New Specification

Rewarding Learning

Centre Number

71	

Candidate Number

ADVANCED
General Certificate of Education
January 2010

Physics

Assessment Unit A2 1

assessing

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

[AY211]

AY211

THURSDAY 28 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.

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

Total Marks	

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1 Two spheres, one of mass 100 g and the other of mass 500 g, approach each other directly travelling at a speed of $9.00\,m\,s^{-1}$ as shown in **Fig. 1.1**.

Examiner Only	
Marks	Remark

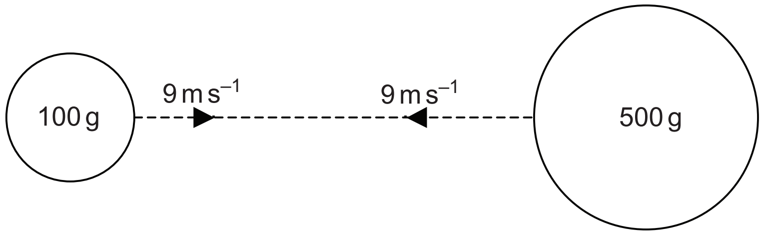

Fig. 1.1

(a) Calculate the momentum of the sphere with the greater momentum of the two, and state its **SI** unit.

Momentum = __________ [2]

SI unit = __________ [1]

After the collision the spheres stick together and move with a common velocity.

(b) Calculate the common velocity of the spheres just after the collision, and state its direction.

Common velocity = ________ $m\,s^{-1}$ [3]

Direction____ [1]

(c) State and explain if the collision between the spheres was elastic or inelastic.

____

____ [1]

2 (a) (i) In the space at **Fig. 2.1**, draw a well labelled diagram of the apparatus required, and the circuit connected to it, to determine the specific heat capacity of a liquid by an electrical method.

[3]

Fig. 2.1

(ii) In conducting such an experiment, the apparatus with the liquid is initially cooled a number of °C below the room temperature. During the experiment it is then heated an equal number of °C above the room temperature. Explain why this is a useful technique to minimise errors of heat exchange with the surroundings in this experiment.

____

____

____ [2]

Examiner Only	
Marks	Remark

(b) (i) In a different experiment, 240 g of milk is heated from room temperature in a container of mass 75.0 g made from copper of specific heat capacity of 0.39×10^3 J kg^{-1} °C^{-1}. A small electrical heater is placed in the milk. The potential difference across the heater is 12.0 V, the current through it is 2.60 A and the heater remains on for 6 minutes and 50 s. During this time, the temperature of the container and its contents increases by 13 °C above room temperature. Calculate the specific heat capacity of the milk.

Examiner Only	
Marks	Remark

Specific heat capacity = _________ J kg^{-1} °C^{-1} [3]

(ii) Assuming that the measurement data given in **(b)(i)** are correct, but that heat losses do occur during the experiment, **explain** if the value you have calculated in **(b)(i)** is higher or lower than the correct specific heat capacity of milk.

____

____

____

____ [2]

3 **(a)** Define angular velocity for a body moving in a circular path.

____ [1]

(b) An object rests on a horizontal turntable which rotates at a constant angular velocity. The object may be displaced from the centre of the turntable along a radius to any displacement *s* as shown on **Fig. 3.1**.

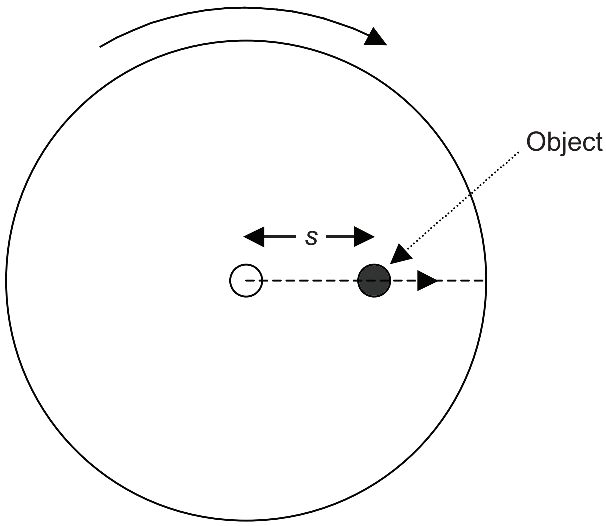

Fig. 3.1

On the axes of **Fig. 3.2**, sketch graphs to show:

1. The variation of the angular velocity ω of the object with its radial displacement *s*.
2. The variation of the acceleration *a* of the object with its radial displacement *s*.

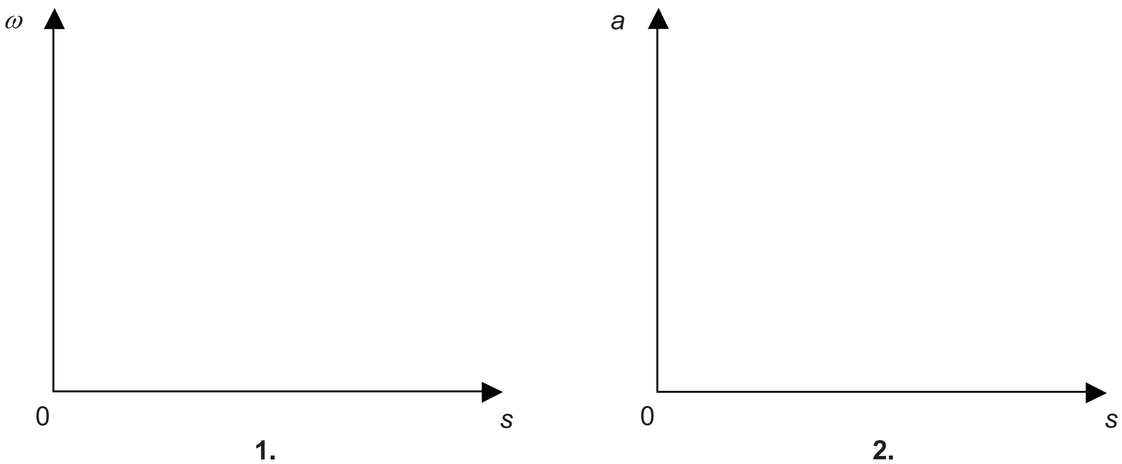

Fig. 3.2 [2]

Examiner Only	
Marks	Remark

Examiner Only	
Marks	Remark

(c) A jet aircraft completes a circular turn of radius of 600 m in a horizontal plane when flying at a constant speed of 153 m s^{-1}.

(i) Calculate the angular velocity of the aircraft.

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

(ii) Calculate the acceleration of the aircraft.

Acceleration = ________ m s^{-2} [2]

(iii) State the direction of the acceleration of the aircraft.

____ [1]

(iv) The pilot of the aircraft has a mass of 75.0 kg. Calculate the restraining force of the pilot's harness needed to keep him stationary in his seat.

Force = ________ N [2]

4 (a) The acceleration *a* of a mass executing simple harmonic motion is given by **Equation 4.1**.

$$a = -\omega^2 x$$ **Equation 4.1**

(i) State clearly what the symbol *x* represents.

____

____ [1]

(ii) Explain the significance of the negative sign in the equation.

____

____ [1]

(b) (i) A mass executing simple harmonic motion starts at the extreme limit of positive displacement at time $t = 0$, the magnitude of this displacement is 0.060 m. The mass executes 100 oscillations in 20.0 s. Use these data to obtain values for A and ω in the equation $x = A \cos \omega t$.

A = ______________________ m

ω = ______________________ rad s^{-1} [2]

Examiner Only	
Marks	Remark

(ii) On the axes of **Fig. 4.1**, sketch a graph of the quantity x with time t for the first two cycles of oscillation. Label the axes with appropriate units and numerical values for the oscillation.

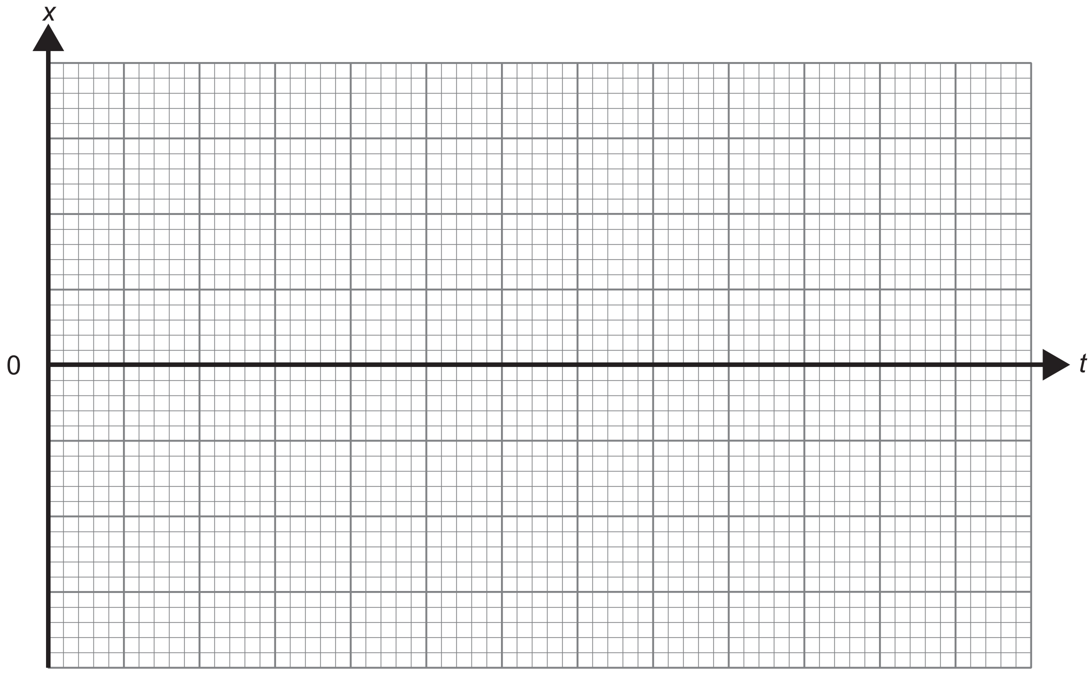

Fig. 4.1 [3]

(iii) Explain how the velocity of the mass at any instant of time after the start may be determined from an accurate displacement/time graph.

____

____

____ [2]

(iv) Calculate the distance and position of the mass relative to the centre of the motion, 0.13 s after the start of the oscillation.

Displacement = ____________ m

Position = ______________________________ [3]

Examiner Only	
Marks	Remark

5 **Fig. 5.1** is a plan view of the apparatus used (by Geiger and Marsden) for alpha particle scattering to establish evidence for the existence of atomic nuclei.

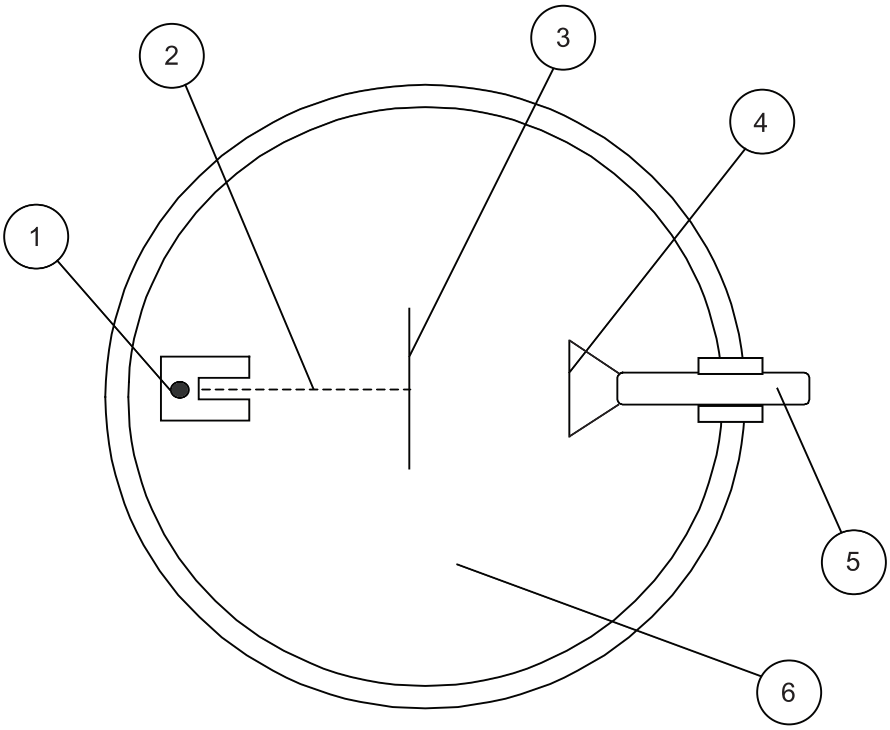

Fig. 5.1

(a) Essential items or requirements of the apparatus are numbered from 1 to 6. State what each number indicates in the apparatus.

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________ [3]

(b) State the function of item 4 and describe briefly how it operates.

____

____

____

______________________________ [2]

Examiner Only	
Marks	Remark

(c) Listed below are two of the results obtained from the experiment. In relation to atomic structure, state the conclusion which may be made from each listed result.

(i) *Most of the alpha-particles experienced no collisions.*

____

____ [1]

(ii) *Very few of the alpha particles (about 1 in 8000) were deflected almost directly backward (backscattered).*

____

____

____ [2]

Examiner Only	
Marks	Remark

6 (a) (i) Define the half-life of a radioactive sample.

Examiner Only	
Marks	Remark

____

____ [1]

(ii) A geological rock sample contains two radioactive isotopes, *X* and *Y*. The half-life of isotope *X* is twice that of isotope *Y*. In the sample there are *n* nuclei of *X* and 3*n* nuclei of *Y*. After two half-lives of isotope *X* find the ratio

$$\frac{\text{Number of nuclei of } Y}{\text{Number of nuclei of } X}$$

remaining in the rock sample.

Ratio = ____________ [3]

(b) Polonium is radioactive and emits alpha particles.
A mole of polonium has a mass of 210 g and its decay constant is $5.80 \times 10^{-8}\,s^{-1}$.

(i) Calculate the radioactive activity of 1.50 mg of polonium.

Activity = _______ Bq [3]

(ii) How many nuclei of the polonium remain after 65.0 days?

Number = ____________ [3]

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

Examiner Only	
Marks	Remark

7 *In certain nuclear processes (or reactions) the binding energy of the products is greater than the binding energy of the reactants, hence energy is released.*

Discuss concisely, some considerations of this statement, making use of an appropriate sketch graph.

You should make reference to the following: mass defect, fission and mass–energy exchange.

____ [7]

Quality of written communication [2]

Examiner Only	
Marks	Remark

8 **(a)** **(i)** Explain briefly what is meant by nuclear fusion.

____

____ [1]

(ii) Suggest two reasons why the D-T reaction is most suitable for terrestrial fusion.

____

____

____

____ [2]

(b) In an attempt to create nuclear fusion, the fuel matter takes the form of a plasma.
Name **two** constituents of a plasma.

____

____ [1]

(c) What does the magnetic confinement of a plasma mean?
Explain why it is necessary.

____

____

____ [2]

Examiner Only	
Marks	Remark

(d) A deuterium nucleus of mass 3.34×10^{-27} kg in a plasma is assumed to behave like a molecule in an ideal gas. The average speed of the nucleus is estimated at $1.33 \times 10^{6}\,\mathrm{m\,s^{-1}}$ when fusion occurs.
Use this data to estimate the temperature of the plasma.

Temperature = _______ K [3]

9 Data Analysis Question
This question contributes to the synoptic assessment requirement of the Specification. In your answer, you will be expected to bring together and apply principles and contexts from different areas of physics, and to use the skills of physics, in the particular situation described.

You are advised to spend about 15 minutes in answering this question.

Static performance of a thermocouple

A thermocouple is a device for measuring temperature. It consists of two wires, X and Y, of different metals which are in contact at the junctions J_1 and J_2. The arrangement is shown in **Fig. 9.1**.

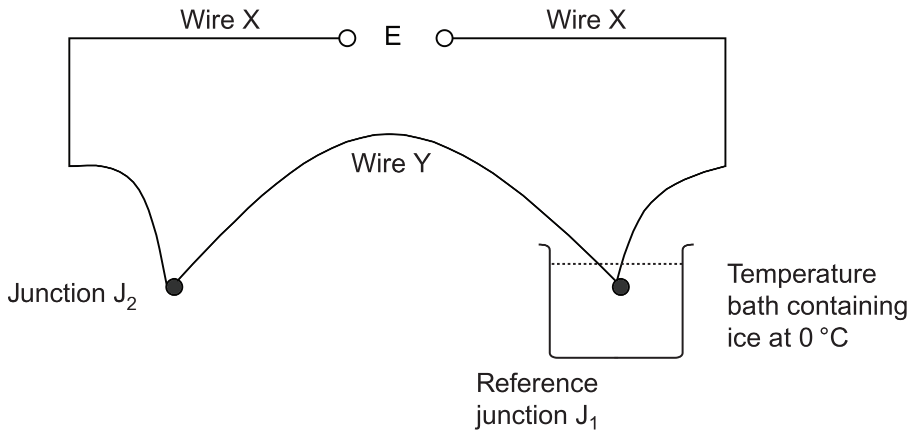

Fig. 9.1

The reference junction J_1 is maintained at an exact temperature of 0 °C. When junction J_2 is maintained at a temperature different from the reference temperature, an output e.m.f. E occurs between the ends of the wires X. The magnitude of E gives a measure of θ, the Celsius temperature of the junction J_2.

The temperature sensing junction J_2 usually has a protective coating placed on it to preserve it from corrosive atmospheres.

The quality of performance of a thermocouple may be considered in different ways. In this question you will consider **Point Accuracy** which is one characteristic of its static performance behaviour.

Static performance is measured when the sensing junction J_2 is placed in a temperature bath beside a standard thermometer at a series of steady °C temperatures. Adequate time is allowed for junction J_2 to stabilise to the steady temperature of the bath. For the purpose of this question it will be assumed that the standard thermometer indicates the exact (correct) temperature in °C.

Point Accuracy

The degree of correctness at any temperature may be defined as:

$$\textbf{\% Point Accuracy} = \pm \frac{\text{Temperature Error}}{\text{Correct Temperature}} \times 100\% \qquad \textbf{Equation 9.1}$$

This indicates the temperature error at any point in the range of the thermocouple.

Table 9.1 shows the results of the output e.m.f. *E* of the thermocouple in mV for values of θ, the temperature in °C of the sensing junction J_2 obtained experimentally under static conditions described previously.

Table 9.1

Temperature J_2 θ/°C	0.00	25	50	75	100	125	160	200
Output *E*/mV	0.00	1.10	2.30	3.73	5.35	6.95	8.90	10.8

(a) In **Table 9.1**, data *E* is recorded to 3 significant figures. State the possible range of values of the output *E* when the temperature is 50 °C.

Range from ___________ to ___________ mV [1]

(b) On the graph grid of **Fig. 9.2**, select a suitable scale for the *E* axis. Plot the point values from **Table 9.1 on Fig. 9.2**. The plotted points do not lie exactly on a straight line, draw a suitable continuous S-shaped curve through all the plotted points. [4]

Examiner Only

Marks	Remark

Examiner Only	
Marks	Remark

(c) The ideal characteristic of the thermocouple is a straight line from the origin to the calculated theoretical output e.m.f. at 200 °C. The theoretical output of the thermocouple is given by **Equation 9.2**.

$$E = A\theta + B\theta^2$$ **Equation 9.2**

Where A and B are constants with values $A = 5.21 \times 10^{-2}$ and $B = 0.950 \times 10^{-5}$ and θ is the temperature of J_2 in °C.

(i) State the units for the constant B.

Units = __________ [1]

(ii) Show that the theoretical output at 200 °C is 10.8 mV.

[2]

(iii) On **Fig. 9.2**, draw this ideal straight line characteristic. [1]

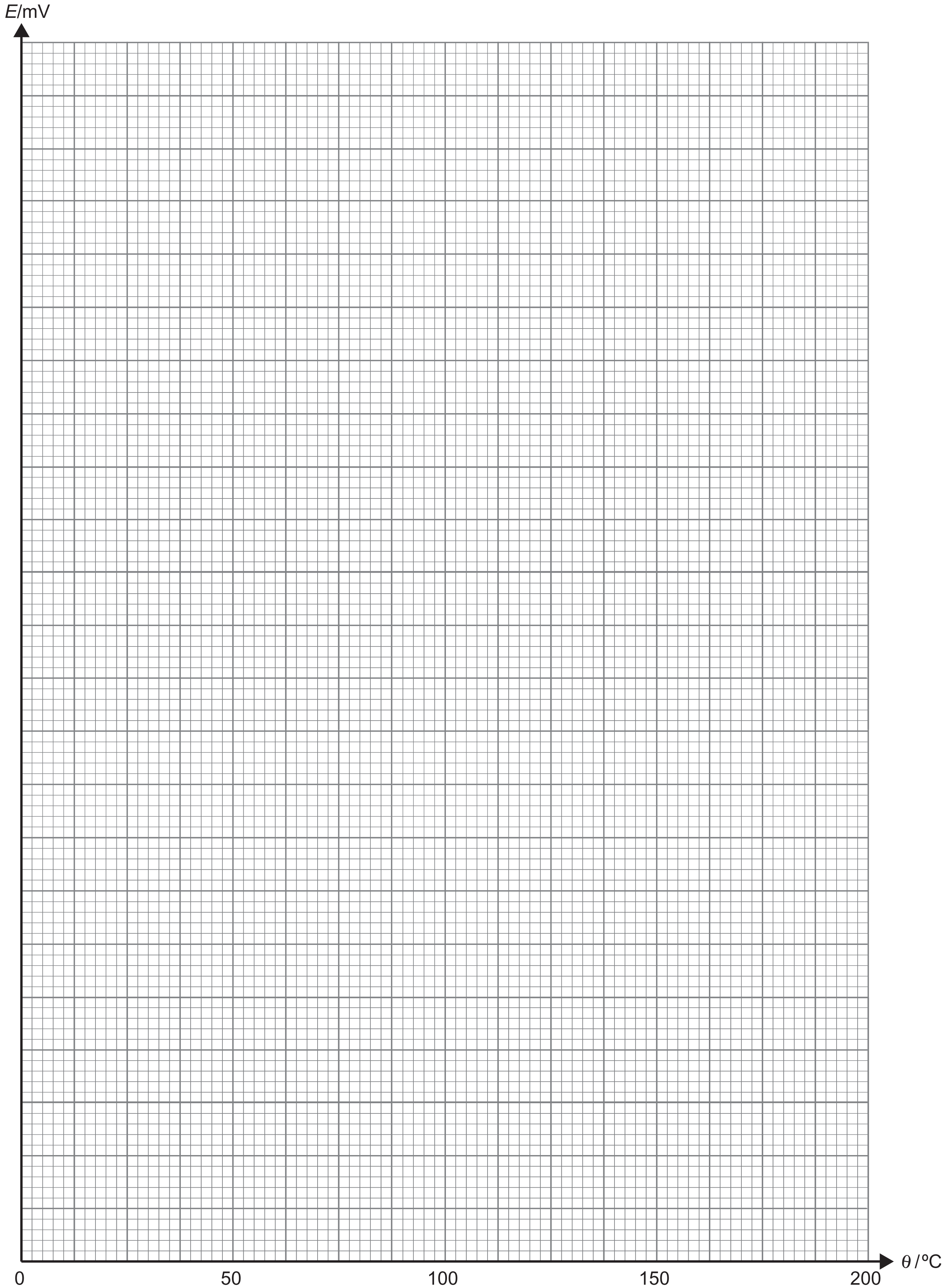

Fig. 9.2

Examiner Only	
Marks	Remark

(d) (i) By considering the linear graph to be the correct indication of temperature for any output signal *E*, determine the exact temperature error when the thermocouple gives an output signal of 8.00 mV.

Error = _________ °C [2]

(ii) Determine the point accuracy of this thermocouple at this output signal of 8.00 mV. Use **Equation 9.1**.

Point accuracy = _________ % [1]

(iii) Is the temperature indicated by the thermocouple above or below the correct value?
Circle the correct response.

Above Below [1]

(e) If the protective coating of this thermocouple was changed for a material of lower thermal conductivity but similar in all other respects, discuss briefly how this would affect the overall performance of the thermocouple.

____

____

____ [1]

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}
	$\left(\frac{1}{4\pi\varepsilon_0} = 8.99 \times 10^{9}\ \text{F}^{-1}\ \text{m}\right)$
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 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 e$V = 1.60 \times 10^{-19}$ 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 $r = r_0 A^{\frac{1}{3}}$