Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
January 2012

Physics

Assessment Unit A2 1

assessing

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

[AY211]

AY211

TUESDAY 24 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** 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 **7**.
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. Candidates should allow approximately 20 minutes for this question.

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

Examiner Only	
Marks	Remark

1 **(a)** State the principle of conservation of momentum.

____

____

____ [2]

(b) Most military aircraft are fitted with an ejector seat which allows the pilot to escape from the aircraft in case of emergency.

One type of ejection system uses an explosion to move the seat, containing the pilot, vertically upwards.

(i) In what direction will the body of the aircraft move **as a result of the ejection system being deployed**? Explain your answer.

____

____

____ [2]

(ii) The ejection system is tested in a stationary aircraft on a runway. The mass of the seat is 200 kg and the total mass of the aircraft including the seat is 9100 kg. When the seat is released it leaves the aircraft at a speed of 180 $\mathrm{m\,s^{-1}}$. In theory, with what initial speed does the body of the aircraft move?

Speed = __________ $\mathrm{m\,s^{-1}}$ [3]

(c) Explain why an explosion such as this can never be considered to be "elastic".

____

____

____ [2]

Examiner Only

Marks	Remark

2 Absolute zero is the theoretical temperature at which the internal energy of a gas is zero.

(a) What is meant by the internal energy of a gas?

____

____ [1]

(b) Describe a simple experiment on the behaviour of gases the results of which can be used to determine the value of absolute zero in °C.
In your description you should include:
1. a labelled diagram of the apparatus,
2. the results taken,
3. a sketch of the graph that will be plotted from the results,
4. how a value for absolute zero is determined from the graph.

1. Labelled diagram of apparatus:

[4]

2. The results taken:

____

____

____ [1]

Examiner Only	
Marks	Remark

3. Sketch of the graph that should be plotted:

[2]

4. How a value of absolute zero in °C is determined from the graph:

____

____

____

______________________________ [2]

Examiner Only: Marks | Remark

3 **(a)** One event in athletics is throwing the hammer. In this event, the thrower swings the hammer around in a circular path on the end of a chain. The hammer accelerates from rest to a constant speed and then, after five revolutions, the thrower releases his grip and the hammer is launched into the air.

The hammer has a mass of 7.30 kg and it takes the thrower 1.86 s to complete the five revolutions. The radius of the circular path is 1.25 m.

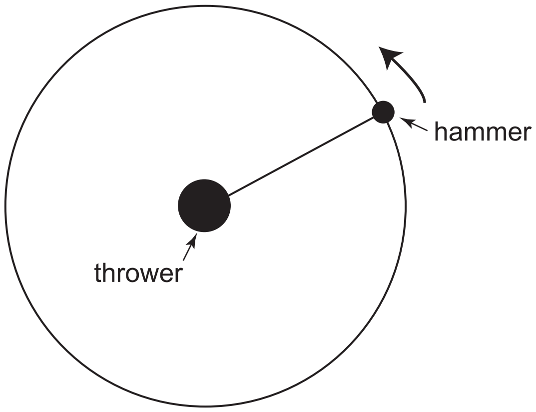
(i) Show that the angular velocity of the hammer is approximately 17 rad s^{-1}.

[1]

(ii) Calculate the linear velocity of the hammer as it moves around the circular path.

Linear velocity = __________ $m\,s^{-1}$ [1]

(b) (i) **Fig. 3.1** shows an overhead view of the hammer being whirled around on the end of the chain. Draw an arrow on **Fig. 3.1** to show the direction of the force which acts on the hammer to keep it moving in a circle at the instant shown.



[1]

Fig. 3.1

(ii) Calculate the magnitude of the force that keeps the hammer in circular motion.

Force = ____________ N [3]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(iii) As the hammer is whirled around, the chain makes an angle θ below the horizontal as shown in **Fig. 3.2**.

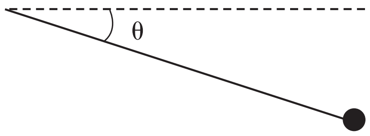


Fig. 3.2

Explain in terms of forces why the chain can never be horizontal.

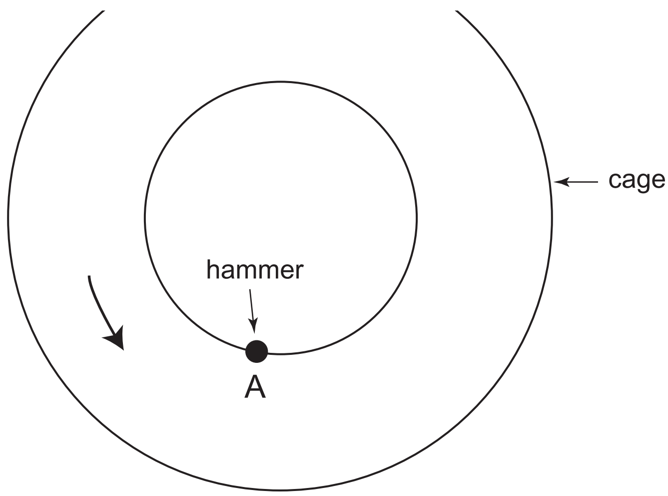
____

____

____

____ [2]

(c) **Fig. 3.3** shows an overhead view of the cage around the hammer thrower as he spins. Indicate on **Fig. 3.3** the first position after the point A on the circle at which the thrower could release the hammer for it to be thrown out of the cage. Draw an arrow to show the direction the hammer will move at the point of release.



[2]

Fig. 3.3

Examiner Only

Marks | Remark

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

____

____

____ [2]

(b) An example of simple harmonic motion is the variation in the position of the water mark on a harbour wall due to the tide.

Fig. 4.1 shows the variation in the position of the water mark, R.

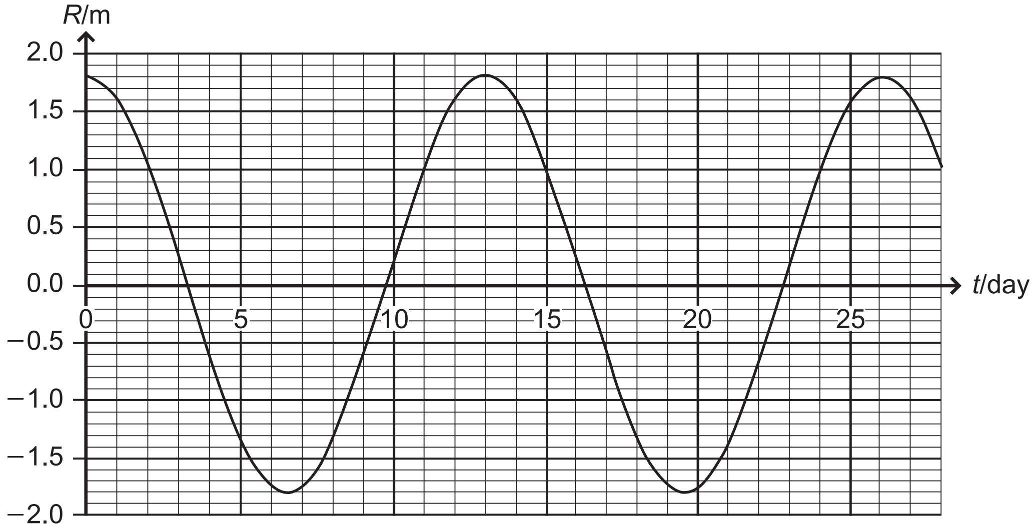


Fig. 4.1

The position of the water mark, R is given by **Equation 4.1**.

$$R = A \cos \omega t \qquad \textbf{Equation 4.1}$$

Rewrite **Equation 4.1** replacing the constants A and ω with their numerical values.

R = ____________________________ [4]

Examiner Only
Marks | Remark

(c) Damping and resonance are two terms that may be associated with an object moving with simple harmonic motion. Describe the cause and effect on the moving object of (i) damping and (ii) resonance.

____

____

____

____

____

____

____

____

____

____ [4]

Examiner Only	
Marks	Remark

5 **(a)** Define the half-life of a radioactive substance.

____

____ [1]

(b) The half-lives of two radioactive isotopes are listed below.

aluminium-28 = 2.4 minutes

radon-219 = 3.96 s

(i) A teacher wants to use one of the above isotopes to carry out an experiment to determine the half-life of a radioactive substance in class. The teacher chooses aluminium-28. Explain why this isotope was chosen rather than radon-219.

____

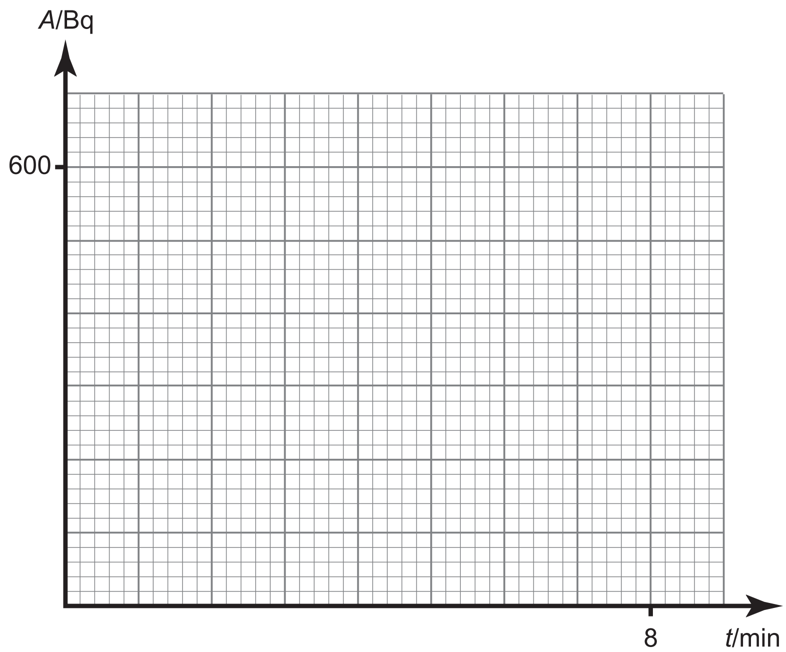
____

____

____

____ [2]

(ii) The initial activity of the aluminium-28 sample was 560 Bq. On **Fig. 5.1** draw a graph of activity (*A*) against time that the students would expect to obtain from the results up to a time (*t*) of 8 minutes.



[3]

Fig. 5.1

Examiner Only	
Marks	Remark

(iii) Calculate the time it would take for the activity of the source to fall to 20 Bq.

Time taken = ____________ minutes [3]

(c) Another student decides to plot a graph of ln(A/Bq) against t/min to determine the half-life. Describe how the value of half-life will be determined from their graph.

____

____

____

____ [2]

Examiner Only	
Marks	Remark

6 **(a)** As a cup of coffee cools, it loses energy. According to Einstein, the coffee must lose an equivalent amount of mass.

(i) The specific heat capacity of coffee is 4184 $J\,kg^{-1}\,°C^{-1}$. Show that the energy lost by a cup containing 250 g of coffee as it cools from 90 °C to 30 °C is 62 760 J.

[2]

(ii) Calculate the equivalent loss in mass of the coffee as it cools.

Loss in mass = __________ kg [2]

(b) Instead of calculating a value from an equation, as in **(a)(ii)**, a student uses scales to find the mass of the coffee in a cup before and after cooling. He takes the difference of these two values and states this as the equivalent mass loss.

How will this value be different from the calculated value?

Explain why it was incorrect for the student to find the equivalent mass lost in this way.

____

____

____

____

____ [2]

Examiner Only	
Marks	Remark

Where appropriate in this question you should answer in continuous prose. You will be assessed on the quality of your written communication.

7 Four of the materials used in a nuclear fission reactor are uranium, graphite, boron and heavy concrete.

Choose three of the materials above. Name the role each plays in the fission reactor and describe how it is achieved.

1. ____

____

____

____

2. ____

____

____

____

3. ____

____

____

____ [6]

Quality of written communication [2]

Examiner Only	
Marks	Remark

8 **(a)** In the process of fusion light nuclei are brought together. It is estimated that each nucleus must have a kinetic energy of 120 keV for fusion to occur. Calculate the temperature needed to give these nuclei enough kinetic energy to come together for nuclear fusion to take place.

Temperature = ___________ K [3]

(b) **(i)** State **two** advantages that fusion reactors would have over current fission reactors.

____

____

____

____ [2]

(ii) In order to achieve the high temperature calculated in **(a)**, confinement must be achieved. Describe how confinement is achieved in the JET fusion reactor.

____

____

____

____

____

____

____

____

____ [3]

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.

The Fermi energy of a metal is the name given to the maximum energy of an electron in an atom at absolute zero.

Equation 9.1 gives the relationship between the Fermi energy, E_F, the free electron density, n, the mass of an electron, m, and elementary charge, e. Planck's constant is h.

$$E_F = \left(\frac{h^2}{8me}\right)\left(\frac{3}{\pi}\right)^{\frac{2}{3}} n^B \qquad \textbf{Equation 9.1}$$

(a) (i) Explain why **Equation 9.1** can be written as **Equation 9.2**

$$E_F = k\,n^B \qquad \textbf{Equation 9.2}$$

where k is a constant.

____

____

____ [1]

(ii) Use the equations given to find the base units of k.

Base units of k = ______________ [3]

Examiner Only	
Marks	Remark

(b) **(i)** A value for the constant B in **Equation 9.2** can be obtained graphically from a plot of $\lg_{10} E_F$ on the y-axis against $\lg_{10} n$ on the x-axis. Explain why the graph will be a straight line that does not pass through the origin.

____

____

____ [3]

(ii) Values of E_F and n are shown in **Table 9.1**. Obtain the corresponding values of $\lg_{10} E_F$ and $\lg_{10} n$ and enter the values in the appropriate columns of **Table 9.1**.

Table 9.1

E_F/eV	n/m^{-3}	$\lg_{10}$ (E_F/eV)	$\lg_{10}$ (n/m^{-3})
4.00	0.360×10^{29}		
8.00	1.03×10^{29}		
12.0	1.90×10^{29}		
16.0	2.91×10^{29}		
20.0	4.06×10^{29}		

[2]

(iii) On the grid of **Fig. 9.1**, plot a graph of $\lg_{10} E_F$ against $\lg_{10} n$. [4]

Examiner Only	
Marks	Remark

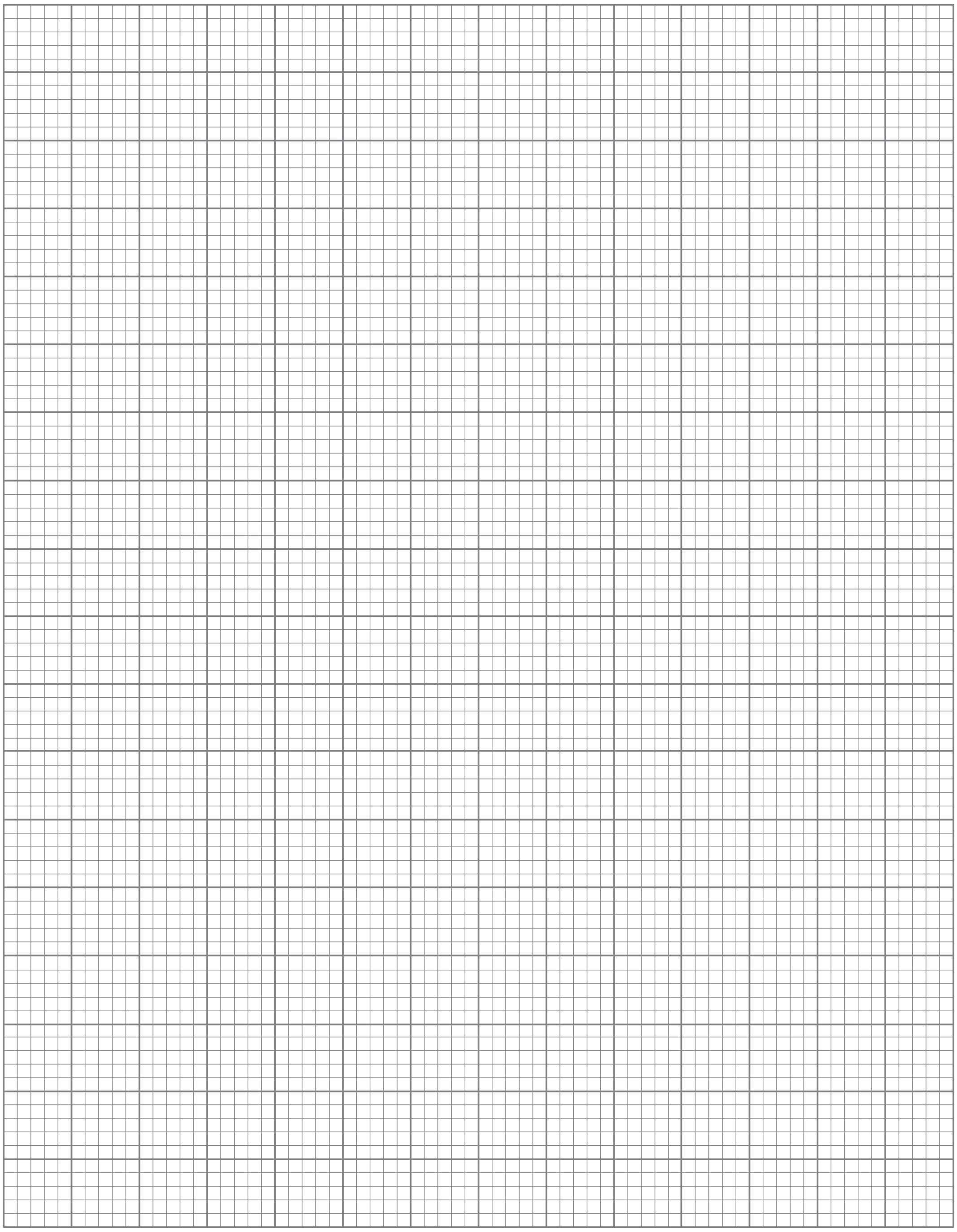


Fig. 9.1

(iv) Calculate a value for the constant *B* from your graph.

B = ______________ [3]

Examiner Only	
Marks	Remark

(v) Calculate a value for the Fermi energy E_F when the free electron density is 3.2×10^{29} m^{-3}

$E_F =$ _______________ eV [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	$c = 3.00 \times 10^{8}$ m s^{-1}
permittivity of a vacuum	$\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}
	$\left(\dfrac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
elementary charge	$e = 1.60 \times 10^{-19}$ C
the Planck constant	$h = 6.63 \times 10^{-34}$ J s
(unified) atomic mass unit	$1\ \text{u} = 1.66 \times 10^{-27}$ kg
mass of electron	$m_e = 9.11 \times 10^{-31}$ kg
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 on the Earth's surface	$g = 9.81$ m s^{-2}
electron volt	$1\ \text{eV} = 1.60 \times 10^{-19}$ J

AY211INS

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	$= 10 \lg_{10} \dfrac{I}{I_0}$

Waves

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

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	$\dfrac{1}{C} = \dfrac{1}{C_1} + \dfrac{1}{C_2} + \dfrac{1}{C_3}$
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 formula $\lambda = \frac{h}{p}$

The nucleus

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