Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
January 2013

Physics

Assessment Unit A2 1

assessing

Momentum, Thermal Physics, Circular Motion, Oscillations and Atomic and Nuclear Physics

[AY211]

AY211

WEDNESDAY 16 JANUARY, AFTERNOON

TIME

1 hour 30 minutes.

INSTRUCTIONS TO CANDIDATES

Write your Centre Number and Candidate Number in the spaces provided at the top of this page.
Answer **all nine** questions.
Write your answers in the spaces provided in this question paper.

INFORMATION FOR CANDIDATES

The total mark for this paper is 90.
Quality of written communication will be assessed in Question **2(b)**.
Figures in brackets printed down the right-hand side of pages indicate the marks awarded to each question.
Your attention is drawn to the Data and Formulae Sheet which is inside this question paper.
You may use an electronic calculator.
Question **9** contributes to the synoptic assessment required of the specification.

For Examiner's use only	
Question Number	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
Total Marks	

If you need the values of physical constants to answer any questions in this paper they may be found in the Data and Formulae Sheet.

Examiner Only	
Marks	Remark

Answer **all nine** questions

1 **(a)** The maximum rotation of a DVD is 1530 revolutions per minute.

(i) Calculate its angular velocity in radians per second.

Angular velocity ____________ rad s^{-1} [2]

(ii) Calculate the period of revolution.

Period = ____________ s [1]

(iii) Calculate the linear speed of a point 4 cm from the centre.

Speed = ____________ m s^{-1} [2]

(b) A motorcycle approaches a hump-backed bridge of radius 124 m, as shown in **Fig. 1.1**. Calculate the maximum speed the motorcycle can have if both its wheels are to remain on the bridge.

Examiner Only	
Marks	Remark

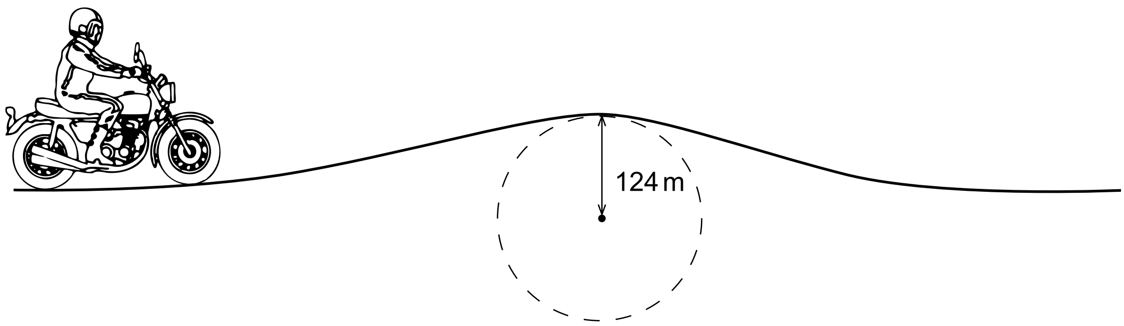

Fig. 1.1

Speed = ___________ $m\,s^{-1}$ [4]

2 **(a)** State the units of specific heat capacity and define specific heat capacity.

____

____

____ [2]

(b) Describe an electrical experiment to obtain a value for the specific heat capacity of water. Include a diagram, state readings to be taken and explain how these readings are used to determine the specific heat capacity.

____

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____

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____

____

____ [5]

Quality of written communication [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(c) A tank contains 160 kg of water at 65 °C.

Calculate the mass of water at 20 °C that must be added in order that the final temperature of the water in the tank is 45 °C.
Assume the heat loss to the tank in this situation is negligible.

Mass of water = ____________ kg [3]

Examiner Only	
Marks	Remark

3 **(a)** When considering the molecules of an ideal gas it is assumed that all collisions between the molecules of the gas, or between the molecules and the walls of the containing vessel, are perfectly elastic.

Explain the meaning of **perfectly elastic** in this context.

____

____

____ [1]

(b) **(i)** A molecule of mass *m* and initial velocity $400\,\mathrm{m\,s^{-1}}$ collides with a stationary molecule of mass $4m$. Assume a perfectly elastic collision occurs. Use this information to construct two equations that will allow the velocity of both molecules, immediately after the collision to be determined.
Note: you are not expected to solve the equations.

[2]

(ii) The mathematical solution for the velocities after the collision results in two possible values for each mass.
mass *m*, velocity $400\,\mathrm{m\,s^{-1}}$ or $-240\,\mathrm{m\,s^{-1}}$
mass $4m$, velocity $0\,\mathrm{m\,s^{-1}}$ or $160\,\mathrm{m\,s^{-1}}$
For each of the two masses, choose which of the possible values is correct and explain why.

Velocity of molecule of mass m = ____________ $\mathrm{m\,s^{-1}}$

Velocity of molecule of mass $4m$ = ____________ $\mathrm{m\,s^{-1}}$

Explanation ____

____

____ [2]

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(Questions continue overleaf)

4 **(a)** Define simple harmonic motion.

____

____

____ [2]

(b) A mass hanging from a vertical spring is pulled down and then released. It oscillates freely about an equilibrium position. At a time of 5.0 s after release, the acceleration of the mass is 49 cm s^{-2} and the mass is a distance 4.0 cm from the equilibrium position.

(i) **(1)** Calculate the natural frequency of the oscillation of this mass–spring system.

Natural frequency = ____________ Hz [3]

(2) Calculate the amplitude of the oscillation.

Amplitude = ____________ cm [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(ii) This mass–spring system experiences light damping as it oscillates.

(1) Describe how the damping could be increased in this oscillating system.

____

____

____ [1]

(2) Describe how increasing the damping will affect the oscillation of the mass–spring system.

____

____

____ [2]

Examiner Only	
Marks	Remark

5 **Equation 5.1** is the relationship for nuclear radius.

$$r = r_0 A^{\frac{1}{3}} \quad \textbf{Equation 5.1}$$

(a) **(i)** Complete **Table 5.1**, for the bromine isotope ${}^{79}_{35}\text{Br}$.

Table 5.1

Symbol from Equation 5.1	**What the symbol represents in words**	**Value for a nucleus of bromine**
A		
r_0		1.2 fm
r		

[3]

(ii) Calculate the volume of a nucleus of bromine.

Volume = ____________ m^3 [2]

(iii) Show that the density of the bromine nucleus is $2 \times 10^{17}\,\text{kg}\,\text{m}^{-3}$

[2]

(b) Estimate by how many orders of magnitude the nuclear density of bromine is bigger than the atomic density of bromine and account for the difference.

Estimate = ____________ [1]

____

____ [1]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

6 **(a) (i)** Define half-life.

____

____

____ [1]

(ii) The equation for radioactive decay is:

$$A = A_0 e^{-\lambda t}$$ **Equation 6.1**

Name the quantities represented by the following symbols in **Equation 6.1**.

A ______________________

A_0 ______________________

λ ______________________ [2]

(iii) Use your definition of half-life and **Equation 6.1** to show that $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$.

[2]

(b) (i) A sample of iodine-131 has a mass of 1.74×10^{-9} kg. One mole of iodine-131 has a mass of 0.131 kg. Show that the number of iodine atoms in the sample is 8.0×10^{15}.

[2]

(ii) The half-life of radioactive iodine-131 is 8 days. Calculate the number of undecayed nuclei remaining after 21 days.

Number of nuclei = ____________ [3]

(iii) Calculate the activity of the sample, in Bq, after 21 days.

Activity = ____________ Bq [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

7 (a) Explain what is meant by the term **binding energy** of a nucleus.

____

____

____ [1]

(b) The mass of a carbon-14 ($^{14}_{6}C$) nucleus is 14.0032 u, the mass of a proton is 1.0073 u and the mass of a neutron is 1.0087 u.

Calculate the binding energy in MeV for carbon-14.

Binding energy = ____________ MeV [3]

(c) The graph in **Fig. 7.1** shows how mean binding energy per nucleon varies with atomic mass number.

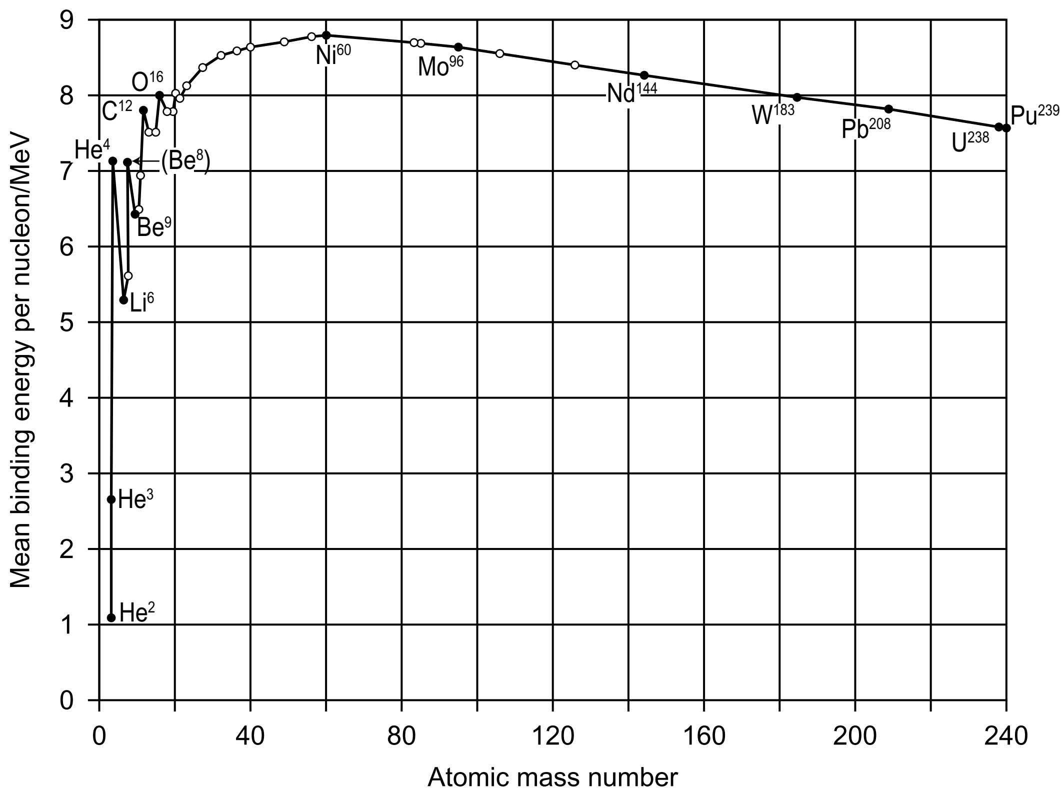

Fig. 7.1

(i) Using a relevant value from **Fig. 7.1** and your answer to **(b)** deduce which of the two isotopes, carbon-12 or carbon-14, will be more stable and explain your answer.

____

____

____

____ [3]

(ii) Explain how the data in **Fig. 7.1** confirms the theoretical basis of nuclear fission and nuclear fusion.

____

____

____

____

____ [3]

Examiner Only	
Marks	Remark

8 **Equations 8.1** and **8.2** represent nuclear reactions that involve the collision of two reactants which results in reaction products and the release of energy.

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{90}_{37}Rb + ^{143}_{55}Cs + 3^{1}_{0}n + 202.5\text{ MeV}$$ **Equation 8.1**

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2^{1}_{1}p + 12.9\text{ MeV}$$ **Equation 8.2**

(a) **(i)** Explain why the three product neutrons in the reaction described by **Equation 8.1** can pose a significant problem in a nuclear reactor and describe how the danger is removed.

____

____

____ [2]

(ii) In the reaction described by **Equation 8.1**, comment on how the optimal energy of the reactant neutron is achieved.

____

____ [2]

(b) Name the process by which the reactants in **Equation 8.2** are provided with the opportunity to collide and state how that process is achieved in the Sun.

____

____

____ [2]

(c) The energy yield per nucleon for the reaction described by **Equation 8.1** is 0.86 MeV. How does this compare with the energy yield per nucleon for the reaction described by **Equation 8.2**?

____

____ [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

9 Data Analysis Question

This question contributes to the synoptic question requirement of the specification. In your answer you will be expected to bring together and apply principles and concepts from different areas of physics, and to use the skills of physics in the particular situation described.

X-ray Photon Emission

X-rays are a type of electromagnetic radiation which can be produced in quanta of energy called photons. X-ray photons can be emitted when electrons bombard a metal and knock out an electron from an inner shell of an atom, see **Fig. 9.1a**. An electron of higher energy from an outer shell can then fall into the inner shell and the energy lost by the falling electron becomes an emitted X-ray photon of energy characteristic of the metal, see **Fig. 9.1b**.

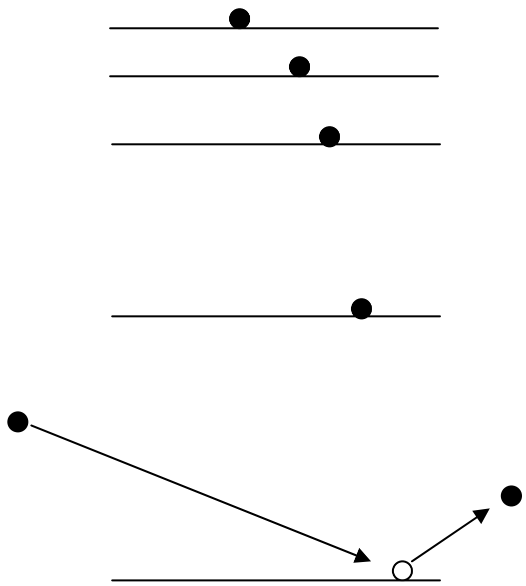

Fig. 9.1a

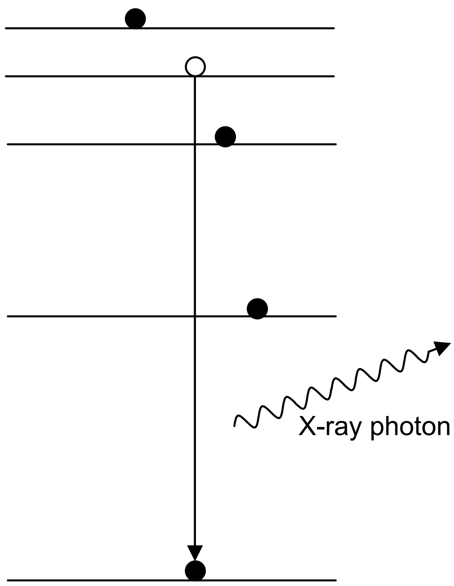

Fig. 9.1b

According to a theory, the energy of the X-ray photon is given by:

$$E = M(Z-1)^2 \qquad \textbf{Equation 9.1}$$

where E is the energy of the photons in keV, Z is the atomic number of the metal target and M is a constant.

Examiner Only	
Marks	Remark

(a) **Table 9.1** gives the energy E of some X-ray photons emitted by various elements.

Table 9.1

Element	**Atomic Number Z**	**E/keV**	**$E^{\frac{1}{2}}$/keV$^{\frac{1}{2}}$**
Titanium	22	4.41	
Iron	26	6.40	
Copper	29	8.06	
Zirconium	40	15.8	
Molybdenum	42	17.5	

(i) Using **Equation 9.1** show how the constant M can be determined by plotting the graph of $E^{\frac{1}{2}}$ against Z.

____

____ [2]

(ii) Calculate the values of $E^{\frac{1}{2}}$ corresponding to the values of E in **Table 9.1** and insert them in the fourth column of the table. Quote these values to three significant figures. [1]

(iii) Select suitable scales for the $E^{\frac{1}{2}}$ and Z axes of the graph grid (**Fig. 9.1**). Plot the points on **Fig. 9.1** and draw the best straight line through the points.

[3]

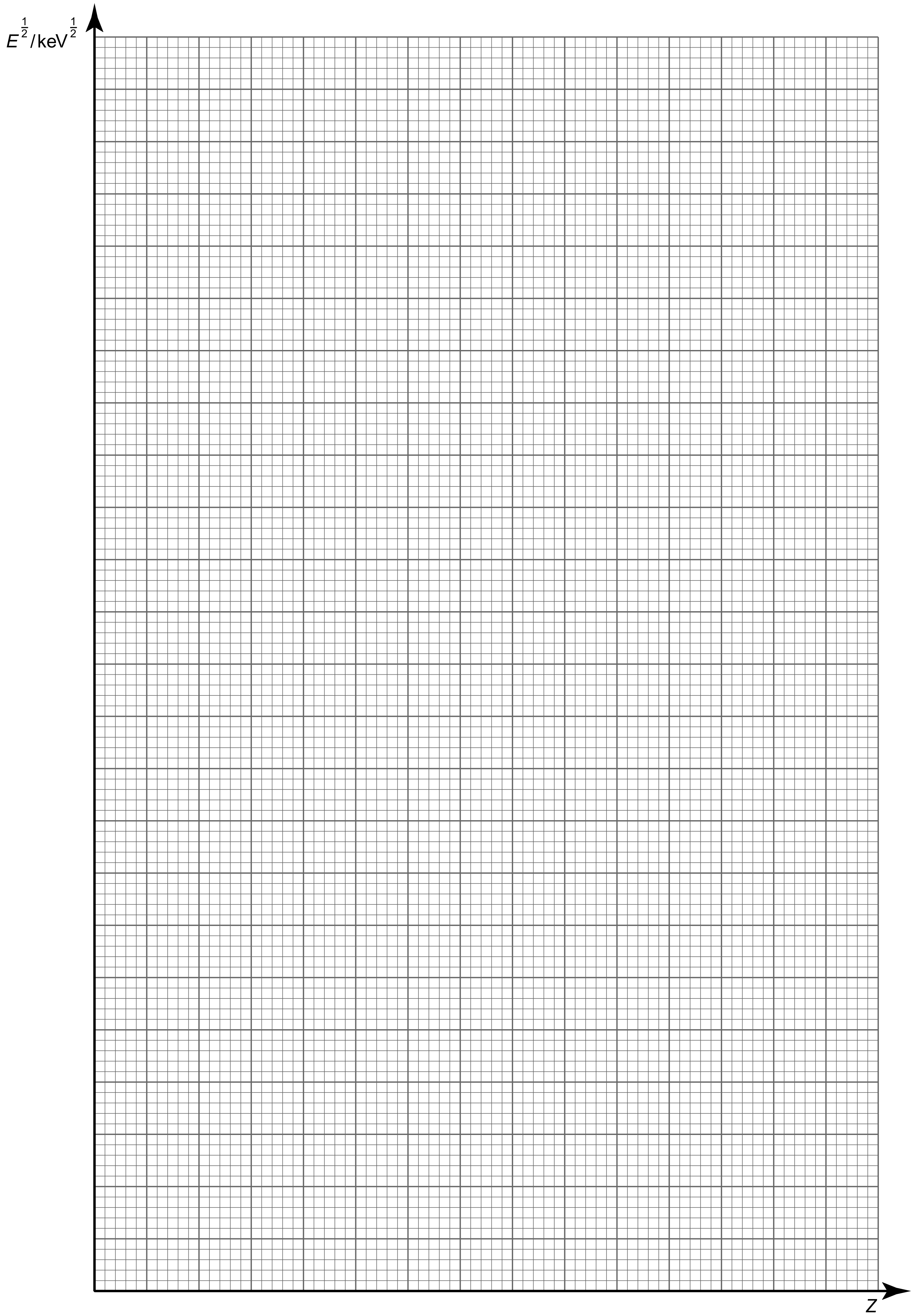

Fig. 9.1

(iv) Determine a numerical value for the constant M from your graph.

Examiner Only	
Marks	Remark

M = ___________ keV [3]

(b) (i) The constant M is a composite constant made up of several constants. It includes a constant known as the Rydberg Constant R, Planck's constant h, the speed of light in a vacuum c and the electronic charge e. M, when expressed in keV, can be shown to be given by:

$$M = \frac{3hcR}{4 \times 10^3 e}$$ **Equation 9.2**

Use your value of M from the graph and the information on the Data Sheet to determine a value for the Rydberg Constant R.

Rydberg Constant R = ____________________ m^{-1} [2]

Examiner Only	
Marks	Remark

(ii) Calculate the percentage difference between the experimentally determined value for the Rydberg constant found in **(b) (i)** compared to the theoretical value of $1.10 \times 10^7 \, m^{-1}$.

Percentage difference = ___________ % [2]

(iii) The Rydberg unit of energy, *Ry*, is closely related to the Rydberg constant, *R*. *Ry* corresponds to the energy of the photon whose wavelength is the inverse of the Rydberg constant, *R*.
Calculate *Ry*.

Ry = ___________ J [2]

THIS IS THE END OF THE QUESTION PAPER

GCE Physics

Data and Formulae Sheet for A2 1 and A2 2

Values of constants

speed of light in a vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\,\mathrm{F^{-1}\,m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
(unified) atomic mass unit	$1\,\mathrm{u} = 1.66 \times 10^{-27}\,\mathrm{kg}$
mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall on the Earth's surface	$g = 9.81\,\mathrm{m\,s^{-2}}$
electron volt	$1\,\mathrm{eV} = 1.60 \times 10^{-19}\,\mathrm{J}$

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The following equations may be useful in answering some of the questions in the examination:

Mechanics

Conservation of energy $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = Fs$ for a constant force

Hooke's Law $F = kx$ (spring constant k)

Simple harmonic motion

Displacement $x = A \cos \omega t$

Sound

Sound intensity level/dB $= 10 \lg_{10} \frac{I}{I_0}$

Waves

Two-source interference $\lambda = \frac{ay}{d}$

Thermal physics

Average kinetic energy of a molecule $\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$

Kinetic theory $pV = \frac{1}{3}Nm\langle c^2 \rangle$

Thermal energy $Q = mc\Delta\theta$

Capacitors

Capacitors in series $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

Capacitors in parallel $C = C_1 + C_2 + C_3$

Time constant $\tau = RC$

Light

Lens formula	$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$
Magnification	$m = \frac{v}{u}$

Electricity

Terminal potential difference	$V = E - Ir$ (e.m.f. E; Internal Resistance r)
Potential divider	$V_{out} = \frac{R_1 V_{in}}{R_1 + R_2}$

Particles and photons

Radioactive decay	$A = \lambda N$
	$A = A_0 e^{-\lambda t}$
Half-life	$t_{\frac{1}{2}} = \frac{0.693}{\lambda}$
de Broglie equation	$\lambda = \frac{h}{p}$

The nucleus

Nuclear radius	$r = r_0 A^{\frac{1}{3}}$