RECOGNISING ACHIEVEMENT

SPECIMEN

Advanced GCE

G494 QP

PHYSICS B (ADVANCING PHYSICS)

Unit G494: Rise and Fall of the Clockwork Universe

Specimen Paper

Candidates answer on the question paper.

Time: 1 hour 15 minutes

Additional Materials:
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name

Centre Number

Candidate Number

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- ✎ Where you see this icon you will be awarded marks for the quality of written communication in your answer.
- You may use an electronic calculator.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **60**.

FOR EXAMINER'S USE		
Section	**Max.**	**Mark**
A	**15**	
B	**45**	
TOTAL	**60**	

This document consists of **17** printed pages and **3** blank pages.

  [Turn Over

Answer **all** the questions.

Section A

1 Fig 1.1 shows three possible paths, **A**, **B** and **C**, of a spacecraft moving near the Earth, but well above the atmosphere.

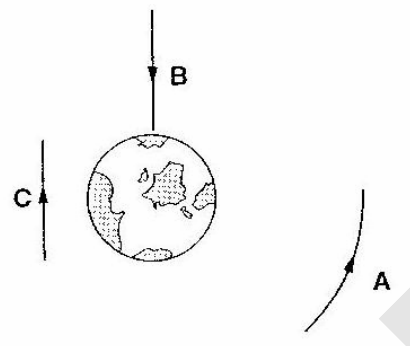


Fig. 1.1

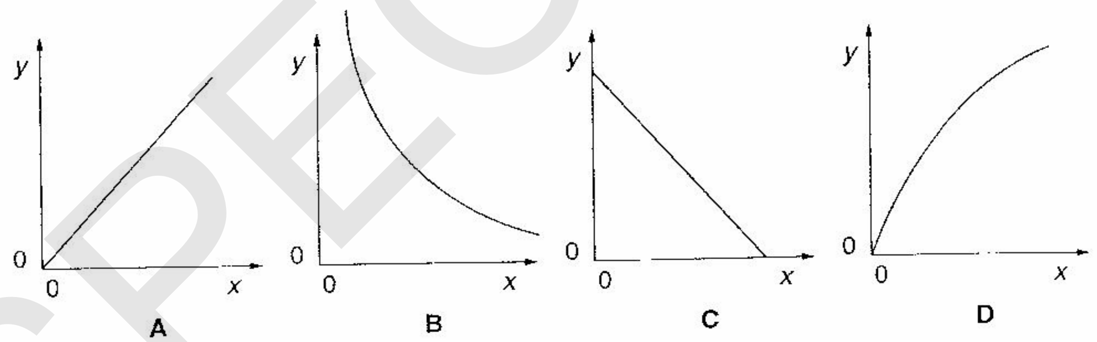
(a) Which path follows a gravitational field line of the Earth?

answer .... **[1]**

(b) Which path follows a gravitational equipotential line of the Earth?

answer .... **[1]**

2 Study the graphs A, B, C, D.



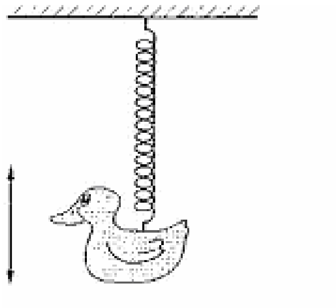
(a) Which graph shows the variation in volume (y) of a fixed mass of ideal gas at constant pressure with absolute temperature (x)?

answer .... **[1]**

(b) Which graph shows the variation in pressure (y) of a fixed mass of ideal gas at constant temperature with volume (x)?

answer .... **[1]**

3 A plastic duck hangs from a long spring. The duck oscillates vertically with a frequency of 0.42 Hz.



The displacement x of the duck at time t is given by the equation

$x = A \cos(2 \pi f t)$

where A = 0.20 m.

Choose the value from the list below which gives the displacement of the duck when t = 2.0 s.

0.11 m 0.20 m -0.11 m -0.20 m

chosen value = ... **[1]**

4 2.0 mol of an ideal gas is kept at a pressure of 1.5×10^5 Pa and a temperature of 310 K.

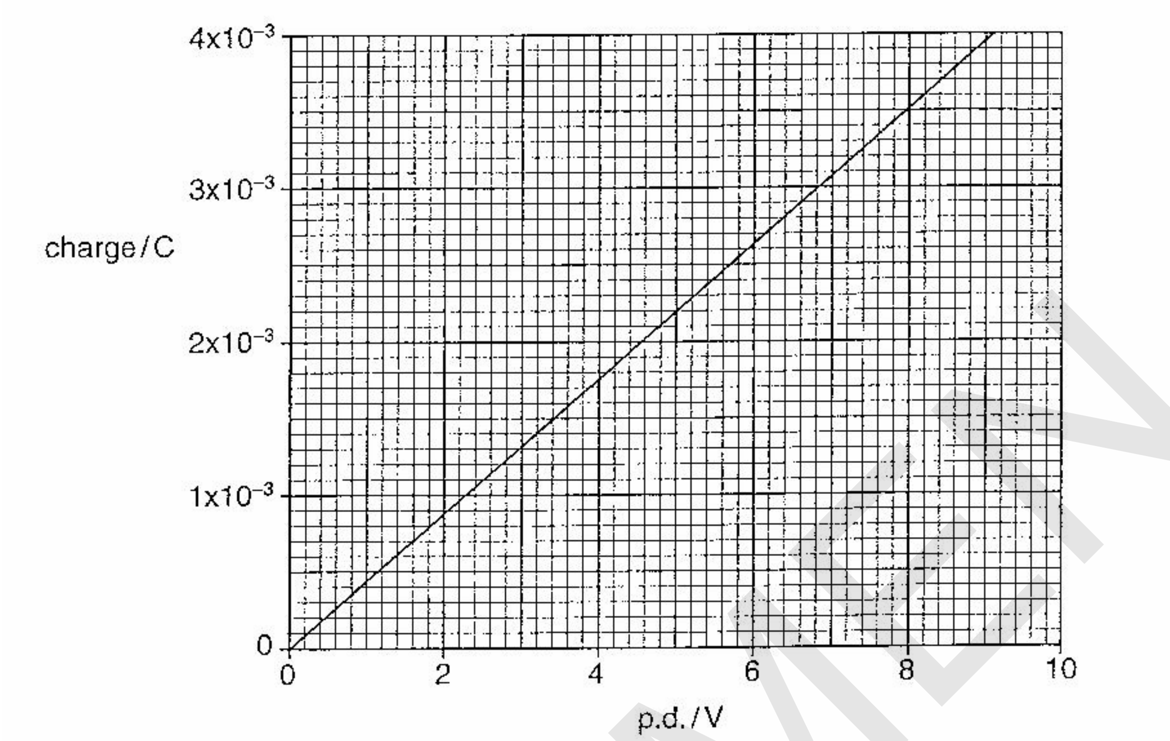
Calculate the volume occupied by the gas under these conditions.

$R = 8.3\ \mathrm{J\ K^{-1}\ mol^{-1}}$

volume = ... m^3

[2]

5 The graph show how the charge on a capacitor varies with p.d. across the capacitor.



Here are a number of values:

440 210 350 700

Use information from the graph to choose from the list the best value for

(a) the capacitance of the capacitor in microfarad

value = ...μF **[1]**

(b) the energy in μJ stored on the capacitor when a p.d. of 4.0 V is applied across it.

value = ... μJ **[1]**

6 A circus clown fires a water gun that ejects water horizontally at a speed of 7.3 m s^{-1}. The water leaves the gun at a rate of 2.7 kg s^{-1}.

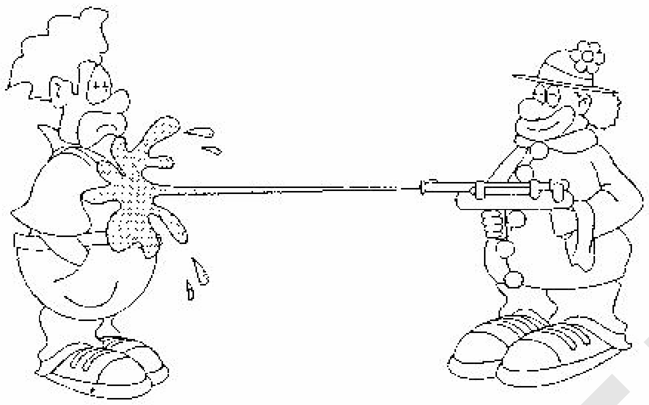


Fig. 6.1

Explain why the clown holding the gun experiences a backward force of about 20 N.

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.... **[3]**

7 Fig 7.1 shows a circuit diagram of a capacitor discharging through a resistor.

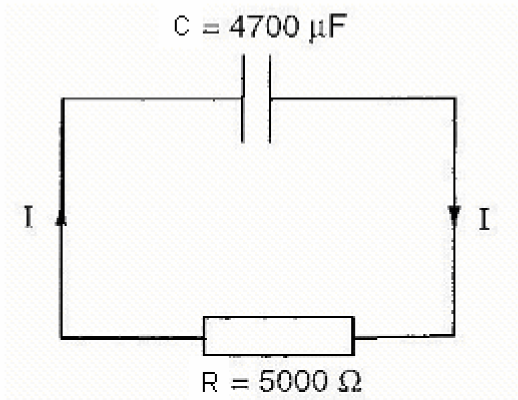

Fig. 7.1

A simple mathematical model of the discharge of the capacitor is shown in Fig. 7.2. It is assumed that the current I is constant over each small time interval Δt. This process is repeated as shown.

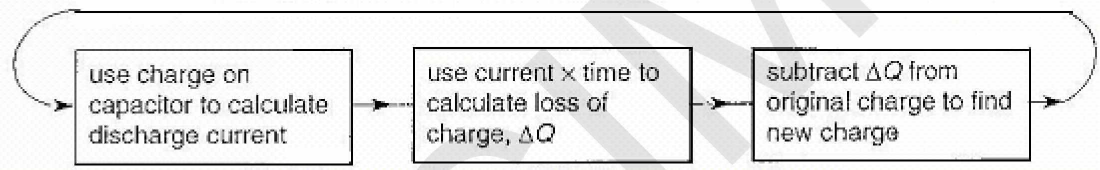

Fig. 7.2

(a) Complete the table for the discharge of the 4700 μF capacitor. The small time interval used is Δt = 2.0 s.

Q	$I = \frac{V}{R} = \frac{Q}{RC}$	$\Delta Q = I\Delta t$	$Q_{new} = Q - \Delta Q$
5.64×10^{-2} C			5.16×10^{-2} C
5.16×10^{-2} C			

[2]

(b) Suggest one reason why mathematical models are useful in physics.

....

....

.... **[1]**

[Section A Total: 15]

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Section B

8 This question is about the time it takes a planet to orbit once around the Sun. This is called the orbital period of the planet.

In this question, the following symbols will be used:

orbital period T

mean radius of orbit R

mass of Sun M_s

mass of planet M_p

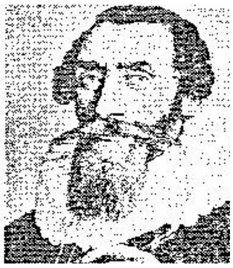


Fig. 8.1

Taken from Measuring the universe, Kitty Ferguson, Reproduced by permission of headline publishing group limited

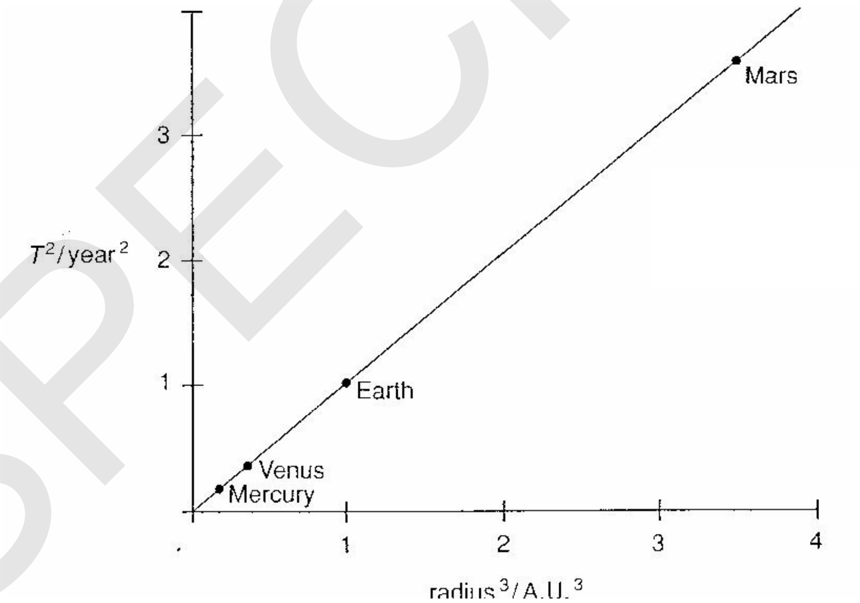
(a) The seventeenth century astronomer Johannes Kepler (Fig. 8.1) suggested a relationship between the orbital period of a planet T and its radius of orbit R.

This relationship can be written as

$$T^2 \propto R^3$$

Kepler found this mathematical relationship by trial and error.

Data for four of the planets are shown in Fig. 8.2.



1 A.U. = distance from Sun to Earth

Fig. 8.2

State which features of the graph show that T^2 is proportional to R^3.

....

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.... **[2]**

(b) Isaac Newton (Fig. 8.3) developed a description of gravity that confirmed Kepler's work.

Newton's confirmation of Kepler was based on his laws of motion and his gravitational law.

Fig 8.3

The centripetal force on a planet of mass M_p orbiting with period T at radius R is given by

$F = - M_p (2\pi)^2/ T^2 R$

Use Newton's Gravitational Law $F = - GM_pM_s/R^2$ to show that $T^2/R^3 = (2\pi)^2/ GM_s$ and hence find the mass of the Sun.

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

Mean radius of Earth's orbit = 1.5×10^{11} m

1 year = 3.2×10^7 s

mass of Sun = ... kg **[4]**

(c) The Sun loses mass at a rate of 6.2×10^{11} kg s^{-1}. Discuss whether this will have had any significant affect on the orbit the Earth over the 40 000 years that humans have made an impact on the planet.

✎ *You will be awarded marks for the quality of your written communication.*

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.... **[3]**

(d) Although Kepler's findings were hugely important, Newton's are considered to be more significant.

Give **one** reason why Newton's approach is considered an advance on Kepler's approach.

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.... **[1]**

[Total: 10]

9 This question is about heating soup with microwaves.

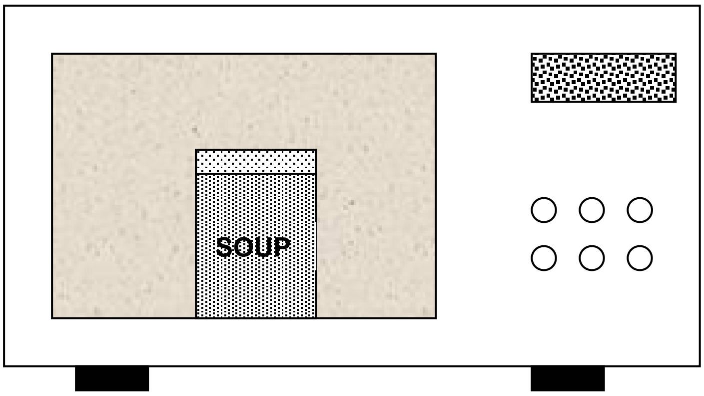

Fig. 9.1

(a) The microwave oven supplies energy to the soup at a rate of 600 W.

The soup, of mass 0.40 kg, has an initial temperature of 20 ^{o} C.

Show that, after three minutes, the maximum temperature will be about 85 ^{o} C.

specific thermal capacity of soup = 4200 J kg^{-1} K^{-1}

[2]

(b) The Boltzmann factor is given as $f = e^{-E/kT}$. Describe what the Boltzmann factor indicates and use it to explain why increasing numbers of molecules evaporate from the soup as its temperature rises.

✐ *You will be awarded marks for the quality of your written communication.*

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.... **[4]**

(c) The soup container has a tight fitting lid on it.

As the temperature rises:

the number of molecules in the vapour increases

the average speed of the molecules in the vapour increases.

Use ideas about momentum to explain why the growing number of molecules in the vapour **and** the increase in average speed of the molecules both increase the pressure of the vapour.

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.... **[4]**

[Total: 10]

10 This question is about some of the physics of the human ear.

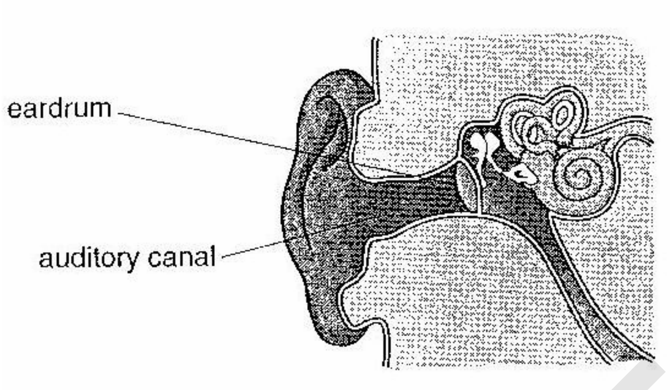

Fig. 10.1

A given sound wave striking the ear drum sets it oscillating in simple harmonic motion.

The ear drum oscillates at a frequency of 2500 Hz with an amplitude of 1.0×10^{-7} m.

(a) **(i)** Calculate the period of the oscillation.

period = ... s **[1]**

(ii) On the axes of Fig. 10.2, draw a graph to show how the displacement of the eardrum varies with time for one oscillation. Assume that the displacement is zero at t = 0.

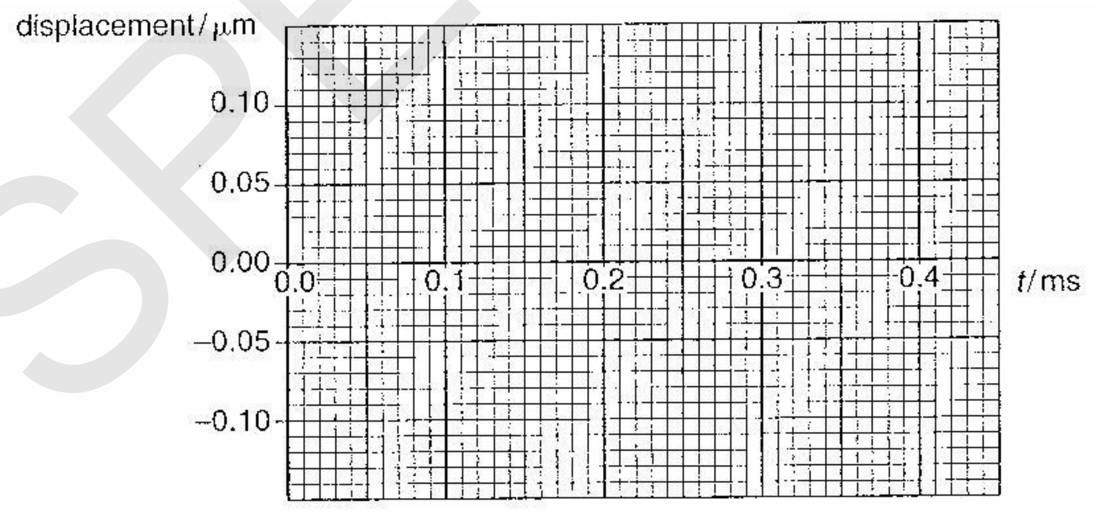

Fig. 10.2

[3]

(iii) Calculate the maximum acceleration of the ear drum.

acceleration = ... m s^{-1} **[2]**

(iv) Mark on the graph on Fig.10.2 a point at which this maximum acceleration occurs. Mark this point **a**. **[1]**

(b) The resonant frequency of the human auditory canal Is around 3000 Hz, which makes the human ear most sensitive at those frequencies.

Explain clearly what this statement means, and suggest circumstances in which lower or higher resonant frequencies might be expected in humans or other mammals.

You will be awarded marks for the quality of your written communication.

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.... **[5]**

[Total: 12]

11 This question is about calculating the age of stars using the radioactive decay of uranium-238.

(a) A sample containing 1.0×10^{-6} kg of uranium-238 contains 2.5×10^{18} uranium-238 atoms.

The activity of the sample is 12 Bq.

Show that the half-life of uranium-238 is about 4.5 billion years.

1 year = 3.2×10^{7} s

[3]

(b) A small sample of rock contains 10 atoms of uranium-238. Estimate, **without calculation**, the number of atoms of uranium-238 that would have been present in that rock at the time when the Solar System is believed to have formed, 5.6 billion years ago, and explain how you obtained that estimate.

Explain clearly why a precise calculation would not have given an accurate answer of the number originally present.

[4]

(c) Astronomers have observed the spectrum of a very old nearby star to determine how much uranium-238 it contains. This value is compared with the amount that is thought to have been present when the star was formed.

Recent observations suggest that the amount of uranium-238 in the star has fallen to 12 % of its original value.

Calculate the age of the star in years.

age of star = ... years **[2]**

(d) The Hubble Law, based on observation of cosmological red shifts, suggest that the universe is much older than the age of the stars measured by finding how much uranium-238 it contains.

Explain the meaning of the term cosmological red shift.

[1]

(e) The Hubble Law suggests that the age of the universe is of the order $1/H_0$ where H_0 is the Hubble parameter. Estimating the value of H_0 is an extremely important task. Values for H_0 have ranged from $1.6 \times 10^{-18}\ \text{s}^{-1}$ to $3.2 \times 10^{-18}\ \text{s}^{-1}$.

(i) Estimate the minimum and maximum age of the universe in years from the value of H_0.

minimum age = ...years

maximum age = ... years **[2]**

(ii) Explain how data from the uranium-238 method of finding the age of stars can be used to help astronomers choose between these values of H_0.

[1]

[Total: 13]

[Section B Total: 45]

Paper Total [60]

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Sources

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OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) G494 MS

Unit G494: Rise and Fall of the Clockwork Universe

Specimen Mark Scheme

The maximum mark for this paper is **60**.

This document consists of **4** printed pages and **4** blank pages.

Section A		
Question Number	**Answer**	**Max Mark**
1(a) **(b)**	B ✓ A ✓	**[1]** **[1]**
2(a) **(b)**	A ✓ B ✓	**[1]** **[1]**
3	A ✓	**[1]**
4	✓method: $V = 2 \times 8.3 \times 310/1.5 \times 10^5$ ✓evaluation: $= 3/2 \times 10^{-2}\ m^3$	**[2]**
5(a) **(b)**	A ✓ C ✓	**[1]** **[1]**
6	Calculation of rate of change = 2.7 x 7.3 = 19.7 kg m s^{-1} ✓ Force on clown is rate of change of momentum ✓ Clear Newton III/ conversation of momentum argument ✓	**[3]**
7(a) **(b)**	First line of table: 2.4×10^{-3}, 4.8×10^{-3} ✓ 2nd line of table: 2.2×10^{-3}, 4.4×10^{-3}, 4.7×10^{-2} ✓ Any sensible point ✓: e.g. to test theories against real situations, to predict outcomes when experimental evidence is not available.	 **[2]** **[1]**
	Total Section A	**[15]**
8(a) **(b)** **(d)**	Straight line ✓ Through origin ✓ $M_p (2\pi)^2/T^2\ R = GM_P M_s/R^2$ worked through to $T^2/R^3 = (2\pi)^2/\ GM_s$ ✓ rearrangement to find M_s ✓ Substitution of correct values M_s ✓ Calculation to give M_s ✓ ecf possible $M_s = 4\pi^2(1.5 \times 10^{11})^3/\ (6.67 \times 10^{-11} \times (3.2 \times 10^7)^2) = 1.8 \times 10^{30}$ kg Kepler's (3rd) Law was empirical/ Newton's (gravitational) was analytical✓ Kepler's law was limited to orbits / Newton's is applicable to wider applications e.g. tides, space flight✓ Any one point. Must be comparison between K's approach and N's approach for the mark	 **[2]** **[4]** **[1]**
	Total	**[10]**
9(a) **(b)** **(c)**	Calculating energy as 108 kJ (can be implicit) ✓ Temp change calculated to 65 K ✓ BF gives proportion of particles with sufficient energy to join vapour/ probability of a particle having sufficient energy. ✓ As T increases –E/kT becomes smaller therefore BF increases ✓ Therefore greater chance/proportion of molecules entering vapour state ✓ QWC: appropriate form and style ✓ Pressure exerted by molecular collisions, force given by $\Delta p/\Delta t$. ✓ Pressure given by F/A ✓ Increase in number of molecules increases $\Delta p/\Delta t$. ✓ Increase in temperature increases $\Delta p/\Delta t$. ✓	 **[2]** **[4]** **[4]**

Section A		
Question Number	**Answer**	**Max Mark**
	QWC: Clear organised answer ✓ There will be a number of paths to mark-worthy points. High quality answers needed for award of marks.	
	Total	**[10]**
10(a)(i)	Period = 1/2500 = 4×10^{-4} s ✓	**[1]**
(ii)	Period ✓ amplitude ✓ sinusoidal shape ✓	**[3]**
(iii)	$a = 4\pi^2 \times 1 \times 10^{-7}$ ✓ $= 24.7$ m s^{-2} ✓	**[2]**
(iv)	Mark on crest or trough ✓	**[1]**
(b)	driving frequency matches natural frequency of oscillator ✓ amplitude of oscillations at resonance will be greater for a specific amplitude of driving wave. ✓ Suggested circumstances should consider and justify variations in the auditory canal e.g. longer a.c. gives lower resonant frequency or changes in speed of sound (due to density of medium) in e.g. less dense air, water Stated and justified difference in a.c. / medium ✓ Consisten explanation of consequence ✓ Clear understanding must be displayed. QWC: clear organisation✓	**[5]**
	Total	**[12]**
11(a)	Calculating $\lambda = 4.8 \times 10^{-18}$ ✓ Half life = 0.693/ = 1.44×10^{17} s ✓ = 4.5 billion years ✓ Allow implicit working	**[3]**
(b)	Stating 5.6 is a little more than a half life✓ Initial number is a bit more than double 10 (accept 21 to 25) ✓ Reason why estimate is the best that can be done: Radioactive decay is random ✓ Need large numbers in random processes for predictable results✓.	**[4]**
(c)	$0.12 = e^{-\lambda t} \rightarrow \ln 0.12 = -4.8 \times 10^{-18}\, t$ $= 1.4 \times 10^{10}$ years ✓method ✓evaluation Allow ecf for evaluation mark 1 mark for time in seconds	**[2]**
(d)	Lengthening of wavelength with expansion of space✓ Allow energy arguments.	**[1]**
(e)(i)	Min = 9.8×10^{9} yr✓ max = 1.9×10^{10} yr ✓ Allow values in seconds	**[2]**
(ii)	Shows younger age is not correct ✓	**[1]**
	Total	**[13]**
	Section B Total	**[45]**
	Paper Total	**[60]**

Assessment Objectives Grid (includes QWC)

Question	AO1	AO2	AO3	QWC	Total
1	2				**2**
2	2				**2**
3		1			**1**
4	1	1			**2**
5	1	1			**2**
6	1	2			**3**
7		2	1		**3**
8(a)			2		**2**
8(b)		4			**4**
8(c)			2	**1**	**3**
8(d)			1		**1**
9(a)	1	1			**2**
9(b)		3		**1**	**4**
9(c)	2	2			**4**
10(a)	3	4			**7**
10(b)			4	**1**	**5**
11(a)	3				**3**
11(b)	1	3			**4**
11(c)	1	1			**2**
11(d)	1				**1**
11(e)		2	1		**3**
Totals	**19**	**27**	**11**		**60**

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