H2 PHYSICS

Exam papers with worked solutions

(Selected from Top JC)

SET A

PAPER 3

Answer

Compiled by

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1 (a) (i) As X is compressing the spring, its velocity decreases but is still larger than Y's. Hence at maximum compression, X and Y must move with a common velocity. Otherwise, the relative motion will cause further compression.

(ii) Conservation of momentum,
Total momentum before collision = Total momentum at maximum compression

$$m_X v_X + m_Y v_Y = (m_X + m_Y)v$$
$$(2.0)(9.0) + (4.0)(3.0) = (2.0 + 4.0)v$$
$$v = 5.0 \text{ m s}^{-1}$$

(iii) Energy stored in spring = Change in kinetic energy before and during collision

$$\frac{1}{2}kx^2 = \left(\frac{1}{2}m_X v_X{}^2 + \frac{1}{2}m_Y v_Y{}^2\right) - \frac{1}{2}(m_X + m_X)v^2$$
$$\frac{1}{2}(150)x^2 = \left(\frac{1}{2}(2.0)(9.0^2) + \frac{1}{2}(4.0)(3.0^2)\right) - \frac{1}{2}(2.0 + 4.0)(5.0^2)$$
$$x = 0.57 \text{ m}$$

(b) (i) The *principle of conservation of momentum* states that the total momentum of a system (of bodies) is constant provided no external force acts on the system.

(ii) Conservation of momentum,
Total momentum before collision = Total momentum after X and Y are separated

$$m_X v_X + m_Y v_Y = m_X v_X' + m_Y v_Y'$$
$$(2.0)(9.0) + (4.0)(3.0) = 2.0v_X' + 4.0v_Y'$$
$$30 = 2.0v_X' + 4.0v_Y' \text{ ……………… (1)}$$

Method 1

Total kinetic energy of the system before collision is equal to the total kinetic energy of the system after separation.

$$v_X - v_Y = -(v_X' - v_Y')$$

$$9.0 - 3.0 = -v_X' + v_Y'$$
$$6.0 = v_Y' - v_X' \text{ .... (2a)}$$

Sub (2a) into (1) :
$30 = 2.0v_X' + 4.0(6.0 + v_X')$
$6 = 6v_X'$
$v_X' = 1.0 \text{ m s}^{-1}$
$v_Y' = 7.0 \text{ m s}^{-1}$

Method 2

EPE stored in spring returned as KE to the system.

$$\frac{1}{2}(2.0)(5.0^2) + \frac{1}{2}(4.0)(5.0^2) + \frac{1}{2}(150)(0.566^2) = \frac{1}{2}(2.0)(v_X')^2 + \frac{1}{2}(4.0)(v_Y')^2 \text{ …. (2b)}$$

Solving (1) and (2b) gives
$v_X' = 1 \text{ m s}^{-1}$
$v_Y' = 7 \text{ m s}^{-1}$

2 **(a)** Simple harmonic motion is defined as the motion taking place in which the acceleration of a body is directly proportional to the displacement of the body from a fixed position (equilibrium position),
and it is in the opposite direction to the displacement from the fixed position (equilibrium position)

(b) **(i)** Damping refers to the process whereby energy is lost from an oscillating system due to some resistive/dissipative forces.

(ii) For an oscillating system, i.e. the machinery system, driven by an applied force from the electric motor of a particular frequency, if the frequency of the applied force is equal to the natural frequency of the machine,

resonance occurs i.e. the amplitude of vibration is maximum and hence loudest noise is produced at resonant frequency.

A small deviation of the frequency of the driving force, i.e. the electric motor's frequency, from the resonant frequency will cause the amplitude and hence the noise to be reduced considerably/significantly

because the amplitude of vibration decrease significantly on either side of the resonant frequency.

3 **(a)** **(i)** *either* lines directed away from sphere,
lines go from positive to negative
or lines shows direction of force on positive charge
so positively charged

(ii) *either* all lines (appear to) radiate from centre
or all lines are normal to surface of sphere

(b) tangent to curve
correct position and direction (opposite to field direction)

(c) **(i)** work done per unit positive charge in bringing a small positive charge from infinity to that point

(ii)
$$V = \frac{q}{4\pi\varepsilon_o r}$$
q = (280) (4π x 8.85 x 10^{-12}) (0.024)
= 0.75 nC

(d) *either* gravitational field is always attractive
or field lines must be directed towards both box and sphere

4 **(a)** If a coil has N turns and that the magnetic flux linking each turn is BA where B is magnetic flux density perpendicular to the plane of the area A, the total flux through the coil is called magnetic flux linkage given by NBA.

(b)

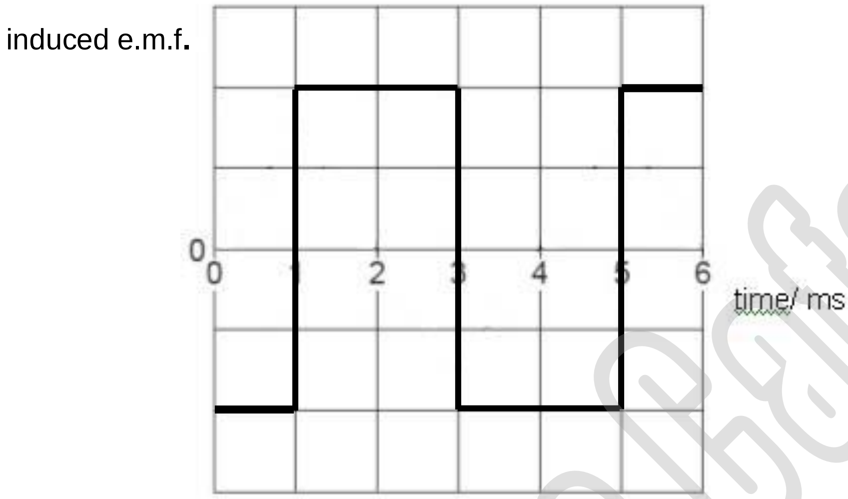


Fig. 4.3

constant e.m.f. for constant gradient of magnetic flux linkage
negative value for positive gradient, positive value for negative gradient
maximum e.m.f. should be the same in both directions

(c) $|\varepsilon| = \Delta\phi/\Delta t = \Delta(NBA)/\Delta t = 3(0.55 - 0)(3.1 \times 10^{-4}) / 1\times10^{-3}$
$= 0.5115 = 0.51$ V

(d) The wooden core will not concentrate the magnetic field lines and thus the flux linkage would be weaker.
The peak e.m.f. would then be smaller.

5 **(a)** **(i)** At point X,

$$P_X V_X = (2.4\times10^4)(1.7\times10^{-3}) = 40.8$$

At point Z,

$$P_Z V_Z = (3.1\times10^4)(1.1\times10^{-3}) = 34.1$$

Since PV = nRT and nR is a constant, hence PV must remain the same if T is constant. From above, since PV values at points X and Z are not equal, we can conclude that the process XZ is not isothermal.

(ii) WD for each square = $(0.1 \times 10^4)(0.05 \times 10^{-3}) = 0.05$ J
Estimated number of squares under the curve = 46 + 22 x 12
= 46 +264 = 310
WD_{XZ} = 0.05 x 310 = 15.5 J

(b) $\Delta U_{XZ} = \Delta U_{XYZ}$ since starting and ending state of both paths are the same
$\therefore W_{XZ} + Q_{XZ} = \Delta U_{XYZ}$
$15.5 - 25.5 = \Delta U_{XYZ}$
$\Delta U_{XYZ} = -10.0$ J
W_{XYZ}= Area under XYZ = $(3.1 \times 10^4)[(1.7-1.1) \times 10^{-3}] = 18.6$ J

Since $\Delta U_{XYZ} = Q_{XYZ} + W_{XYZ}$
$\therefore Q_{XYZ} = -10.0 - 18.6 = -28.6$ J

6 **(a)** **(i)** Nuclear fission is a nuclear reaction whereby a heavy nucleus splits into two roughly equal fission fragments with the emission of neutrons and the release of energy.

(ii) Number of protons= 35 Number of neutrons = 60

(b) **(i)** gamma radiation

(ii) 200 MeV = $200 \times 10^6 \times 1.6 \times 10^{-19}$ J = 3.2×10^{-11} J

(iii) **1.** total power generated = number of processes per unit time × energy in each process
$3065 \times 10^6 = N/t \times 3.2 \times 10^{-11}$
$N/t = 9.58 \times 10^{19}$

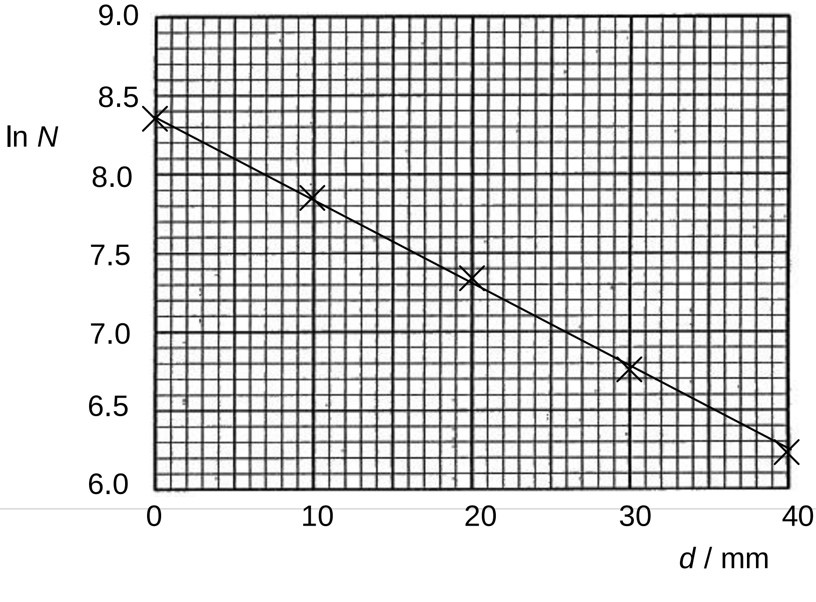
2. waste heat produced in each second = $70/100 \times 3065 \times 10^6 = 2.146 \times 10^9$ W

(iv) 97/100 (Waste heat in one second) = (mass of water in one sec)c($\Delta\theta$)
$97/100\ (2146 \times 10^6) = m\ (4200)(3.5)$
$m = 1.416 \times 10^5 = 1.42 \times 10^5$ kg

(c) **(i)** use electric or magnetic field
beta particles (charged) will be deflected by field while gamma radiation (no charge) will not

(ii) **1.**

Total thickness *d* of lead / mm	0	10	20	30	40
Number of counts *N* in 10 mins	4250	2510	1500	850	500
ln *N*	8.35	7.83	7.31	6.75	6.21



correct ln N values
good y-scale and x-scale
straight line graph with points plotted correctly

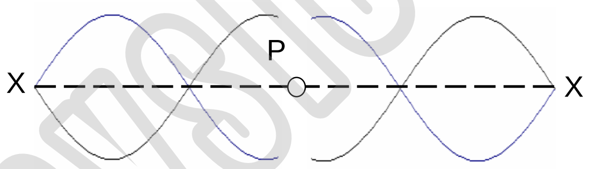
(ii) **2.** N <u>decreases exponentially</u> with d

(iii) <u>Background radiation</u> is likely to be present and thus the <u>readings will include that and register higher values</u>.

7 The term *superposition* of waves refers to the interaction (or meeting) of two or more waves <u>at a point</u> producing a resultant wave at the point where its instantaneous displacement is the <u>vector sum of the instantaneous displacements</u> in the individual waves.

(a) **(i)** Nodal conditions satisfied for 22.5 MHz but not for 15 MHz.
The outer ends of the aerial the current waves form a node (due to electron movement frustrated by termination of aerial) while antinodes exist at the inner ends.

(ii)



One and a half nodal loop on each side
Node at X and antinode at P

(iii) Maximum amplification or maximum energy transfer

(b) **(i)**

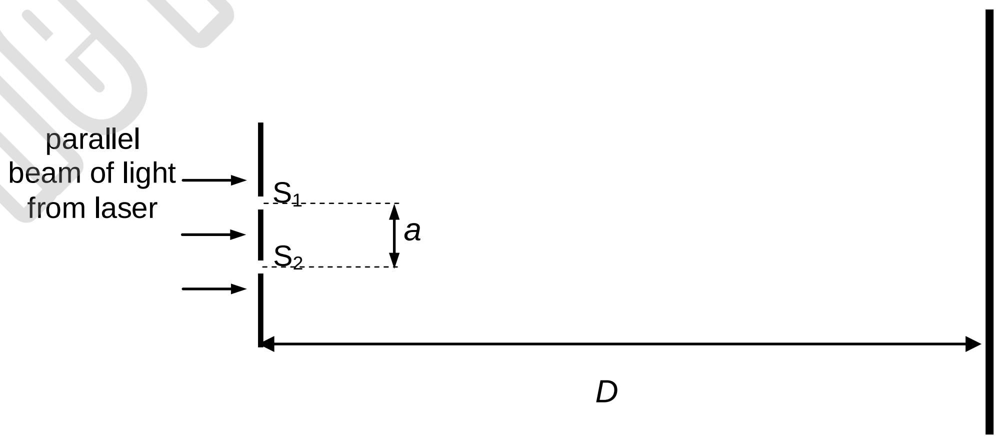


diagram showing correct a and D. (a must be centre to centre or equivalent)

(ii) x – ruler
D - ruler or measuring tape
a – travelling microscope

(iii) *D*'s range: 0.2 - 3 m
$a = 310 \times 10^{-6} \times$ (value of *D* given)

(c) **(i)** Peak decreases in intensity and width of the pattern increases.

(ii) With slit width at 0.2 mm, a minimum is at A or intensity at A is zero.
As slit width decreases, diffraction effect increases and the central order expands covering a larger area on screen that includes A and the intensity at A increases.
As the slit width continues to decrease, the intensity of the light that passes through the slit decreases and this affects (which reduces) the intensity of the central order. The intensity at A starts to decrease. With the slit completely closed, the intensity at A goes to zero.

(iii) $d \sin \theta = n \lambda$

$\lambda = 5.7 \times 10^{-7}$ m

8 **(a)** **(i)** an electron requires 1.7 eV of energy to escape from the metal (surface)

(ii) $\phi = h f_o$
$f_o = \phi / h$
$= 1.7 \times 1.60 \times 10^{-19} / (6.63 \times 10^{-34})$
$= 4.1 \times 10^{14}$ Hz

(iii) Energy of photon = h f or hc/λ
$h f = \phi + K_{max}$
$K_{max} = hc/\lambda - \phi$
$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / 560 \times 10^{-9} - (1.7 \times 1.60 \times 10^{-19})$
$= 8.3 \times 10^{-20}$ J

(b) energy of light photon = hf
a blue light photon has more energy than a red light photon (or has higher frequency)
an electron in the surface absorbs a photon
an electron needs a certain amount of energy to escape from the metal (or frequency higher than threshold frequency)
a blue light photon gives an electron enough energy to escape whereas a red light photon does not

(c) **(i)** electron from level L falls to level K gives rise to K_α line
electron from level M falls to level K gives rise to K_β line

(ii) photon energy of K_α line = -11.4 – (-69.6) = 58.2 keV
hc/λ = photon energy of $K\alpha$ line
$\lambda = (6.63 \times 10^{-34} \times 3 \times 10^{8}) / (58.2 \times 10^{3} \times 1.6 \times 10^{-19})$
$= 2.14 \times 10^{-11}$ m

(iii) While it is possible for an electron in the K-shell to be given exactly 58.2 keV to lift it to the L-shell, this is unlikely in practice.
Inner electrons are normally dislodged/knocked out from the atom
and this requires a potential difference of at least 69.6 kV

(d) a wave can penetrate thin barriers (or gaps)
wave-like nature allows an electron to transfer
Since gap is small, probability of transfer of an electron (or tunnelling effect) is not zero.

(e) $\lambda = h / mv$

$v = h / m\lambda$

$= (6.63 \times 10^{-34}) / (9.11 \times 10^{-31} \times 1 \times 10^{-9})$

$= 7.3 \times 10^{5}$ m s^{-1}