Mock Exam 2

CANDIDATE NAME

CENTRE NUMBER

CANDIDATE NUMBER

PHYSICS **9702**

Paper 4 A Level Structured Questions **2 hours**

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
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.
DO **NOT** WRITE IN ANY BARCODES.

Answer **all** questions.

Electronic calculators may be used.
You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

The total mark for this paper is 84.

A ball of mass 37 g is held between two fixed points A and B by two stretched helical springs, as shown in Fig. 2.1.

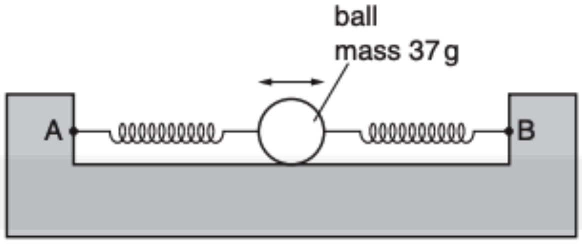


Fig. 2.1

The ball oscillates along the line AB with simple harmonic motion of frequency 3.5 Hz and amplitude 2.8 cm.

(a) Show that the total energy of the oscillations is 7.0 mJ.

[2]

(b) At two points in the oscillation of the ball, its kinetic energy is equal to the potential energy stored in the springs.
Calculate the magnitude of the displacement at which this occurs.

displacement = ... cm [3]

(c) On the axes of Fig. 2.2 and using your answers in **(a)** and **(b)**, sketch a graph to show the variation with displacement *x* of

(i) the total energy of the system (label this line T), [1]

(ii) the kinetic energy of the ball (label this line K), [2]

(iii) the potential energy stored in the springs (label this line P). [2]

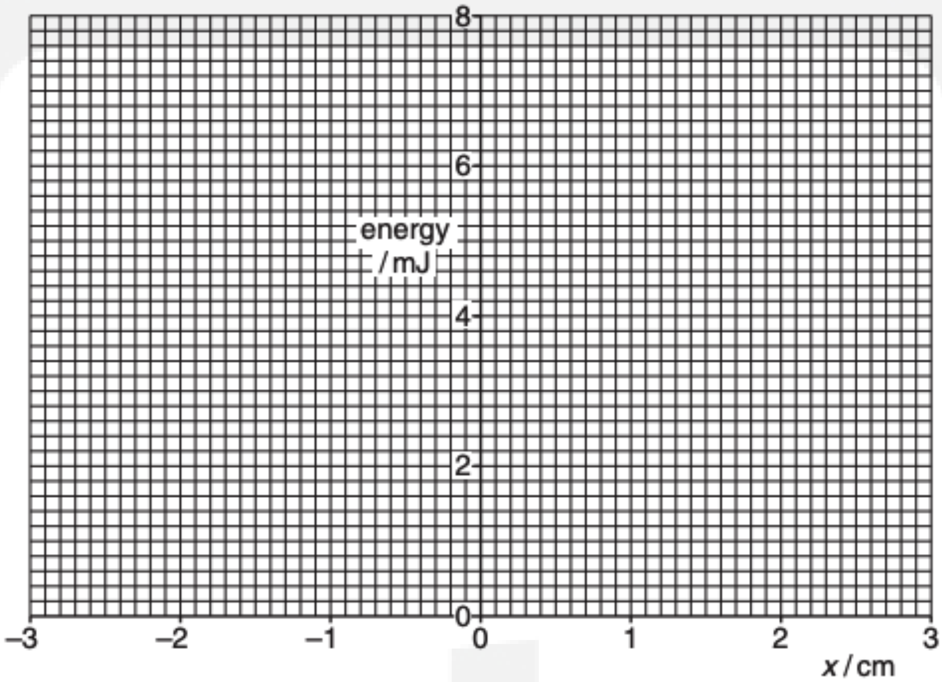


Fig. 2.2

(d) The arrangement in Fig. 2.1 is now rotated through 90° so that the line AB is vertical and the ball oscillates in a vertical plane.

Suggest one form of energy, other than those in **(c)**, that must be taken into consideration when plotting new graphs to show energy changes with displacement.

....[1]

6 Fig. 6.1 shows a tube containing small pellets of lead. When the tube is inverted the pellets of lead fall freely through a vertical height equal to the length of the tube. The pellets are warm after the tube has been inverted many times.

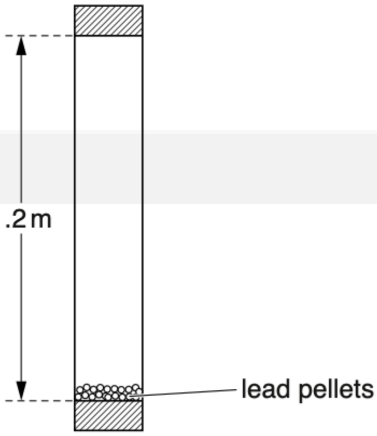


Fig. 6.1

(a) Describe the energy changes that take place to the lead pellets following one inversion of the tube.

....

....

.... **[2]**

(b) The tube is used in an experiment to determine the specific heat capacity of lead. The following results are obtained.

total mass of lead pellets = 0.025 kg
number of inversions = 50
length of tube = 1.2 m
change in temperature of the lead = 4.5 °C

Use this information to calculate the specific heat capacity of the lead.

(c) State **two** assumptions you have made in your calculation of the specific heat capacity.

....

....

....

.... **[2]**

(d) State and explain the change, if any, you would expect to see in the temperature rise if the mass of the lead pellets is doubled.

....

....

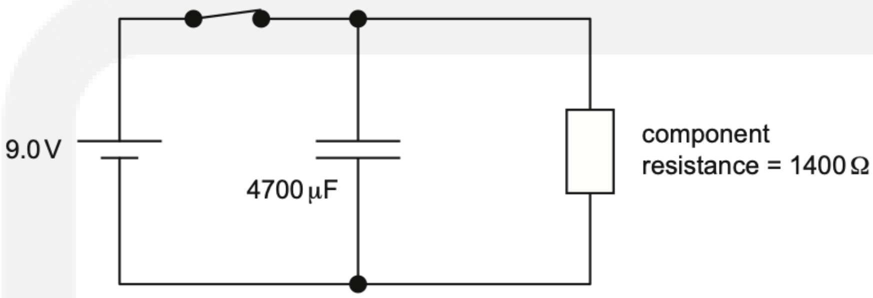
....

.... **[2]**

2 This question is about using capacitors as energy storage devices.

The diagram below shows a simple circuit which models how a capacitor can be used as a back-up power supply. The component is modelled as a single resistor.

In normal use the switch is closed and the p.d. across the component is 9.0 V. Opening the switch models a failure in the power supply.



(a) **(i)** The operating range of the component is 5.2 V to 9.0 V.

Show that 3.5 s after the switch is opened the p.d. across the component will be about 5.3 V.

[2]

(ii) Estimate the average power delivered to the component during this time.
Explain why the value is an average.

average power = ... W

Explanation:

....

....

....
[3]

In recent years, **supercapacitors** have been developed. These components charge and discharge in a similar manner to standard capacitors but can have capacitances of more than 10 000 F.

These can be used as back-up power supplies in many circumstances.

(b) A 120 F supercapacitor has an internal resistance of 30 mΩ. At time t = 0.0 s it stores 300 J.

Calculate the minimum time taken for the capacitor to transfer 250 J through discharging.

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(b) A 120 F supercapacitor has an internal resistance of 30 mΩ. At time t = 0.0 s it stores 300 J.

Calculate the minimum time taken for the capacitor to transfer 250 J through discharging. Suggest why this is a minimum value.

time = ... s

Suggestion:

....

....

....

[4]

38 **(a)** This question is about the electric field strength E near to a proton leading to the Bohr model for the hydrogen atom.

(i) Show by calculation that E is about $1 \times 10^{12}\,\text{V m}^{-1}$ at distance $40 \times 10^{-12}\,\text{m}$ from the centre of the proton.

[2]

(ii) **Fig. 38.1** shows the electric field strength E near to a proton.

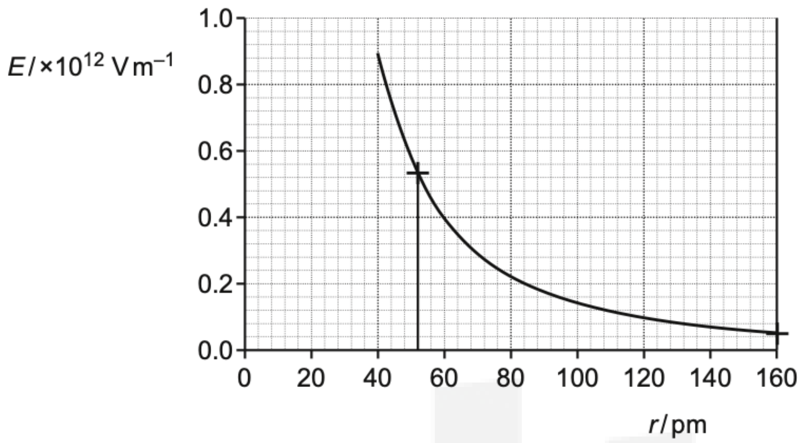


Fig. 38.1

Use any two points on the graph to show that the electric field strength E follows an inverse square law with distance r (a law of the form: $E \propto {}^1/r^2$).

[2]

(iii) State what the area under the graph between two r values represents and make an estimate of its value between the marked r values 52 and 160 pm.

Area represents ....

value of area = ... units .... **[2]**

(b) In the Bohr model of the atom the electron travels at speed v in a circular orbit of radius r around the proton as shown in **Fig. 38.2**.

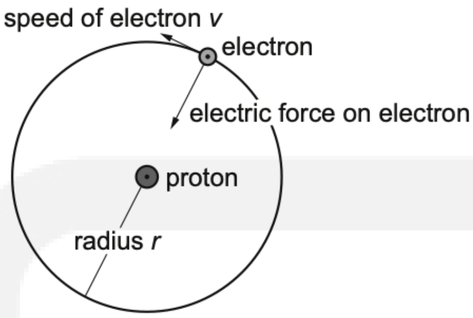


Fig. 38.2

(i) Show that the kinetic energy of the electron in orbit is $\frac{k e^2}{2r}$

where k is the electric force constant = $1/4\pi\varepsilon_o$.

[1]

(ii) **Fig. 38.3** shows the variation of kinetic energy and potential energy of the electron with the radius of its orbit r.

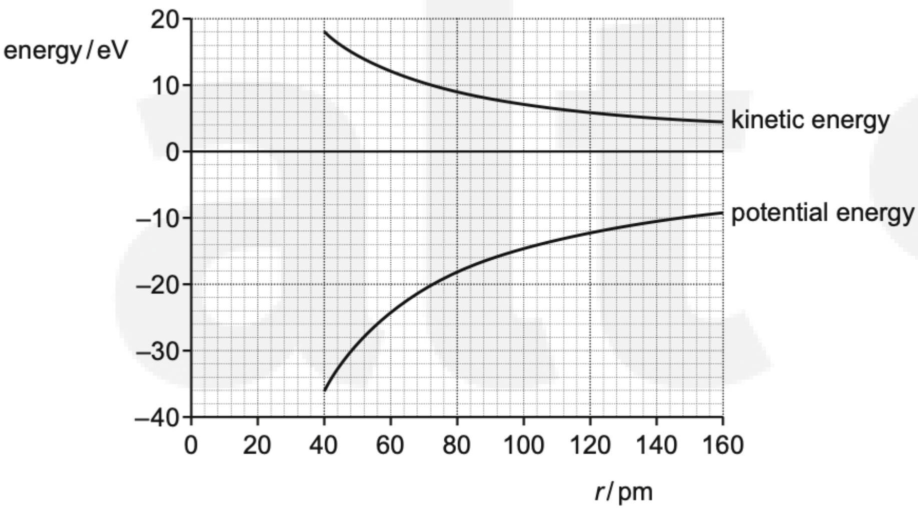


Fig. 38.3

The total energy of the electron in orbit is:

kinetic energy + potential energy ($E_{total} = E_{kinetic} + E_{potential}$).

Show that the total energy of the orbit = $\frac{-k\,e^2}{2r}$ and sketch the graph on **Fig. 38.3**.

[2]

(iii) Accelerating electrons emit electromagnetic radiation.

Suggest why Bohr had to introduce the quantisation principle of allowed energy levels into his model atom.

....

....

.... **[1]**

(iv) In Bohr's quantised model the radius of orbit for the ground state of the electron (lowest total energy) is given by the equation:

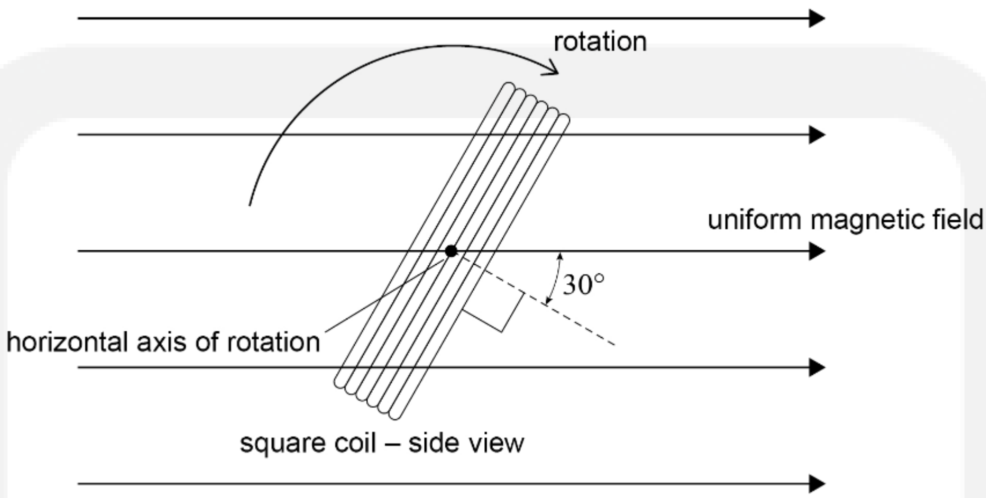
$r = \frac{\varepsilon_0 h^2}{\pi m e^2}$ where m and e are the mass and charge of the electron.

Show that the potential of an electron in the ground state is about –14 V.

[2]

0 5 A square coil of wire is rotating at a constant angular speed about a horizontal axis. **Figure 4** shows the coil at one instant when the normal to the plane of the coil is at 30° to a magnetic field.

Figure 4



The area of the coil is $5.0 \times 10^{-4}\ \text{m}^2$ and the flux density of the uniform magnetic field is $2.5 \times 10^{-2}\ \text{T}$.

a The maximum flux linkage of the coil during its rotation is 1.5×10^{-3} Wb turns.

Calculate the number of turns in the coil.

[2 marks]

number of turns = ____________________

b Calculate the flux linkage of the coil at the instant shown in **Figure 4**.

[1 mark]

flux linkage = ____________________ Wb turns

11 **(a)** State Hubble's law.

....

....

.... **[1]**

(b) The redshift of a specific spectral line in the spectrum of a galaxy can be used to determine its recession velocity v. The fractional change z in the wavelength of a spectral line is given by the equation

$$z = \frac{v}{c}$$

where c is the speed of light in a vacuum.

The table of Fig. 11.1 shows data for some of our closest galaxies. The distance of the galaxy from the Earth is d.

Galaxy	z / 10^{-3}	v / 10^{3} m s^{-1}	d / 10^{23} m
A	1.12	336	1.50
B	1.61	483	2.14
C	1.85	555	2.46
D	2.26	678	3.00
Messier 109	3.38		

Fig. 11.1

(i) Complete the table by determining v and d for the galaxy Messier 109. **[2]**

(ii) Fig. 11.2 shows the data for the first four galaxies plotted on a *v* against *d* graph.

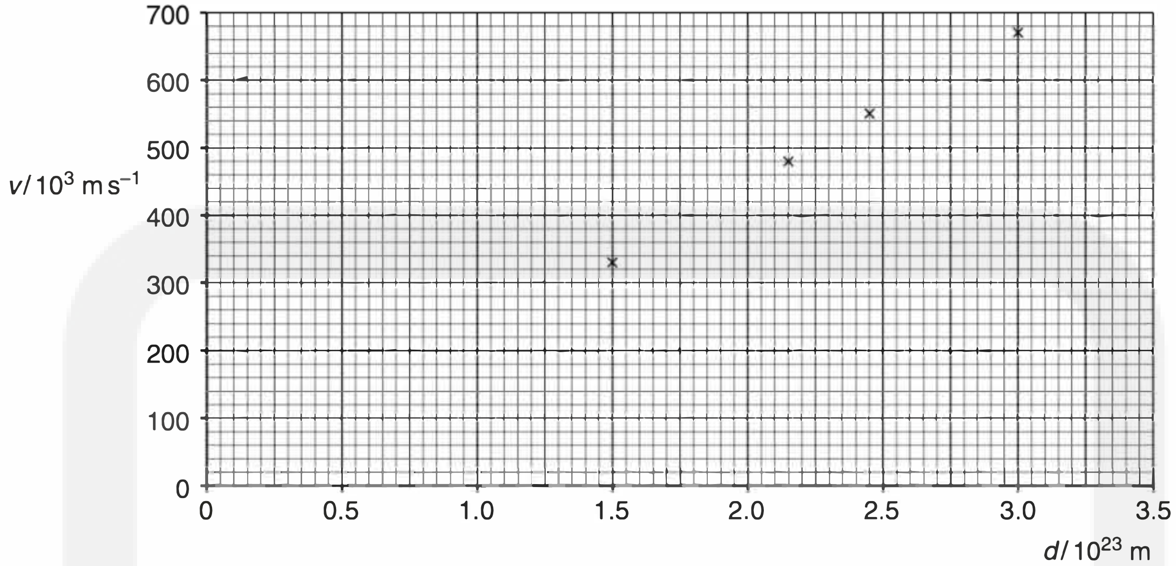


Fig. 11.2

Use Fig. 11.2 to determine the age of the Universe in years.
$1\,y = 3.16 \times 10^7\,s$

age = ... years **[3]**

(c) One piece of observational evidence for the big bang is that galaxies are receding from each other.
Explain what is meant by the big bang and suggest **one** other observation that support the big bang model of the Universe.

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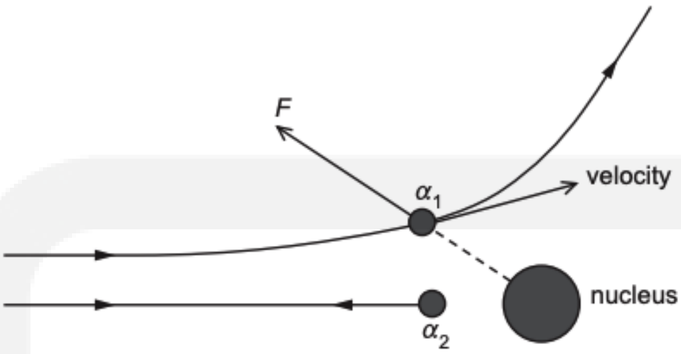
....

.... **[3]**

33 The figure shows two possible paths of alpha particles of the same initial kinetic energy near a massive atomic nucleus.



(a) State one effect of the repulsive force *F* on the motion of the alpha particle at position α_1.

....

.... **[1]**

(b) At the position α_2 the alpha particle is as close as it can get to the nucleus.

State what has happened to the original kinetic energy of the alpha particle.

....

.... **[1]**

(c) **(i)** What combination of alpha particle kinetic energy and proton number *Z* of the target nucleus will result in the closest possible approach?

Place a tick in the correct box for closest possible approach.

	Low proton number *Z* of target nucleus	**High proton number *Z* of target nucleus**
Low alpha kinetic energy		
High alpha kinetic energy		

[1]

(ii) A 7.7 MeV alpha particle makes a head-on collision with an aluminium nucleus $^{27}_{13}Al$.

Calculate the distance of closest approach between the centres of the alpha particle and the aluminium nucleus.

distance of closest approach = ... m **[2]**

41 This question is about neutron stability and the β-decay process.
This table shows the properties of the free particles that combine to form atoms.

Particle	**Symbol**	**Mass / u**	**Half-life $t_{1/2}$ / s**
electron	${}^{0}_{-1}e$	0.000549	stable ∞
proton	${}^{1}_{1}p$	1.007276	stable ∞
neutron	${}^{1}_{0}n$	1.008665	650

(a) **(i)** Calculate the maximum energy available when a free neutron decays into a proton and a β-particle.

1 u = 931 MeV

energy = ... MeV **[2]**

(ii) The β-particles from neutron decay have a spectrum of energies up to this maximum value as shown in **Fig. 41.1**.

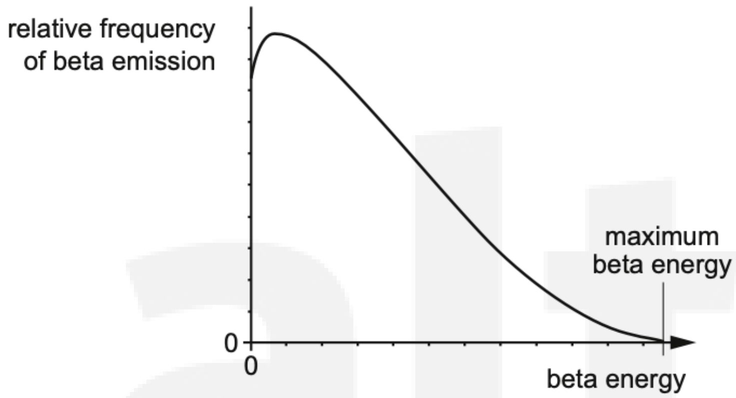


Fig. 41.1

State why the beta particles are emitted with a range of energies.

....

.... **[1]**

(iii) Estimate the number of neutrons that would decay in one second from a sample of 10^4 free neutrons.

number per second = ... **[2]**

(iv) A down quark has electric charge of $-\frac{1}{3}e$ and an up quark has electric charge $+\frac{2}{3}e$.

State what is happening in terms of quarks during β-decay.

....

.... **[1]**

25 Fluorine-18 is a common radioactive isotope used in positron emission tomography (PET). Fluorine-18 emits positrons. A patient is injected with a radiopharmaceutical containing fluorine-18.

(a) Describe how a PET scanner is used to locate an area of increased activity within the patient.

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.... **[4]**

(b) The half-life of fluorine-18 is 110 minutes.
Calculate the time *t* in minutes for the activity of the radiopharmaceutical to decrease to 30% of its initial activity.

t = ... minutes **[3]**

2 **(a)** State what is meant by an *ideal* gas.

....

....

....[2]

(b) The product of pressure p and volume V of an ideal gas of density ρ at temperature T is given by the expressions

$$p = \tfrac{1}{3}\rho\langle c^2\rangle$$

and

$$pV = NkT,$$

where N is the number of molecules and k is the Boltzmann constant.

(i) State the meaning of the symbol $\langle c^2\rangle$.

....[1]

(ii) Deduce that the mean kinetic energy E_K of the molecules of an ideal gas is given by the expression

$$E_K = \tfrac{3}{2}kT.$$

[2]

(c) In order for an atom to escape completely from the Earth's gravitational field, it must have a speed of approximately $1.1 \times 10^4\,\mathrm{m\,s^{-1}}$ at the top of the Earth's atmosphere.

(i) Estimate the temperature at the top of the atmosphere such that helium, assumed to be an ideal gas, could escape from the Earth. The mass of a helium atom is $6.6 \times 10^{-27}\,\mathrm{kg}$.

temperature = ... K [2]

(ii) Suggest why some helium atoms will escape at temperatures below that calculated in **(i)**.

....

....[1]

10 **(a)** A student observes different stars from the Earth.
Give **two** reasons why some stars appear brighter than others.

1 ....

....

2 ....

.... [2]

(b) State what is meant by a standard candle.

....

.... [1]

(c) A spectral line from a star within a galaxy is observed to have a wavelength of 660.9 nm. The same spectral line measured in the laboratory is observed to have a wavelength of 656.3 nm.

(i) Show that the speed of the star relative to the Earth is $2.1 \times 10^{6}\,\text{m}\,\text{s}^{-1}$.

[1]

(ii) Calculate the distance to the star.

The Hubble constant is $2.3 \times 10^{-18}\,\text{s}^{-1}$.

distance = ... m [2]

(iii) State and explain what can be concluded about the Universe based on this change in observed wavelength.

....

....

....

....

.... [3]

[Total: 9]