Name:		Centre/Index Number:		Class:	

DUNMAN HIGH SCHOOL
Preliminary Examination
Year 6

H2 PHYSICS 9749/02

Paper 2 Structured Questions

15 September 2022

2 hours

Candidates answer on the Question Paper

READ THESE INSTRUCTIONS FIRST

Write your centre number, index number, name and class at the top of this page.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

Answer **all** questions in the spaces provided on the question paper.

The use of an approved scientific calculator is expected, where appropriate.
You may lose marks if you do not show your working or if you do not use appropriate units.

The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	10
2	9
3	6
4	6
5	8
6	9
7	10
8	22
Total	80

This document consists of **20** printed pages.

Data

speed of light in free space,	c =	3.00×10^{8} m s^{-1}
permeability of free space,	μ_o =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	ε_o =	8.85×10^{-12} F m^{-1}
		$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	e =	1.60×10^{-19} C
the Planck constant,	h =	6.63×10^{-34} J s
unified atomic mass constant,	u =	1.66×10^{-27} kg
rest mass of electron,	m_e =	9.11×10^{-31} kg
rest mass of proton,	m_p =	1.67×10^{-27} kg
molar gas constant,	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant,	k =	1.38×10^{-23} J K^{-1}
gravitational constant,	G =	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall,	g =	9.81 m s^{-2}

Formulae

uniformly accelerated motion,	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas,	W	=	$p\Delta V$
hydrostatic pressure,	p	=	ρgh
gravitational potential,	ϕ	=	$-Gm/r$
temperature,	T/K	=	T/°C + 273.15
pressure of an ideal gas,	p	=	$\frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule,	E	=	$\frac{3}{2}kT$
displacement of particle in s.h.m.,	x	=	$x_0 \sin \omega t$
velocity of particle in s.h.m.,	v	=	$v_0 \cos \omega t$
		=	$\pm\omega\sqrt{x_o^2 - x^2}$
electric current,	I	=	$Anvq$
resistors in series,	R	=	$R_1 + R_2 + \ldots$
resistors in parallel,	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential,	V	=	$\frac{Q}{4\pi\varepsilon_o r}$
alternating current / voltage,	x	=	$x_0 \sin \omega t$
magnetic flux density due to a long straight wire,	B	=	$\frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil,	B	=	$\frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid,	B	=	$\mu_0 nI$
radioactive decay,	x	=	$x_0 \exp(-\lambda t)$
decay constant,	λ	=	$\frac{\ln 2}{t_{\frac{1}{2}}}$

Answer **all** questions in the spaces provided.

1 A golfer strikes a ball so that it leaves the ground with a velocity of $6.0\,\mathrm{m\,s^{-1}}$ at an angle θ to the horizontal, as illustrated in Fig. 1.1.

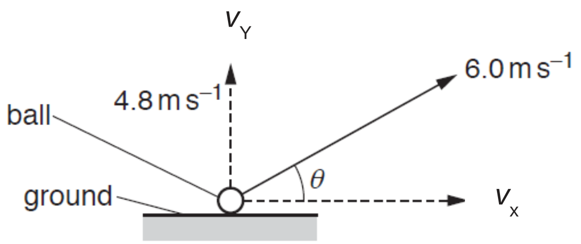

Fig. 1.1 (not to scale)

The magnitude of the initial vertical component, v_Y, of the velocity is $4.8\,\mathrm{m\,s^{-1}}$. Assume that air resistance is negligible.

(a) Show that the magnitude of the initial horizontal component, v_X, of the velocity is $3.6\,\mathrm{m\,s^{-1}}$.

[1]

(b) The ball leaves the ground at time $t = 0$ and reaches its maximum height at $t = 0.49\,\mathrm{s}$.

On Fig. 1.2, sketch separate lines to show the variation with time t, until the ball returns to the ground, of

(i) the vertical component, v_Y, of the velocity (label this line Y), [2]

(ii) the horizontal component, v_X, of the velocity (label this line X). [2]

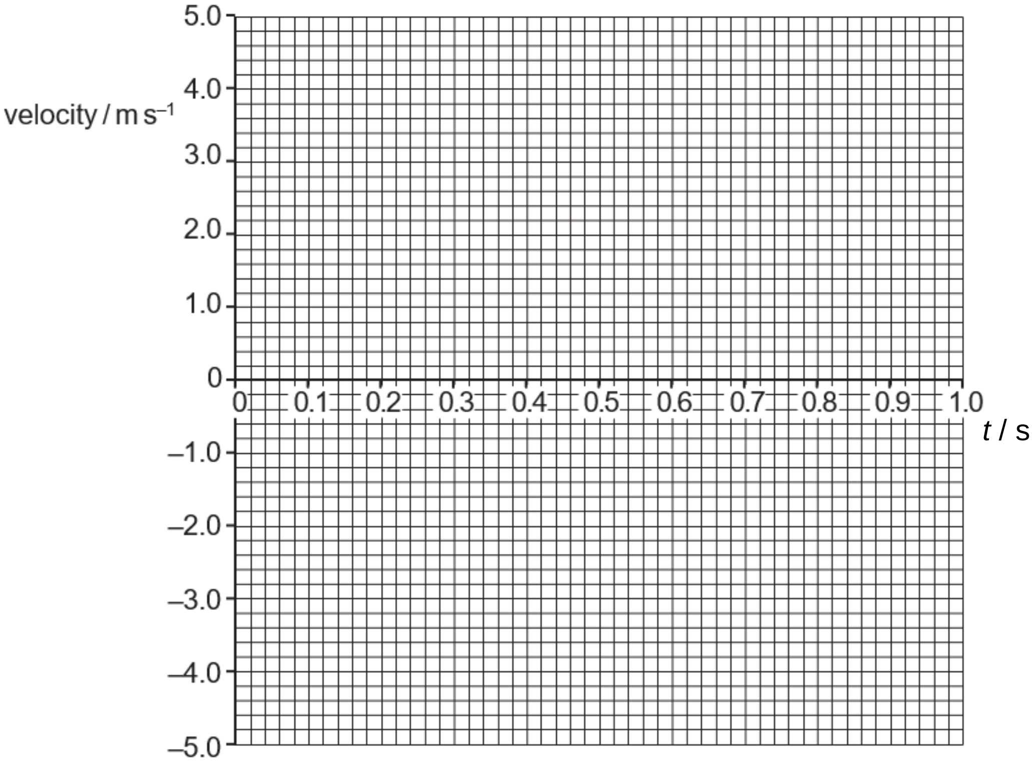

Fig. 1.2

(c) Calculate the maximum height reached by the ball.

maximum height = ... m [2]

(d) For the movement of the ball from the ground to its maximum height, determine the ratio

$$\frac{\text{kinetic energy at maximum height}}{\text{change in gravitational potential energy}}.$$

ratio = ... [2]

(e) In practice, air resistance is not negligible.

State and explain how the actual time taken for the ball to reach maximum height is affected compared to the time calculated when air resistance is assumed to be negligible.

....

.... [1]

[Total: 10]

2 **(a)** The variation with extension x of the tension F in a spring is shown in Fig. 2.1.

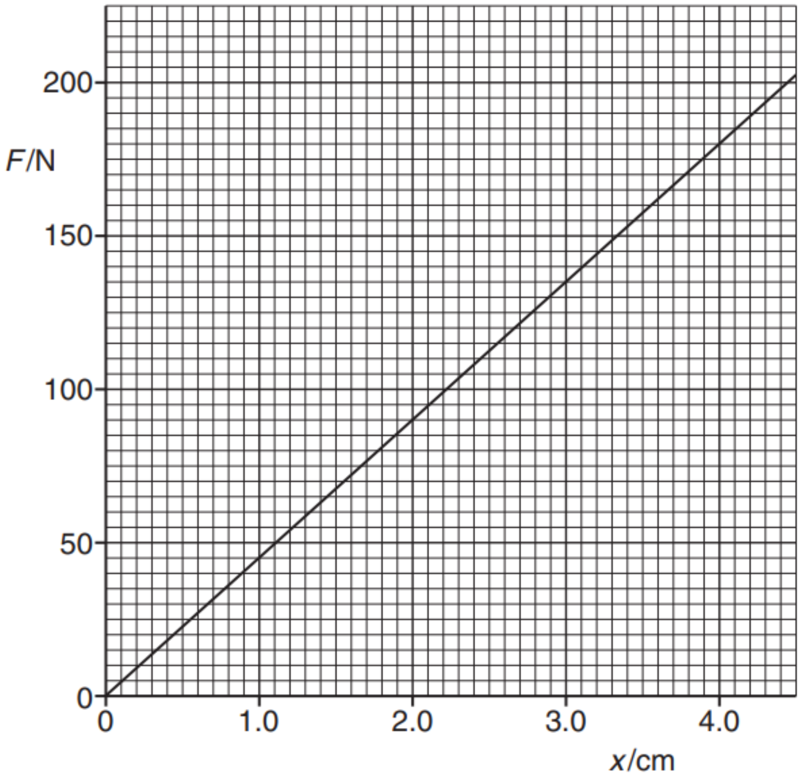

Fig. 2.1

Calculate the energy stored in the spring for an extension of 4.0 cm. Explain your working.

energy = ... J [3]

(b) The spring in **(a)** is used to join two frictionless trolleys A and B, of mass M_1 and M_2 respectively, as shown in Fig. 2.2.

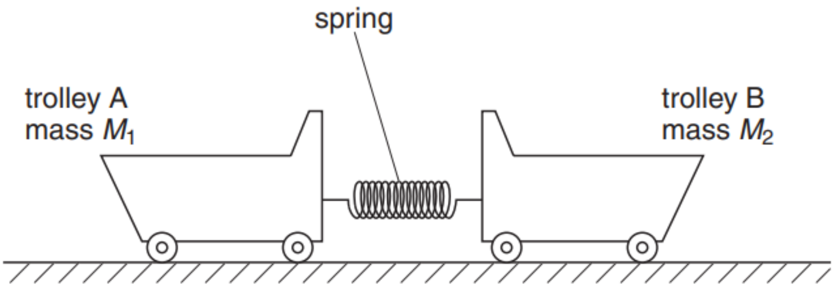

Fig. 2.2

The trolleys rest on a horizontal surface and are held apart so that the spring is extended. The trolleys are then released at the same time.

(i) Explain why, as the extension of the spring is reduced, the momentum of trolley A is equal in magnitude but opposite in direction to the momentum of trolley B.

……………………………………………………………………………………………….

……………………………………………………………………………………………….

……………………………………………………………………………………………….

…………………………………………………………………………………………… [2]

(ii) At the instant when the extension of the spring is zero, trolley A has speed V_1 and trolley B has speed V_2.

Write down

1. an equation, based on momentum, to relate V_1 and V_2,

…………………………………………………………………………………….... [1]

2. an equation to relate the initial energy E stored in the spring to the final energies of the trolleys.

…………………………………………………………………………………….... [1]

(iii) **1.** Show that the kinetic energy E_K of an object of mass m is related to its momentum p by the expression

$$E_K = \frac{p^2}{2m}.$$

[1]

2. Trolley A has a bigger mass than trolley B.
Use the expression in **(iii)1.** to deduce which trolley, A or B, has the larger kinetic energy at the instant when the extension of the spring is zero.

....

.... [1]

[Total: 9]

3 Two progressive sound waves Y and Z meet at a fixed point P. The variation with time t of the displacement x of each wave at point P is shown in Fig. 3.1.

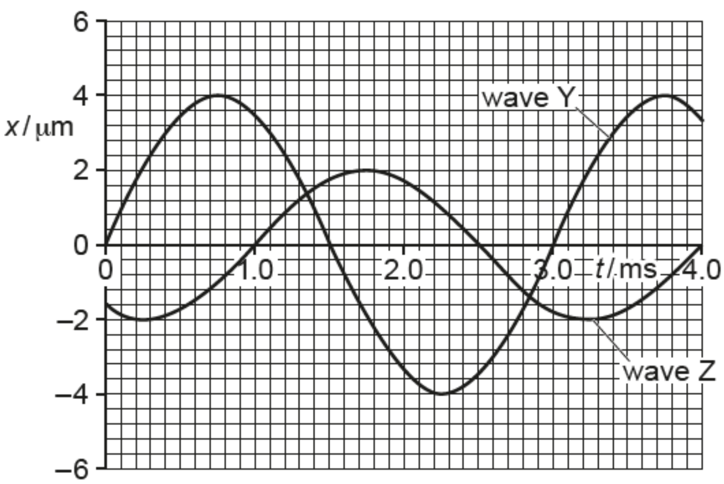

Fig. 3.1

(a) Determine the phase difference between the waves.

phase difference = ...° [1]

(b) The two waves superpose at P. Use Fig. 3.1 to determine the resultant displacement at time t = 0.75 ms.

resultant displacement = ……………………μm [1]

(c) The intensity of wave Y at point P is I.

Determine, in terms of I, the intensity of wave Z.

intensity = …………………… [2]

(d) The speed of wave Z is 330 m s^{-1}.

Determine the wavelength of wave Z.

wavelength = …………………… m [2]

[Total: 6]

4 **(a)** The circuit in Fig. 4.1 contains a battery of electromotive force (e.m.f.) E and negligible internal resistance connected to four resistors R_1, R_2, R_3 and R_4, each of resistance R.

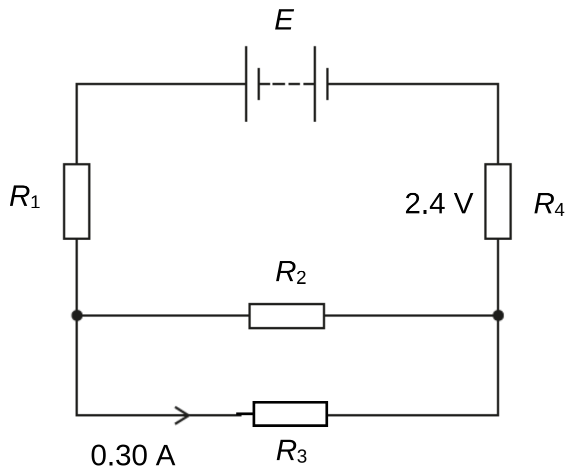

Fig. 4.1

The current in R_3 is 0.30 A and the potential difference across R_4 is 2.4 V.

(i) Show that R is equal to 4.0 Ω.

[2]

(ii) Determine the e.m.f. E of the battery.

E = ... V [2]

(b) The battery in **(a)** is replaced with another battery of the same e.m.f. but with an internal resistance that is not negligible.

State and explain the change, if any, in the total power produced by the battery.

…...

.... [2]

[Total: 6]

5 Fig. 5.1 shows a simple laminated iron core transformer consisting of a primary coil of 25 000 turns and a secondary coil of 625 turns.

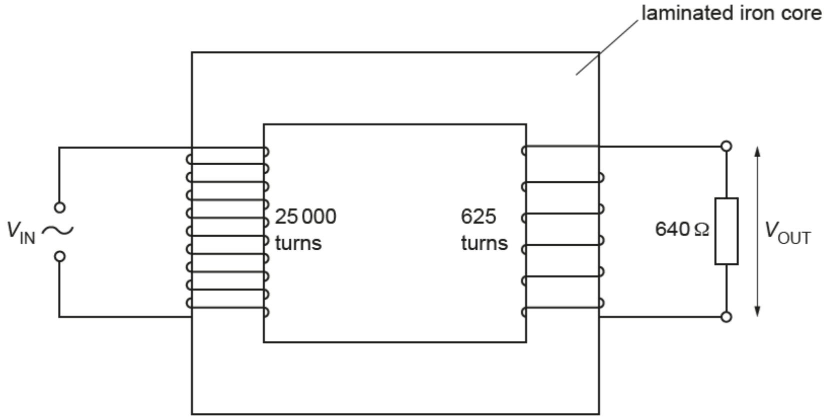

Fig. 5.1

The output potential difference V_{OUT} is applied to a load resistor of 640 Ω.

(a) **(i)** State the function of the iron core.

…...………………………………………………………………………………………….

……………………………………………………………………………………………. [1]

(ii) Explain why the iron core is laminated.

…...………………………………………………………………………………………….

…...………………………………………………………………………………………….

…...………………………………………………………………………………………….

……………………………………………………………………………………………. [2]

(b) The input p.d. V_{IN} is a sinusoidal alternating voltage of peak value 12 kV and period 40 ms.

(i) Calculate the maximum value of V_{OUT}.

maximum V_{OUT} = ... V [1]

(ii) Calculate the root-mean-square (r.m.s.) current in the load resistor.

r.m.s. current = ... A [1]

(iii) On Fig. 5.2, sketch the variation with time t of the power P dissipated in the load resistor for time $t = 0$ to $t = 40$ ms. Assume that $P = 0$ when $t = 0$.

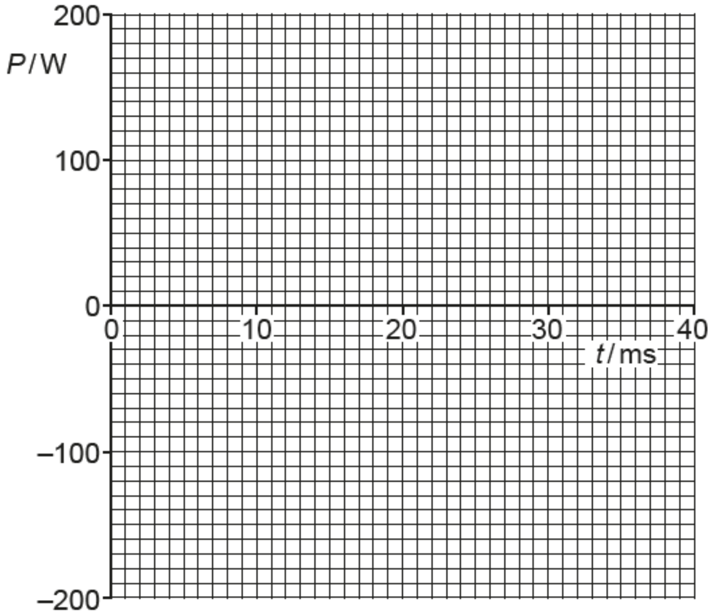

Fig. 5.2

[2]

(c) Deduce, with reference to Fig. 5.2, the mean power in the load resistor.

…...…………………………………………………………………………………………….

…...…………………………………………………………………………………………….

…...…………………………………………………………………………………………….

………………………………………………………………………………………………. [1]

[Total: 8]

6 **(a)** State an experimental phenomenon that provides evidence for the wave nature of matter.

…………………………………………………………………………………………………… [1]

(b) Electrons are accelerated from rest through a potential difference of 4.8 kV.

Calculate the de Broglie wavelength of the beam of electrons.

wavelength = ... m [3]

(c) A polished calcium plate in a vacuum is investigated by illuminating the surface with light. It is found that no photoelectric current is produced when the frequency of the light is less than 6.93×10^{14} Hz.

(i) Explain how the particulate nature of electromagnetic radiation accounts for this phenomenon.

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

……………………………………………………………………………………………… [3]

(ii) Calculate the work function of calcium.

work function = ... eV [2]

[Total: 9]

7 Strontium-90 decays with the emission of a β-particle to form Yttrium-90. The reaction is represented by the equation

$$^{90}_{38}\text{Sr} \rightarrow {}^{90}_{39}\text{Y} + {}^{0}_{-1}\text{e} + 0.55\text{ MeV}$$

The half-life of Strontium-90 is 27.7 years

(a) Define *half-life.*

....

.... [1]

(b) Suggest, with a reason, which nuclide $^{90}_{38}\text{Sr}$ or $^{90}_{39}\text{Y}$ has a greater binding energy.

....

....

....

....

.... [3]

(c) At the time of purchase of a Strontium-90 source, the activity is 3.7×10^6 Bq.

(i) Calculate, for this sample of strontium,

1. the initial number of atoms,

initial number = ... [2]

2. the initial mass.

initial mass = ...kg [2]

(ii) Determine $\frac{A}{A_o}$, where A is the activity of the sample 5.0 years after purchase and A_o is the initial activity.

$\frac{A}{A_o}$ = ... [2]

[Total: 10]

8 In the late 17th century, scientists were embroiled in a debate about the fundamental nature of light – whether it was a wave or a particle. In the 1860, the Scottish physicist James Clerk Maxwell described light as a propagating wave of electric and magnetic fields. This Wave Theory of light is successful in explaining the laws of reflection and refraction of light, as well as the diffraction and interference effects of light in the Thomas Young double slit experiment. According to the Wave Theory, energy is emitted continuously.

However, the Wave Theory of light cannot explain the concept of blackbody radiation. Fig 8.1 shows how the intensity I of the emitted radiation varies with its wavelength λ at the different temperatures. In 1900, the German physicist Max Planck, introduced the idea that energy is quantised to explain the observation that with increasing temperature of the body, the peak of the radiation curve shifts to shorter wavelength with higher intensity.

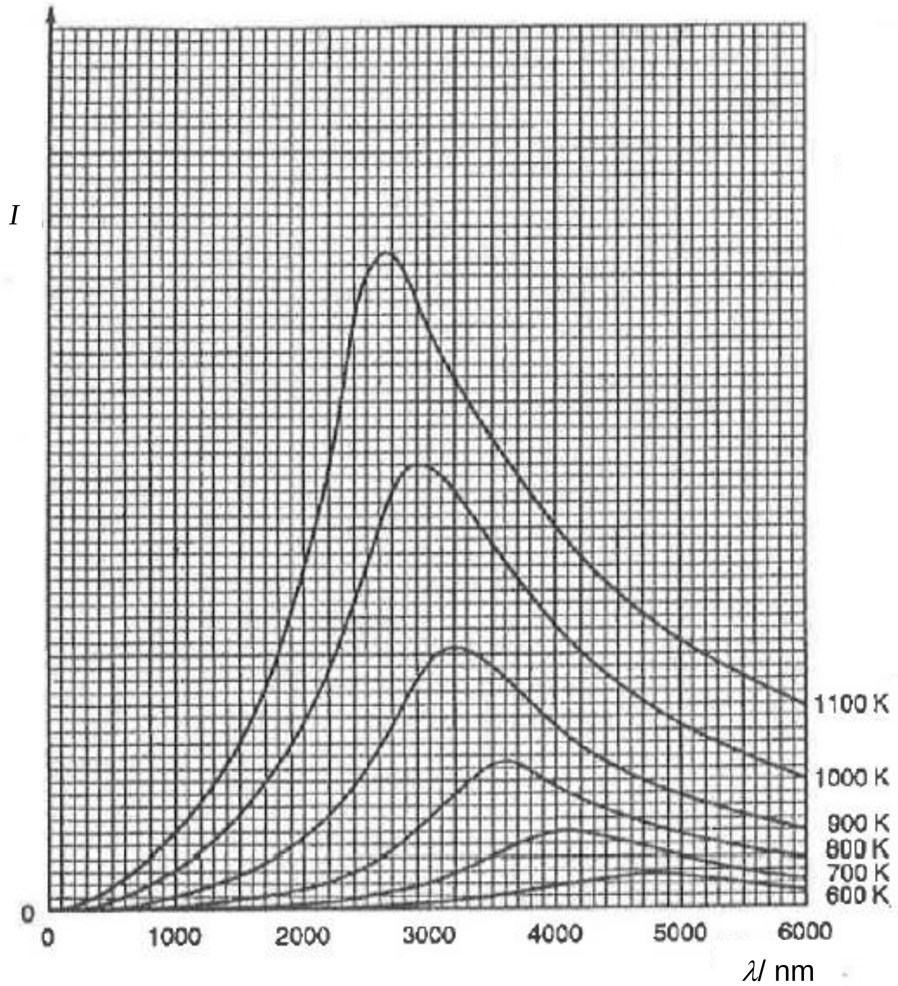

Fig. 8.1

(a) Explain what is meant by energy is *quantised*.

……………………………………………………………………………………………………

…………………………………………………………………………………………………… [1]

(b) **(i)** On the horizontal axis of Fig. 8.1, indicate with the letter V, a wavelength that is in the visible region of the electromagnetic spectrum. [1]

(ii) Use Fig. 8.1 to suggest why, at a temperature of 1100 K, the object would glow with a red colour.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [2]

(c) The radiation emitted by a body may be used as a means to determine the temperature of the body.

(i) Suggest and explain a property of the radiation that could be used for this purpose.

....

.... [1]

(ii) Suggest one advantage and one disadvantage of this method of measuring temperature.

advantage: ....

.... [1]

disadvantage: ....

.... [1]

The Wave Theory also does not explain the line spectra of hydrogen. In 1913, a Danish physicist, Neils Bohr successfully matched the wavelength of the emission line spectra to the discrete energy levels in hydrogen, again using quantisation. In the Bohr model, the hydrogen atom is pictured as a heavy, positively charged nucleus orbited by a light, negatively charged electron. According to Bohr, the angular momentum, which is the product of the linear momentum of the electron and its radius of orbit around the nucleus, is quantised. He further added that the electron with linear momentum p can only move in those orbits with radius r provided the angular momentum of the electron is an integer multiple of $\frac{h}{2\pi}$

$$\text{angular momentum} = pr = \frac{nh}{2\pi}$$

where n is a positive integer and h is the Planck constant.

At the ground state, the electron is in the smallest orbit, with the lowest energy, and has an orbital radius known as the Bohr radius.

(d) **(i)** Show that the linear speed v, in m s^{-1}, of the electron in the hydrogen atom is related to its orbital radius r, in m, by

$$v = \frac{15.9}{\sqrt{r}}$$

[3]

(ii) Using your expression in **(d)(i)** to calculate the Bohr radius r_o.

r_o = ………………….. nm [2]

(iii) Hence, by considering the potential and kinetic energies of the electron, show that the total energy of the electron in the ground state is –13.6 eV.

[2]

(e) The measured wavelength, λ, of selected lines in the hydrogen spectrum are given empirically by

$$\frac{1}{\lambda} = 1.097 \times 10^{7}\left(1 - \frac{1}{n^2}\right)$$

where n is an integer greater than or equal to one.

Fig. 8.2 represents part of the emission spectrum of atomic hydrogen. It contains a series of lines, the wavelengths of some of which are marked.

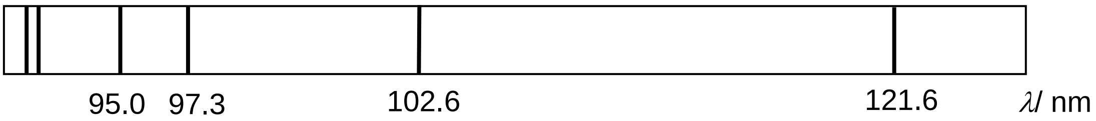

Fig. 8.2

These lines are part of the Lyman series due to electron transitions from higher energy levels to the ground state.

(i) Calculate the minimum wavelength given by this equation.

wavelength = ……………….. nm [1]

(ii) Show that the energy E of a photon and its wavelength λ are related by

$$E\lambda = 1.99 \times 10^{-16} \text{ J nm}$$

[2]

(iii) Use the relation given in **(e)(ii)**, complete Fig. 8.3 to determine the photon energies equivalent to all the wavelengths marked in Fig. 8.2.

wavelength λ / nm	$E = \frac{hc}{\lambda}$ / eV
121.6	
102.6	
97.3	
95.0	

Fig. 8.3

[1]

(iv) Use your answers in **(e)(iii)** to map a partial energy level diagram for hydrogen. You can leave your energy levels to 3 significant figures.
Show and label clearly, the electron transitions responsible for the emission lines with labelled wavelengths in Fig. 8.2.

[3]

(v) Another emission line in the hydrogen spectrum occurs at a wavelength of 434.1 nm. Identify and label on your answer in **(e)(iv)** the electron transition responsible for this line. [1]

[Total: 22]