HWA CHONG INSTITUTION
JC2 Preliminary Examination
Higher 2

CANDIDATE NAME		**CT GROUP**	**22S**
CENTRE NUMBER		**INDEX NUMBER**	

PHYSICS — 9749/03

Paper 3 Longer Structured Questions — **18 September 2023**

SECTION A BOOKLET — **2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

INSTRUCTIONS TO CANDIDATES

Write your **Centre number**, **index number, name** and **CT class** clearly on all work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paperclips, highlighters, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A

Answer **all** questions.

Section B

Answer **one** question only. **Circle** the question number on the cover page.

You are advised to spend one and a half hours on Section A and half an hour on Section B.

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

You are reminded of the need for good English and clear presentation in your answers.

For Examiner's Use		
Section A		
1		**8**
2		**8**
3		**9**
4		**8**
5		**8**
6		**7**
7		**12**
Section B		
8		**20**
9		**20**
Deductions		
P3		**80**

Data	
speed of light in free space,	$c = 3.00 \times 10^{8}$ m s^{-1}
permeability of free space,	$\mu_o = 4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space,	$\varepsilon_o = 8.85 \times 10^{-12}$ F m^{-1} $\approx (1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge,	$e = 1.60 \times 10^{-19}$ C
the Planck constant,	$h = 6.63 \times 10^{-34}$ J s
unified atomic mass constant,	$u = 1.66 \times 10^{-27}$ kg
rest mass of electron,	$m_e = 9.11 \times 10^{-31}$ kg
rest mass of proton,	$m_p = 1.67 \times 10^{-27}$ kg
molar gas constant,	$R = 8.31$ J K^{-1} mol^{-1}
the Avogadro constant,	$N_A = 6.02 \times 10^{23}$ mol^{-1}
the Boltzmann constant,	$k = 1.38 \times 10^{-23}$ J K^{-1}
gravitational constant,	$G = 6.67 \times 10^{-11}$ 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	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	T/K = T/ °C + 273.15
pressure of an ideal gas	$P = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean kinetic energy of a molecule of an ideal gas	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_o \sin \omega t$
velocity of particle in s.h.m.	$v = v_o \cos \omega t$ $= \pm\omega\sqrt{(x_o^2 - x^2)}$
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	$x = x_o \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_o \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

Section A

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

1 **(a)** Define gravitational potential at a point.

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

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

(b) A satellite is orbiting the Earth with an orbital radius of 6610 km at a speed of 7780 m s^{-1}. The satellite is boosted into a higher orbit of radius 6890 km by firing its thrusters.

(i) State and explain the effect on the gravitational potential energy of the satellite.

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

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

(ii) Show that the linear speed v of a satellite in a circular orbit of radius R about the centre of the Earth is given by

$$v = \sqrt{\frac{GM}{R}}$$

where G is the gravitational constant and M is the mass of the Earth.

Explain your working.

[1]

(iii) Show that the speed of the satellite in the new orbit is 7620 m s^{-1}.

[1]

(iv) The satellite has a mass of 120 kg. Using your result in **(b)**, calculate the **change** in

1. kinetic energy,

change in kinetic energy = ……………………. J [2]

2. total energy.

change in total energy = …………………..… J [2]

[Total: 8]

2 **(a)** **(i)** The pressure p in an ideal gas is given by the expression

$$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$$

State the meaning of each of the symbols in the equation.

N : ……………………………………………………………………………………………….

m : ………………………………………………………………………………………………

V : ……………………………………………………………………………………………….

$\langle c^2 \rangle$: …………………………………………………………………………………...…

[2]

(ii) Using the equation in **(i)** and the equation of state of an ideal gas, $pV = NkT$, derive an expression for the relationship between the internal energy of the ideal gas and the thermodynamic temperature T.

[2]

(b) **(i)** The gravitational field is relatively weak on the surface of the Moon. The escape speed (i.e. the minimum speed which a body must have in order to escape to an infinite distance) from the Moon is 2.38 km s^{-1}.

Argon-40 may be assumed to be an ideal gas. Calculate the temperature of argon-40 gas at which the r.m.s speed of its atoms is equal to the escape speed from the Moon.

temperature = ………………….. K [2]

(ii) An appreciable amount radioactive potassium-40 is discovered below the lunar surface. It is known that potassium-40 decays to form argon-40 gas.

With reference to your answer in **(b)(i)**, discuss the likelihood of argon-40 being present in the Moon's atmosphere.

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

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

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

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

[Total: 8]

3 A spring hangs vertically from a fixed point.

A mass of 1.2 kg is attached to the free end of the spring, as shown in Fig. 3.1.

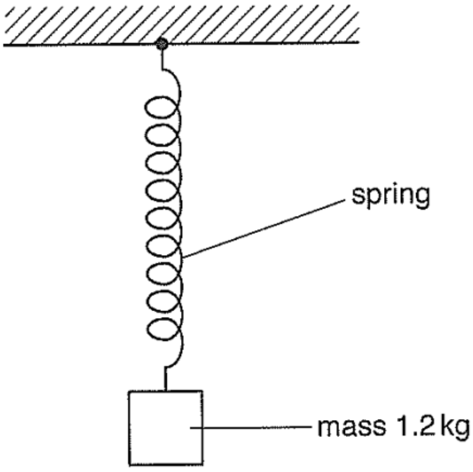

Fig. 3.1

The mass is at the maximum displacement below the equilibrium position at t = 0 s.

It undergoes vertical oscillations with frequency 2.5 Hz and amplitude 3.4 cm.

Take upwards as positive.

(a) The variation with the vertical displacement x of the velocity v of the mass on the spring is shown in Fig. 3.2.

On Fig. 3.2.

(i) indicate the values where the graph cuts the axes,
(ii) mark the starting position at t = 0 s and label this point **A**.

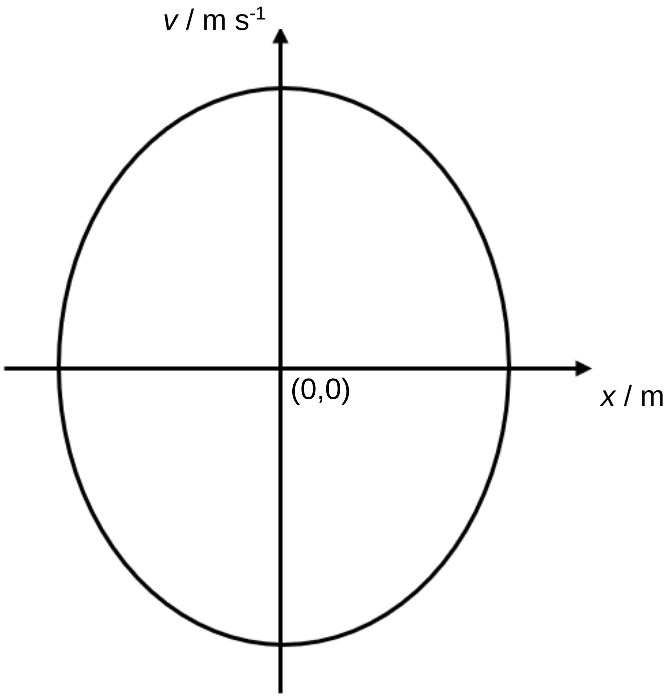

Fig. 3.2

[2]

(b) For the oscillations of the mass, determine the total energy E_T.

E_T = ………………………. J [2]

(c) **(i)** On Fig. 3.2, mark the position where the potential energy E_P is equal to the kinetic energy E_K for the first time upon releasing the mass. Label this point **B**. [1]

(ii) Determine the displacement d of the mass at **B**.

d = ………………………. m [2]

(d) Calculate the phase difference between the positions **A** and **B**.

phase difference = ………………………. rad [2]

[Total: 9]

4 An optical telescope detects light in the visible spectrum. It has an aperture of width 20.0 cm which is 1.50 m from the eyepiece. It is pointed at a binary star system 8.14×10^{16} m away, as shown in Fig. 4.1.

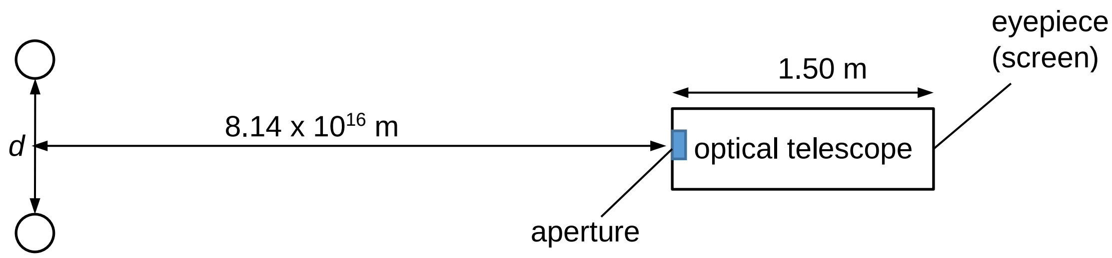

Fig. 4.1 (not drawn to scale)

(a) State Rayleigh's Criterion.

....

....

.... [2]

(b) The two stars are **just** resolvable on this telescope for wavelength of 600 nm.

Calculate the separation *d* of the stars if the plane of the stars' orbits is perpendicular to the earth (i.e. "face-on") as shown in Fig. 4.1.

Show your working clearly.

d = ... m [2]

(c) The light of the entire visible spectrum (400 nm to 700 nm) collected by the telescope is passed through a diffraction grating with 500 lines per mm.

(i) Find the angular width of the second order spectrum.

angular width = …………………………… ° [3]

(ii) State an advantage of using the second order spectrum instead of the first order spectrum to determine the wavelength of a radiation.

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

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

[Total: 8]

5 **(a)** A thermistor and a filament bulb are connected in parallel to a battery as shown in Fig 5.1. The e.m.f. E of the battery is unknown and its internal resistance is negligible.

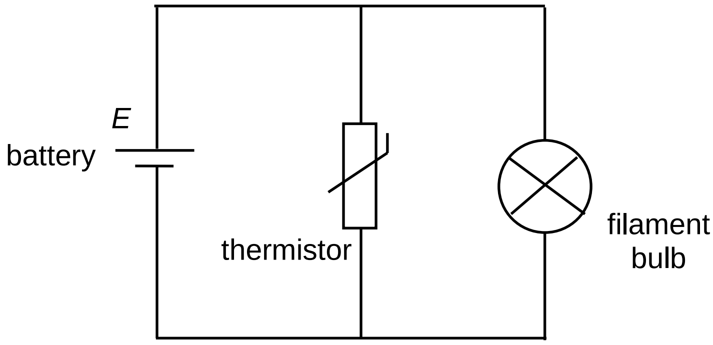

Fig 5.1

Fig. 5.2 shows the current-voltage (I-V) characteristics of the filament bulb and the thermistor.

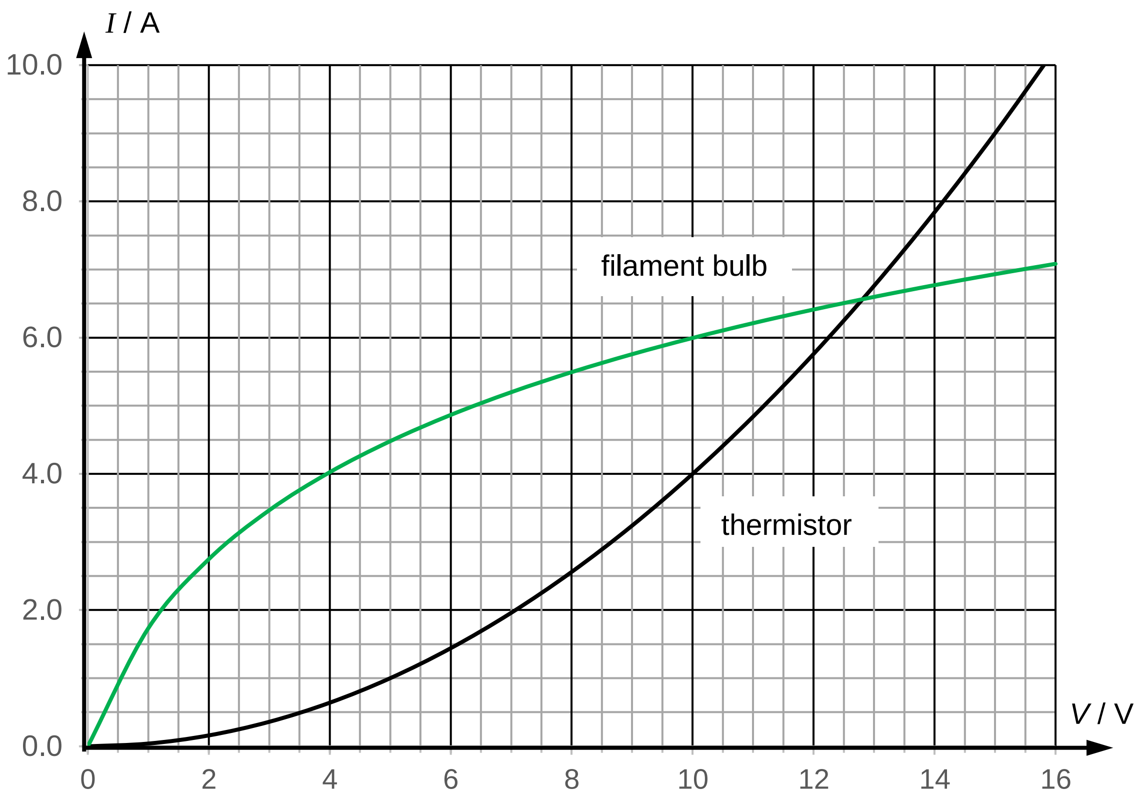

Fig 5.2

(i) Describe the main features of Fig. 5.2 that show the characteristics of the negative temperature coefficient thermistor in terms of current, voltage and resistance.

……..

……..

……..

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

(ii) The current through the battery is 8.0 A.

Using Fig. 5.2, determine

1. the current through the filament bulb and the thermistor

current through the filament bulb = ………………………. A [1]

current through the thermistor = ………………………. A [1]

2. the e.m.f. of the battery.

e.m.f. = ………………………………. V [1]

(b) The filament bulb is now connected in series with a fixed resistor of 2.5 Ω and a battery, as shown in Fig 5.3. The e.m.f. *E* of the battery is 14.0 V and its internal resistance is negligible.

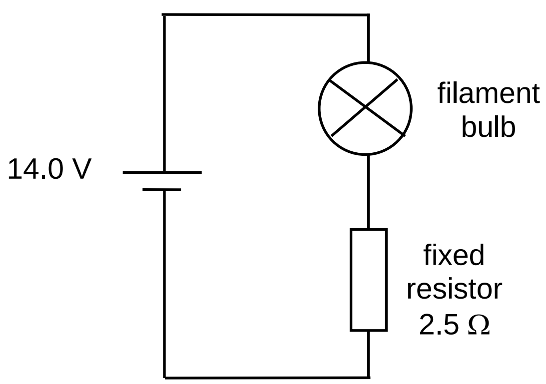

Fig. 5.3

The variation with the potential difference V of the current I for the filament bulb is shown in Fig. 5.4.

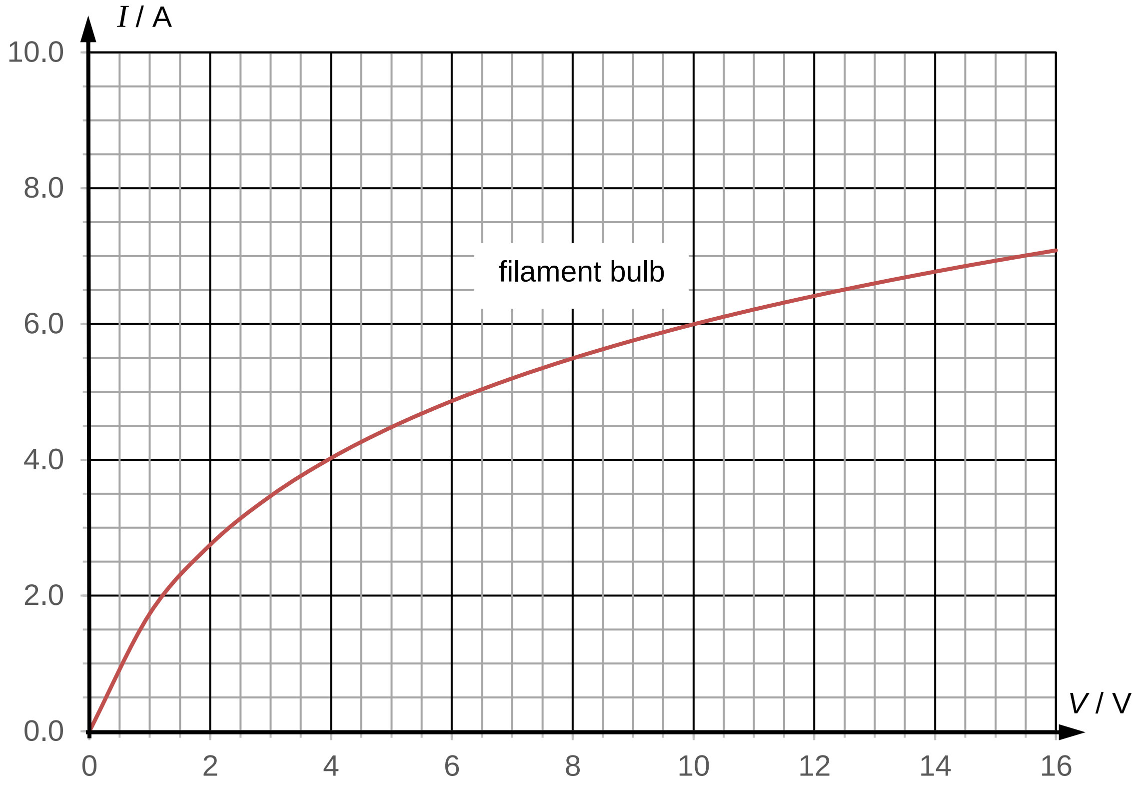

Fig 5.4

(i) On Fig 5.4, draw a line to show the variation with the potential difference V of the current I through the fixed resistor. [1]

(ii) Using Fig. 5.4, determine the current through the filament bulb.

current = ………………………….. A [1]

(iii) Using Fig. 5.4, determine the potential difference across the fixed resistor.

potential difference = …………………………….. V [1]

[Total: 8]

6 **(a)** The variation of an alternating voltage V_P in volts with time t in seconds is given by

$$V_P = 170 \sin (314\, t)$$

The alternating voltage V_P is connected to the primary coil of an ideal transformer as shown in Fig. 6.1. An electric heater with resistance 130 Ω is connected to the secondary coil of the transformer.

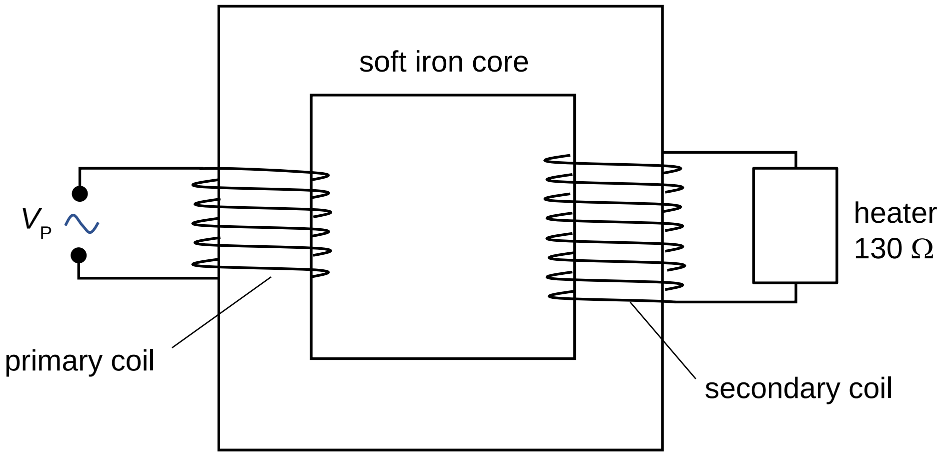

Fig. 6.1

The primary coil consists of 2000 turns and the secondary coil consists of 3500 turns.

(i) Determine r.m.s. potential difference, $V_{S,\ r.m.s.}$ of the secondary coil.

$V_{S,\ r.m.s}$ = ………………. V [2]

(ii) Determine the peak current, $I_{P,\ peak}$ in the primary coil.

$I_{P,\ peak}$ = ………………. A [3]

(b) In Fig. 6.1, the mean power dissipated in the heater is P.

The number of turns in secondary coil is halved while keeping the V_P and the number of turns in primary coil constant.

Determine the new mean power dissipated in the heater in terms of P. Explain your answer.

………..

………..

………..

……… [2]

[Total: 7]

7 Fig. 7.1 shows the energy levels of a hydrogen atom. Transitions A, B, C and D represent some of the possible transitions of an excited electron of the atom.

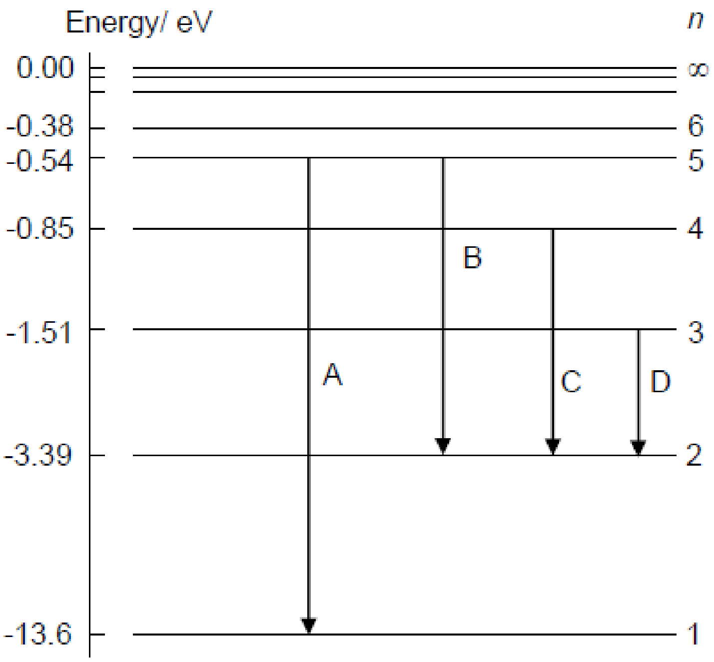

Fig. 7.1

(a) Explain why the energy levels are negative.

....

....

....

....

....

.... [3]

(b) Which of the transitions A, B, C, or D would lead to the emission of radiation of the shortest wavelength?

.... [1]

(c) Using your answer in **(b)**, calculate the wavelength of the radiation and state the region of the electromagnetic spectrum in which this radiation lies.

wavelength = ……………………. nm [2]

region = ……….……………..………………… [1]

(d) List all possible transition(s) in an emission spectrum if an unexcited hydrogen atom is separately bombarded by the following. Explain your answer.

In the case where no transitions are possible, state so clearly and explain your answer.

(i) An incoming electron with energy 12.6 eV

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

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

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

(ii) An incoming photon with energy 12.6 eV

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

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

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

(e) Suggest an application of emission spectrum.

……

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

[Total: 12]

End of Paper 3 Section A