022\times10^{-4})(1.661\times10^{-27})(3\times10^{8})^2$

$= 6.73\times10^{-13}\,J$

$= \frac{7.995\times10^{-13}}{1.6\times10^{-19}} = 0.421\,MeV$ M1 A1

(ii) ${}^{1}_{1}p + {}^{2}_{1}H \Rightarrow {}^{3}_{2}He + \gamma$ B1 for correct order
B1 for correct atomic numbers

(iii) A gamma ray photon is released, hence products exist at a lower energy. B1

(iv) The two nuclei are positively charged and hence experience a huge electrostatic repulsion when brought near to each other. Hence a high pressure overcomes this repulsion to allow fusion to occur. B1

(c) (i) Alpha particle. B1

(ii) $\lambda = \frac{\ln 2}{2.9} = 0.239\,year^{-1}$ M1 A1

(iii) $N = N_0 e^{-\lambda t}$ M1

$\frac{x}{210} N_A = \frac{105}{210} N_A e^{-0.239(10)}$ M1

$x = 9.62g$ A1

(iv) They "tunnel" out of the nucleus via quantum tunnelling. B1

6 (a) (i) The principle of superposition states that if two or more waves of the same kind exist simultaneously at a point, the resultant displacement is the vector sum of the individual displacements due to the waves at this point. B1 B1

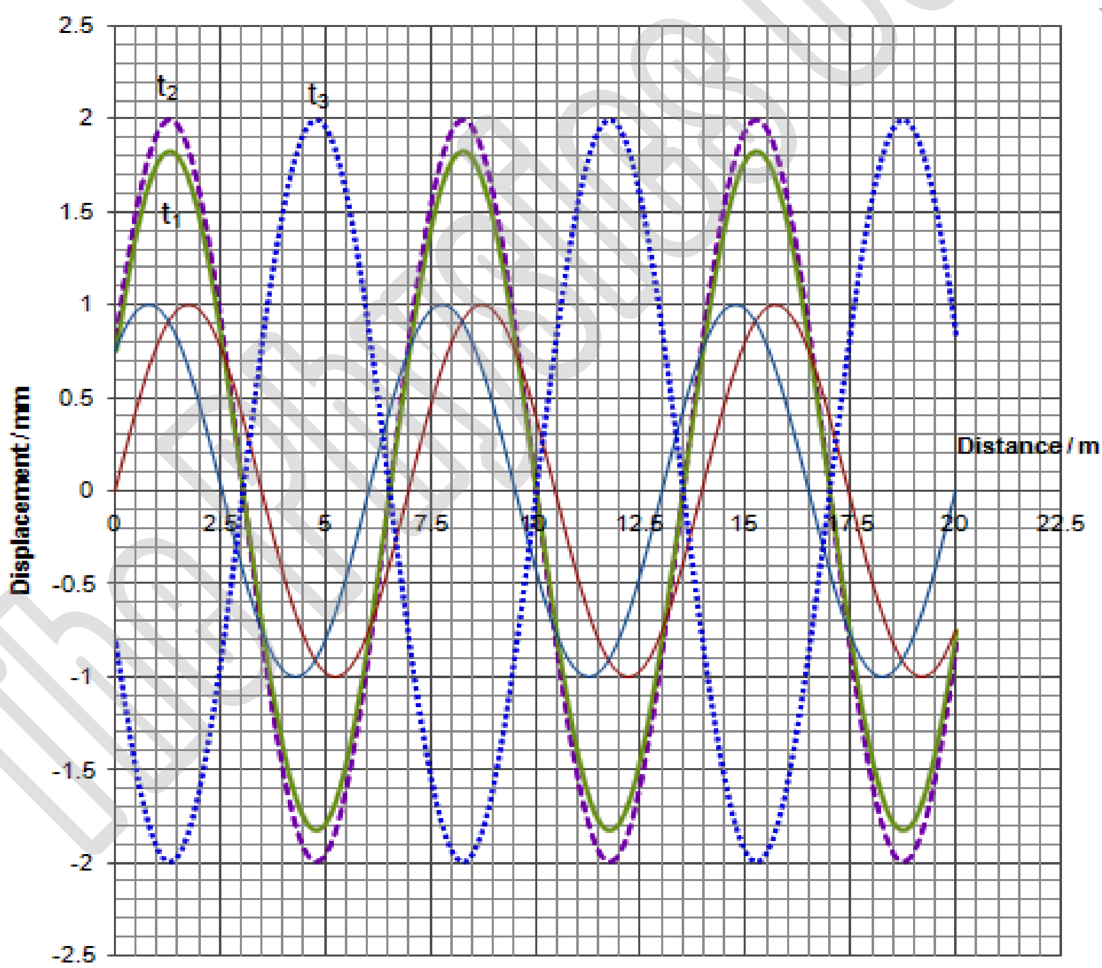
(ii) Maximum displacements vary with time:

1. at the instant shown, max. displacement = 0.9 + 0.9 = 1.8 mm. B1
2. at the instant shown + $\frac{1}{14}T$, max. displacement = 1.0 + 1.0 = 2.0 mm since waves are in phase at this instant in time. B1

3. the instant shown + $\frac{1}{14}T + \frac{1}{2}T$, max. displacement = 2.0 mm since wave are in phase again. But the waveform is now the reflection of the waveform in part 2.

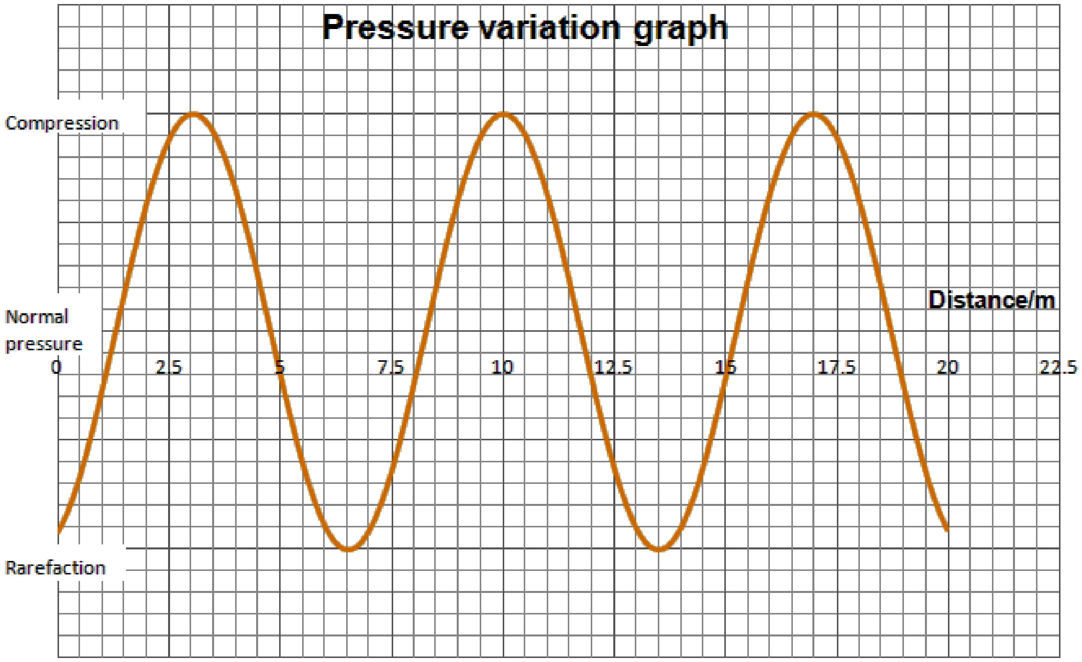
Correct waveform: B1
1. sine wave
2. sine wave with amplitudes at all points away from the nodes higher than before.
3. reflection of waveform in part 2 about the x-axis. B1

Stationary wave is formed.
At every instant in time, positions of the nodes and antinodes remain unchanged. B1
Locations of antinodes: where waves A and B intersect. (x = 1.25 m, 4.75 m, 8.25 m, 11.75 m, …) B1
Locations of nodes: midway between 2 adjacent antinodes. (x = 3 m, 6.5 m, 10 m, …)
Distance between 2 adjacent node and antinode is λ/4, where λ is the wavelength of the underlying progressive waves, i.e. waves A and B. (λ = 7 m)



(iii) Displacement antinodes → Pressure nodes
Displacement nodes → Pressure antinodes B1

Centres of compression: x = 3 m, 10 m, etc..
Centres of rarefaction: x = 6.5 m, etc… B1



(b) (i) 1. Two sources are said to be coherent if they produce waves with a constant phase difference. B1

2. Most light sources are not coherent since the emission of photons is random. The splitting of a single source ensures that the two interfering wave trains are from a single point source so that they are coherent. B1

A permanent interference pattern can only be formed if there is a constant phase relationship between the two interfering wave trains. B1

(ii) Replace the light source with a laser beam. B1

(iii) For destructive interference,

Path diff = odd number multiples of λ

= (n - ½) λ

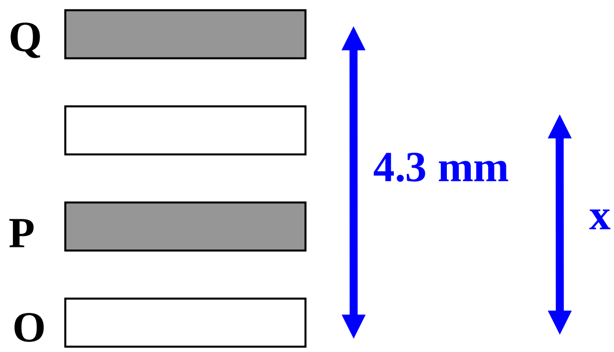
where n is the order of minima (n = 1, 2, 3, …)

Hence for the 2nd order minima,

$S_1Q - S_2Q = 3\lambda/2$ B1

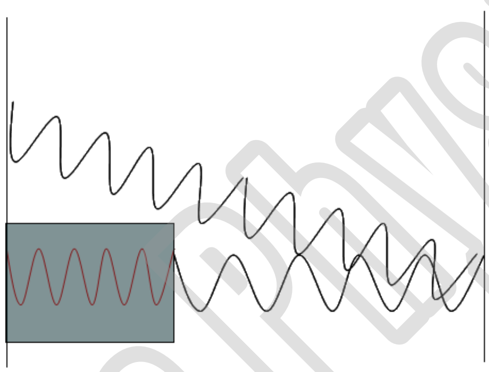
(iv) Use $x = \lambda D/a$ B1
where:
x = 4.3 x 2 / 3 = 2.8667 mm B1

Thus λ = 908 nm B1



(v) Explain:
When the material is placed in front of one of the slits, the speed of light in the material is decreased and wavelength of light in the material is shorter. Hence, the optical path (distance travelled by light) is increased. B1

Describe:
As a result, the central fringe will shift in the direction of the covered slit (i.e. downwards if S_2 is covered; upwards if S_1 is covered), such that the path difference = 0. B1



7 (a) (i) *Magnetic field strength* at a point is the force acting on per unit current in a wire of unit length lying at right angles to the magnetic field.

(ii) Maximum change in flux occurs when the coil is perpendicular to the magnetic field and rotates 180°.

Initial flux = (120)(0.5)(0.05)(0.04)cos(0) = 0.12 Wb
Final flux = (120)(0.5)(0.05)(0.04)cos(180) = - 0.12 Wb

Change in flux = -0.12 – 0.12 = - 0.24 Wb = - 240 mWb.

(b) Estimated value of I_{max} = V / R = 12 / 0.8 = 15 A

This value is an estimate because the rotation of the coil may result in an e.m.f. generated to oppose that supplied. Hence the net forward e.m.f. may be less, and the max current will thus be less and this value is only an estimate based on the assumption that the coil does not rotate within this period of time.

(c) (i) The current rises gradually from zero to maximum value instead of immediately as the when the current first starts to flow through the coil, there is an increase in magnetic field strength in the coil and thus an increase in magnetic flux.

By Faraday's law, this increase in magnetic flux causes an induced emf that opposes this change and this causes the increase in current to be more gradual.

(ii) The current drops from P to Q as the coil starts to rotate due to the current flowing in the coil in the presence of the magnetic field. As the coil rotates, the magnetic flux through the coil changes and hence there is an induced emf in the opposite direction to that supplied by Faraday's law. Thus the current drops gradually as the induced emf increases.

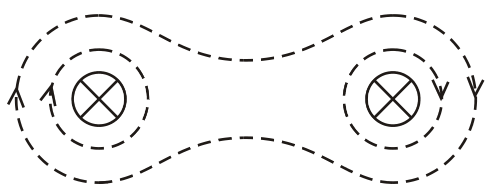
(iii) The current becomes steady as the rotation of the coil becomes constant this means that the induced emf is the opposite direction is now constant and thus the net emf and current is now steady.

(d) | Force acting on side AD | = | Force acting on side BC |
= NBILsin θ
= (120)(0.5)(2)(0.05) sin 90°
= 6 N

Thus max. moment acting on the coil = 2 (6 x 2 / 100) = 0.24 Nm

(e) There will be energy is loss in the resistor through heating whenever the circuit is in use, not just at the start of the motor.

(f) (i)



correction direction of field lines [1]
appropriate spacing of lines: increasing separation with distance from wires [1]

(ii) The of the wire acceleration increases because the force is getting larger the closer the wires get together.