National Junior College 2022 Preliminary Examination

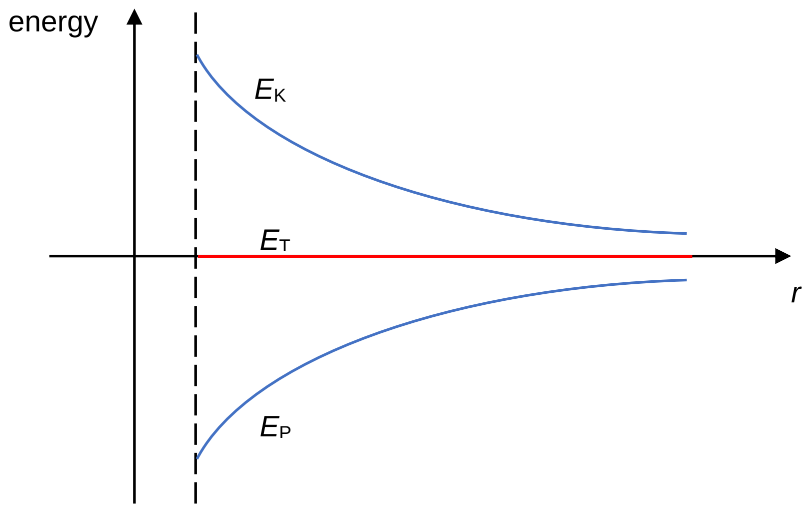
9749 H2 Physics

Paper 3

Suggested Solution

Section A

1 **(a)**



E_K positive and decreasing, not touching x-axis — B1

E_P (roughly, but not too far off) symmetrical to E_K — B1

E_T clearly shown (visibly or written in text) on the x-axis — B1

(b) **(i)** Kinetic energy lost equals the gain in gravitational potential energy when object of mass m moves from the surface of Earth to infinity

$\frac{1}{2} mv^2 - 0 = 0 - (-GMm / R)$ — B1

$v^2 = 2GM / R$

(ii) gravitational field strength at the surface of planet $g = GM / R^2$ equals the acceleration of free fall at the surface of planet — B1

from **(i)**, $v^2 = 2 (GM / R^2) \times R$ — M1

$v^2 = 2gR$ — A0

(c) **(i)** $3/2\ kT = \frac{1}{2} m v^2 = mgR$ — C1

$T = 2mgR / 3k = (2 \times 6.6 \times 10^{-27} \times 9.81 \times 6.4 \times 10^{6}) / (3 \times 1.38 \times 10^{23})$ — C1

$T = 2.0 \times 10^4$ K — A1

(ii) temperature where all substances have minimum internal energy — B1

2 **(a)** sum of random distribution of kinetic and potential energies of the molecules of the gas B1

no intermolecular forces for ideal gas M1

so no potential energy A1

therefore, internal energy equals to total kinetic energy of the molecules only

(b) **(i)** higher temperature increases r.m.s. speed and change in momentum of each molecule colliding with wall of container M1

increase volume reduces frequency of collision M1

force is product of frequency of collision and change in momentum which is constant when increase in change in momentum is balanced by reduction in frequency of collision A1

(ii) increase in internal energy = $\frac{3}{2}k(460 - 280) \times 1.2 \times 6.02 \times 10^{23}$ (= 2692 J) C1

heat supplied = $1.2 \times 0.032 \times c \times (460 - 280)$ (= $6.912c$) C1

heat supplied = increase in internal energy – work done on gas
$6.912c = 2692 + 1300$ (correct use of first law) C1

c = 580 J kg^{-1} K^{-1} or 578 J kg^{-1} K^{-1} A1

(c) constant volume so no work done B1

less thermal energy needed for same temperature rise, so smaller specific heat capacity B1

3	**(a)**	series of distinct coloured lines against dark background		B1
	(b)	photon emitted when electron changes from higher to lower energy		B1
		energy of photon proportional to frequency		M1
		each line represents photon of specific / distinct energy		A1
		only transition between discrete energy levels leads to specific energies		
	(c)	$\Delta E = 1.5 - 0.85$ (= 0.65 eV or 1.04 × 10^{-19} J)		C1
		wavelength $= \frac{hc}{\Delta E} = \frac{6.63\times10^{-34}\times3\times10^{8}}{1.04\times10^{-19}} = 1.91\times10^{-6}$ m		M1
		wavelength is longer than visible light / infrared, so not visible		A1
	(d)	**(i)**	waves passing slits spread	B1
			waves from each slit overlap	M1
			with phase difference 360° / path difference λ	A1
		(ii)	angle of λ_1 maximum $= \tan^{-1}\frac{147-73.5}{240}$ (= 17.027° or 0.29718 rad)	C1
			$\sin\theta_2 = \sin 17.027° \times \frac{654\times10^{-9}}{488\times10^{-9}}$ (⇒ $\theta_2 = $ 23.106° or 0.40328 rad)	C1
			$\frac{x-73.5}{240} = \tan 23.106°$	M1
			x = 175.9 cm	A1

4 **(a)** emission of electrons from a metal surface when surface is irradiated with electromagnetic radiation above threshold frequency B1

(b) photon has energy dependent on frequency B1

minimum energy required to remove electron from surface B1

emission if energy of photon greater than minimum / work function / threshold energy B1

so, threshold frequency exist

(c) **(i)** stopping potential is the minimum potential difference to stop the most energetic electrons from reaching the anode B1

(ii) for positive values of *V*, all the electrons emitted from cathode will reach anode B1

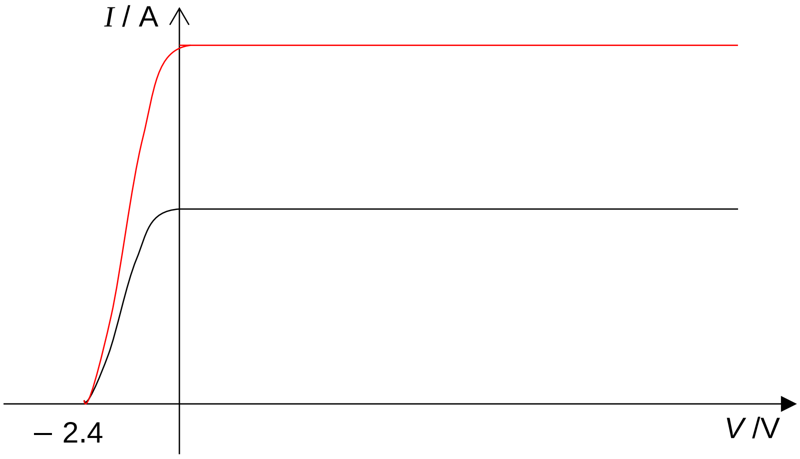
(iii) $E = \phi + eV_s$

$hf = 1.6 \times 1.6 \times 10^{-19} + 2.4 \times 1.6 \times 10^{-19}$ C1

$f = 9.7 \times 10^{14}$ Hz A1

(iv) same V_s B1

saturated current doubled B1



5 **(a)** **(i)** magnetic flux density decreases with distance from straight wire, so magnetic flux linkage in loop decreases as it falls M1

e.m.f. induced in loop proportional to rate of change of magnetic flux linkage A1

OR

loop cuts magnetic flux as it falls (M1)

e.m.f. induced proportional to rate of cutting of magnetic flux (A1)

(ii) magnetic flux into page through the loop decreasing B1

induced current produces magnetic flux into page to oppose the decrease B1

(right hand grip rule gives) induced current flowing clockwise in loop B1

OR

magnetic flux density is higher in upper half then lower half of loop, so rate of flux cut and induced e.m.f. larger in upper half than lower half of loop (B1)

direction of induced e.m.f. (drives induced current left to right) is same in both halves, so net e.m.f. (B1)

drives current clockwise in loop (B1)

(b) induced e.m.f.

$$= -\frac{\Delta\Phi}{\Delta t} = -\frac{(30-120)\times10^{-3}\times\pi\times0.050^2}{0.040}$$ M1

$= 0.0177\ \mathrm{V} = 18\ \mathrm{mV}$ A0

6 **(a)** period = 15 ms C1

frequency = 1 / period = 1 / 0.015 = 67 Hz A1

(b) r.m.s current
= 0.75 / √2 C1

= 0.53 A A1

(c) energy
= $I_{rms}^2 R t = 0.53^2 \times 450 \times 30 \times 10^{-3}$ C1

= 3.8 J A1

(d) instantaneous power P dissipated in resistor is $P = I^2 R$ where I is instantaneous current and R is resistance of resistor B1

current sill flows in resistor in opposite directions during half-cycles, so heating resistor B1

OR

average power <P> dissipated in resistor is $\langle P \rangle = I_{rms}^2 R$ where I_{rms} is root-mean-squared current and R is resistance of resistor (B1)

I_{rms} not zero, so heating resistor (B1)

Section B

7 **(a)** progressive: energy transferred along direction of propagation of wave B1

longitudinal: particles along wave oscillate along axis parallel to direction of propagation of waves B1

(b) **(i)** amplitude = 2.0×10^{-11} m A1

frequency = 500 Hz A1

(ii) maximum speed
$= \omega x_0 = (2\pi \times 500) \times 2 \times 10^{-11}$ M1

$= 6.3 \times 10^{-8}\ \mathrm{m\ s^{-1}}$ A0

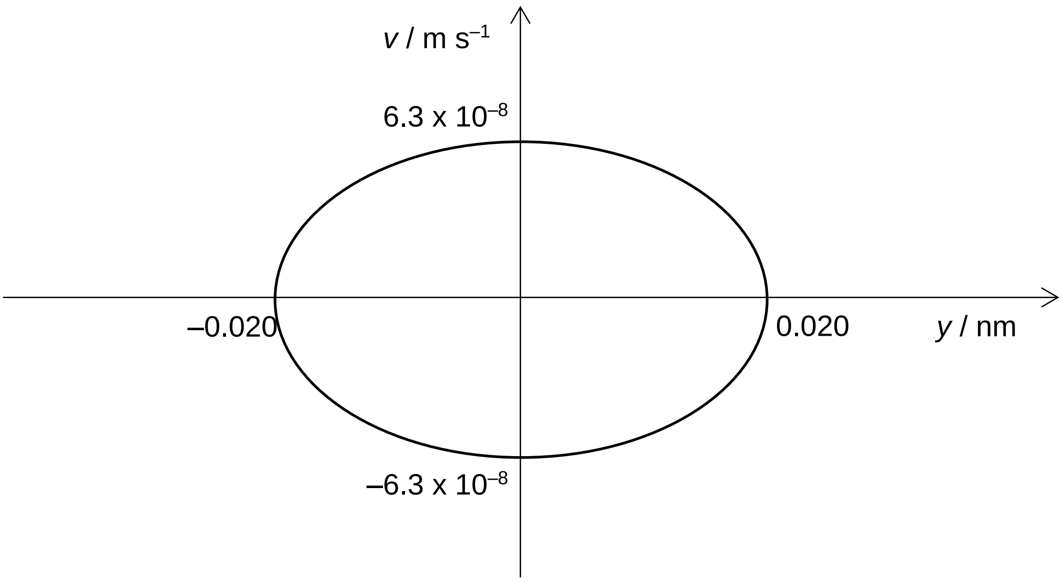
(iii) maximum kinetic energy = ½ mv_0^2

$\frac{1}{2} \times m \times (6.3 \times 10^{-8})^2 = 2.4 \times 10^{-19}$ C1

$m = 1.2 \times 10^{-4}\ \mathrm{kg}$ A1

(iv) ellipse / circle M1

with correct axes labels A1



(c) **(i)** energy transferred from beating wings to the ear / eardrum vibrates at same frequency as beating wing B1

frequency within audible range of person (20 Hz – 20kHz) B1

(ii) intensity $\propto \frac{1}{\text{distance}^2}$ C1

$\frac{1.6I}{I} = \left(\frac{2.0}{2.0-x}\right)^2$ where I is original intensity C1

x = 0.42 m A1

[Turn over

(iii)	air molecule travels $4 \times 5.0 \times 10^{-9}$ (= 2.0×10^{-8} m) each cycle	C1
	total distance covered in 1800 beats = $1800 \times 2.0 \times 10^{-8} = 3.6 \times 10^{-5}$ m	A1
(iv)	device generate sound at same frequency as buzzing sound	B1
	of equal / similar amplitude	B1
	and 180° out-of-phase / anti-phase	B1
	leads to destructive interference of buzzing sound and the generated sound	B1
	that cancels the buzzing sound	

8 **(a)** **(i)** **1.** mass B1

2. positive electric charge B1

(ii) magnetic force acts on moving charge in magnetic field, force on it may not be due to electric field B1

(b) **(i)** magnitude of magnetic flux density at wire *X*

$= \frac{\mu_0 I}{2\pi d} = \frac{4\pi \times 10^{-7} \times 290}{2\pi \times 0.050}$ M1

$= 1.2 \times 10^{-3}$ T A0

(ii) $F = BIL \Rightarrow \frac{F}{L} = BI$

force per unit length
$= 1.2 \times 10^{-3} \times 290$ C1

$= 0.35$ N m^{-1} A1

(c) **(i)** electron moving perpendicular in magnetic field experience a magnetic force B1

force
$= Bqv = 4.64 \times 10^{-3} \times 1.6 \times 10^{-19} \times 2.9 \times 10^{7}$ M1

$= 2.15 \times 10^{-14} = 2.2 \times 10^{-14}$ N A0

(ii) magnetic field between the wires is not uniform B1

magnetic force / resultant force on electron not constant M1

so, claim is incorrect A0

(iii) curve downwards B1

(d) [Method 1]
electric force on electron $= qE = 1.6 \times 10^{-19} \times \frac{13500}{0.10} = 2.16 \times 10^{-14}$ N M1

either force equal to **(c)(i)**, so constant velocity
or force ≠ **(c)(i)**, so cannot be constant velocity A1

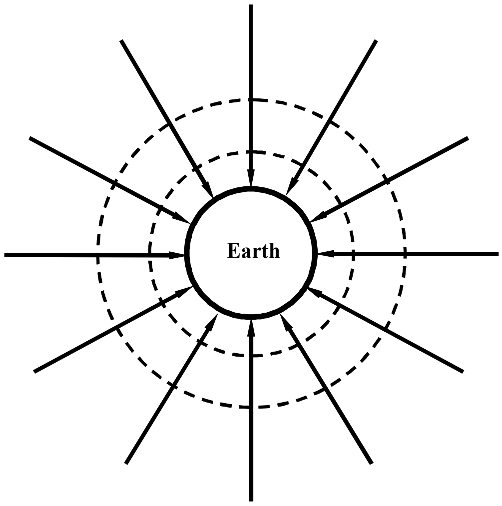
[Method 2]
For electron to move at constant velocity, magnetic force = electric force
$Bev = eE \Rightarrow v = \frac{13500}{0.10} / 4.64 \times 10^{-3} = 2.91 \times 10^{7}$ m s^{-1} M1

either given speed = speed required, so constant velocity
or given speed < speed required, so cannot be constant velocity A1

(e) minimum **four** field lines directed towards Earth radially B1

minimum **two** concentric circles for equipotential surface B1

minimum **three** circles with increasing distance between one circle and next outer circle B1



(f) **(i)** gravitational field strength by earth = gravitational field strength by moon

$\frac{GM_{\text{Earth}}}{x^2} = \frac{GM_{\text{moon}}}{(3.84\times10^8 - x)^2}$ C1

$\frac{5.98\times10^{24}}{x^2} = \frac{7.35\times10^{22}}{(3.84\times10^8 - x)^2}$ C1

$x = 3.5 \times 10^8$ m A0

(ii) *either* acceleration (or resultant force) of spaceship and its displacement from P is in the same direction

or spaceship accelerates towards Earth if displaced left of P or towards moon if displaced right of P M1

so claim incorrect A1