Oxford Cambridge and RSA

A Level Physics B (Advancing Physics)

H557/02 Scientific literacy in physics

Practice paper – Set 1

Time allowed: 2 hours 15 minutes

You must have:
- the Advance Notice (inserted)
- the Data, Formula and Relationships booklet

You may use:
- a scientific calculator
- a ruler (cm/mm)

First name	
Last name	

Centre number						**Candidate number**					

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number and candidate number.
- Answer **all** the questions.
- Write your answer to each question in the space provided. If additional space is required, use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the barcodes.

INFORMATION
- The total mark for this paper is **100**.
- The marks for each question are shown in brackets **[ ]**.
- This document consists of **24** pages.

SECTION A

Answer **all** the questions.

1 This question is about the diffraction of light by a reflection grating formed by a CD (compact disc)

(a) Fig. 1 shows a beam of light illuminating a reflection grating. A_1, A_2, A_3 and A_4 are four reflecting strips. Light reflected from the grating in the direction shown produces a bright image on a distant screen. The diagram also shows the wave crests of the light leaving A_1.

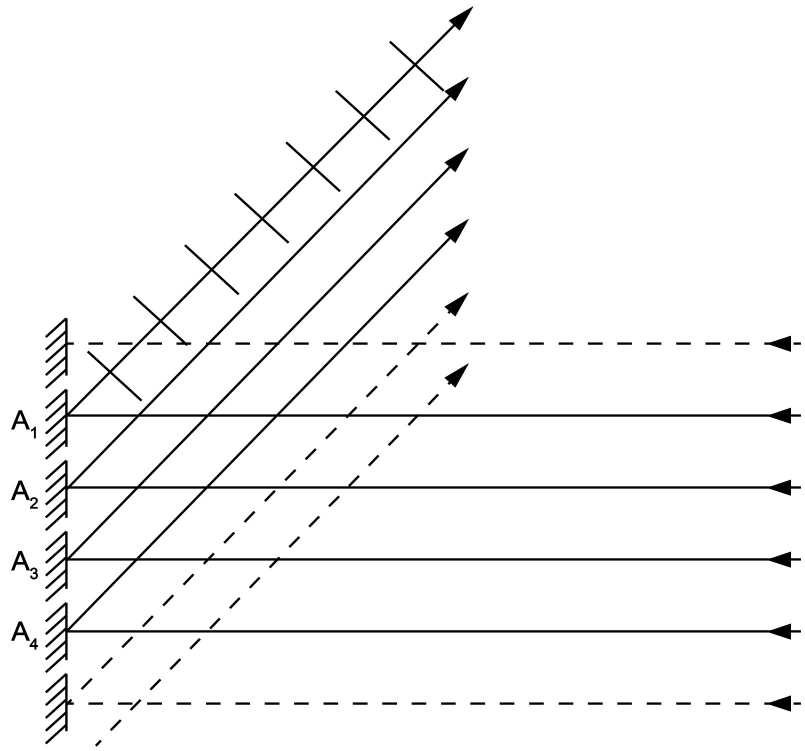

Fig. 1

(i) On Fig. 1:

1 draw in the corresponding wave crests for the light leaving A_2 and A_4, which give rise to the bright image

2 mark and label the path difference between adjacent beams

[3]

(ii) Explain:

1 why a bright image is seen on the screen at this angle

....

....

2 why the image is so bright.

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[3]

(b) (i) Explain why spectra are seen when a CD is viewed in white light.

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.... **[2]**

(ii) The spacing of the reflecting strips on a CD is 1.6 μm. Calculate the angle at which a bright image will be seen for light of wavelength 580 nm.

[2]

2 This question is about using airbags and seat belts to improve driver and passenger safety. In a test laboratory, a car travelling at 11.0 m s^{-1} strikes a wall head-on and comes to rest in 0.12 s.

A crash test dummy of mass 72 kg is belted into the driver's seat of the car.

(a) Calculate the change of momentum of the dummy in the crash.

change of momentum = ... kg m s^{-1} **[2]**

(b) In the crash, the dummy is brought to rest by the seat belt from a speed of 11.0 m s^{-1} in a time of 0.15 s.

Show that the average force on the dummy is between seven and eight times its weight.

[2]

(c) The seat belt does not stop the head of the dummy moving forward. With no airbag, the head could strike the steering wheel. Fig. 2.1 shows how the force on the dummy's head changes over time if it strikes the steering wheel. The area between the line and the time axis gives the impulse of the force.

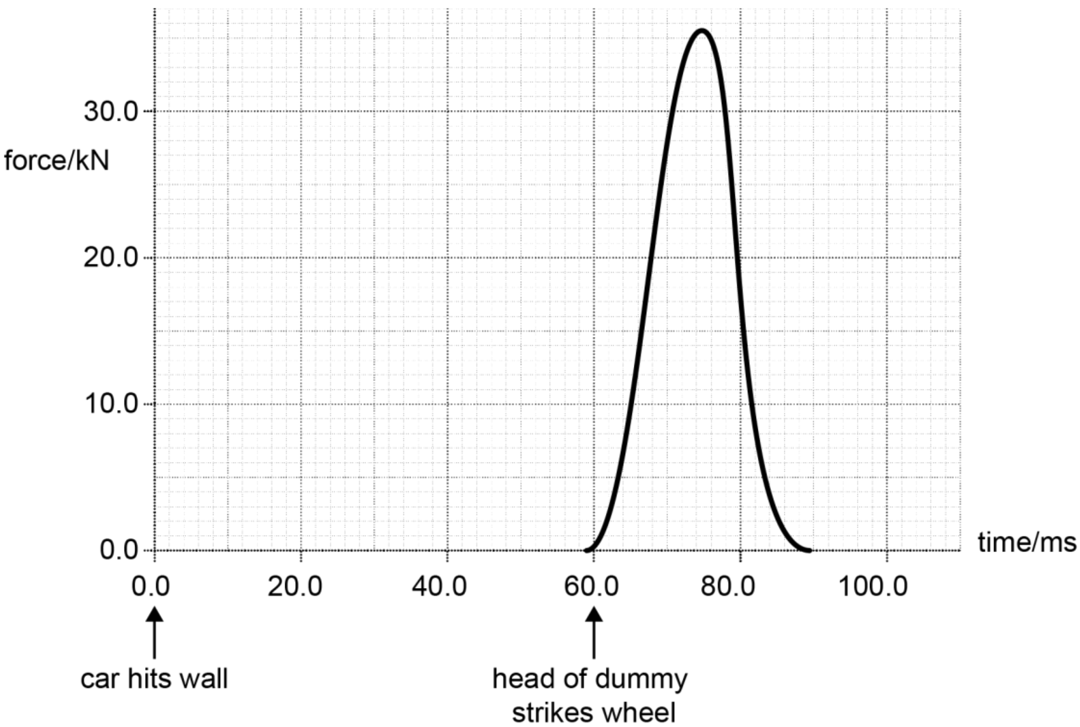

Fig. 2.1

(i) If an airbag is installed it will begin to inflate from the steering wheel about 20 ms after the collision and takes a further 20 ms to fully inflate. Draw a second curve on the graph of Fig. 2.1 to show how the force on the head of the dummy will change over time when the airbag is present.

[2]

(ii) State and explain how the graph is similar to the original curve and also how it differs from it.

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....**[2]**

(iii) Airbags are designed to start deflating 40 ms after the collision. State and explain why this improves the protection that the airbag gives to the dummy.

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....**[2]**

3 This question is about carbon-14 in the body.
All living matter contains carbon-14, which decays, following the equation:

$$^{14}_{6}C \rightarrow ^{14}_{7}N + X + \bar{\nu}$$

(a) Identify the particle X in this equation.

.... **[1]**

(b) The decay constant λ of carbon-14 is 3.8×10^{-12} s^{-1}.

Calculate the half-life of carbon-14 in years.

1 year = 3.2×10^{7} s

half-life = ……………..years **[3]**

(c) A man of mass 65 kg contains about 1.3×10^{-11} kg of carbon-14.

Show that the activity of the carbon-14 in a 65 kg man is about 2 kBq.

u = 1.7×10^{-27} kg

[3]

(d) When an organism dies, the carbon-14 stops being replaced and gradually decays away.

(i) A preserved human body, about 65 kg in mass, was found in a glacier in the Alps. It is thought to be 5000 years old.

State why the activity of the carbon-14 in the body is about 1 kBq.

....**[1]**

(ii) A measurable activity is about 10 Bq (significantly larger than the background count).

Estimate the mass of tissue from the preserved body from the glacier which would have an activity of 10 Bq due to carbon-14, and suggest why museums are reluctant to allow radiocarbon dating of this sort on their specimens.

[2]

SECTION B

Answer **all** the questions.

4 This question is about modelling simple harmonic motion.
Fig.4.1 shows a trolley of mass 1.0 kg tethered between two extended springs. The springs obey Hooke's law.

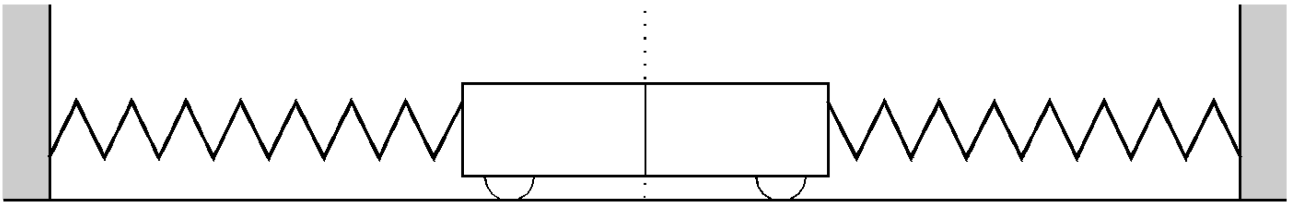

Fig. 4.1

Fig. 4.2 shows the trolley displaced 0.10 m to the right. Both springs are still in tension.

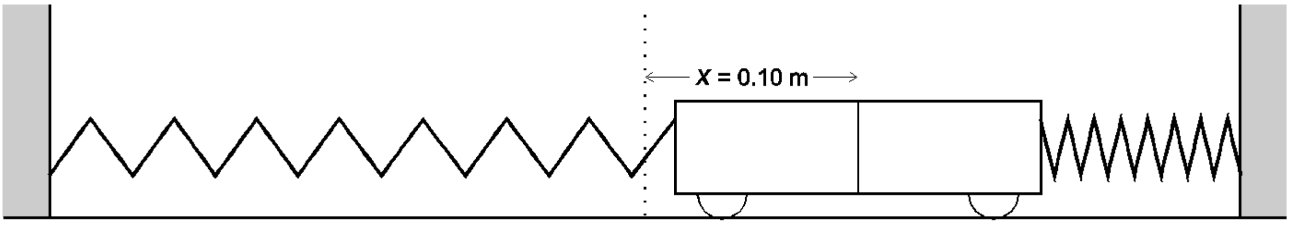

Fig. 4.2

(a) In Fig. 4.2 the resultant force on the trolley is 4.0 N to the left. Calculate the force constant of the spring/trolley system.

force constant = ... N m^{-1} **[1]**

(b) The trolley will move with simple harmonic motion if the equation $a \propto -x$ is true, where a is the acceleration and x the displacement from the centre.

Explain why acceleration is proportional to the negative of the displacement for this spring/trolley system.

....

....

....**[3]**

(c) A modelling program produced the graph of Fig. 4.3. The program calculated the acceleration at time intervals of 0.2 s, and used these values to estimate the changes in velocity and displacement for the next time interval.

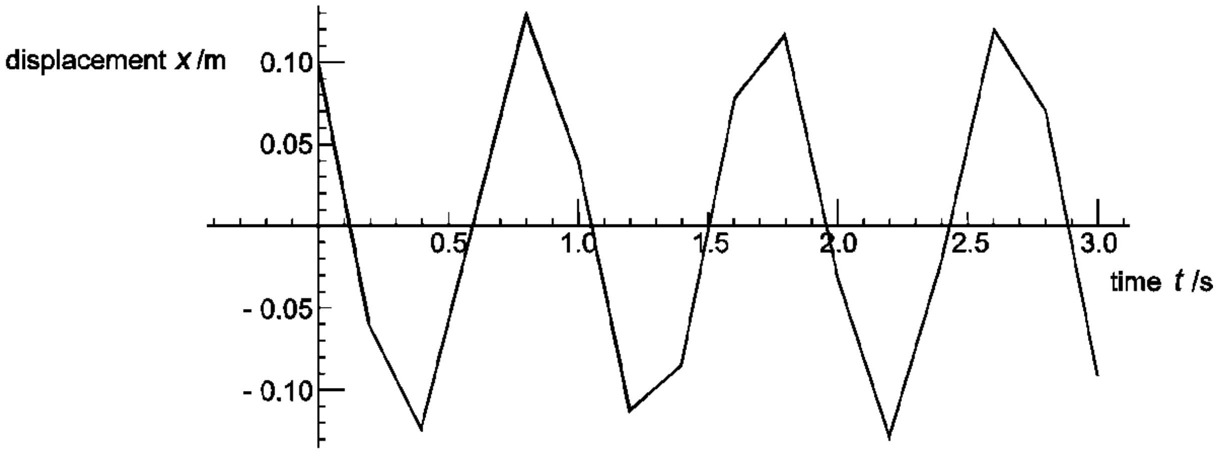

Fig. 4.3

(i) Use the graph of Fig. 4.3 to estimate the period of the oscillation predicted by the model.

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

(ii) Compare your answer in part **(i)** to the period of a spring/trolley system of mass *m* and spring constant *k* calculated using the equation

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Suggest a reason for any differences between the two values of the time period. .....

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.... **[3]**

(iii) Suggest **one** method for improving the model in part **(c) (i)** and explain why the improvement would give a result closer to the value of the period *T* calculated from the equation. ....

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....**[3]**

(d) A student suggests that the model does not represent the real situation because the amplitude of a real oscillator decreases exponentially with time.

Explain what this statement means and suggest how the student could demonstrate that the amplitude of a spring/trolley system decreases exponentially. ....

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....[4]

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5 This question is about the gravitational fields of asteroids and moons in the Solar System.

(a) (i) A roughly-spherical asteroid has a radius of about 5×10^2 m and a mass of 3.0×10^{12} kg. Show that an 1100 kg spacecraft would have a weight of about 0.9 N on the surface of the asteroid.

[2]

(ii) By equating the gravitational force on the spacecraft with the centripetal force required to keep the spacecraft on the surface of the asteroid**,** explain why the spacecraft cannot remain on the equator of the asteroid if the asteroid makes one revolution every 80 minutes.

[5]

(iii) The gravitational potential energy of the spacecraft on the asteroid is about – 450 J.

Explain why this quantity is negative.

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.... **[2]**

(iv) Explain why the spacecraft will escape the asteroid if it is projected vertically upwards from the surface with a velocity greater than about 0.9 m s^{-1}.

....

.... **[2]**

(b) Titan, one of Saturn's moons, is very much larger than this asteroid. It has an atmosphere of nitrogen, while the atmosphere of the planet Saturn is mostly hydrogen.

The table shows the gravitational potential energy that one molecule of each gas would have on the surface of Titan.

molecule	E_{grav} /10 $^{-19}$ J
nitrogen	-1.7
hydrogen	-0.12

(i) State why these two values are different.

[1]

(ii) The temperature T of the surface of Titan is 93 K. Calculate a value for the typical kinetic energies of particles at this temperature. Use this value with the values of the gravitational potential energy E_{grav} in the table to explain why Titan has an atmosphere of nitrogen but no hydrogen.

[4]

6 This question is about a portable, flexible electrical extension cable. The cross-section of the cable is shown in Fig. 6.1

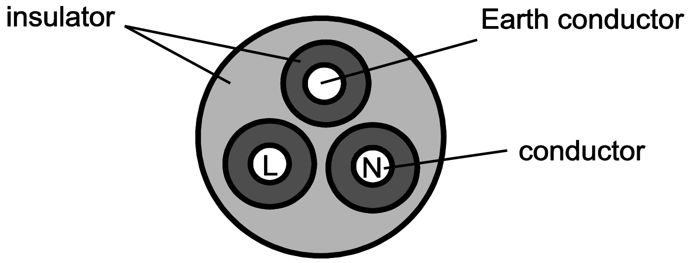
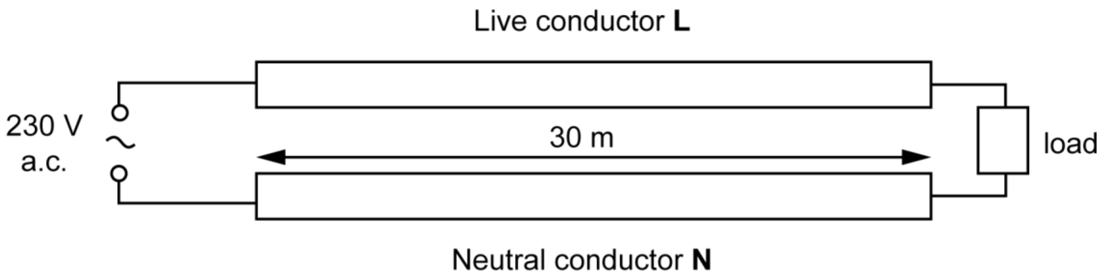


Fig. 6.1

(a) The live **L** and neutral **N** conductors are connected in series with the load and the supply as shown below.



(i) The cable is 30 m long, so that the total length of conductor is 60 m. The conductor has a diameter of 1.5 mm.

Copper has a conductivity of 5.9×10^{7} S m^{-1}.

Calculate the conductance of the cable.

conductance = ... S **[3]**

(ii) Calculate the voltage dropped across the 60 m of cable when it carries a current of 13 A.

voltage dropped = ... V **[2]**

(iii) Explain why a 2.8 kW 230 V kettle would take slightly longer to boil when connected to the mains supply with this extension lead, but the performance of a 500 W electric drill would not be significantly affected by using this extension cable.

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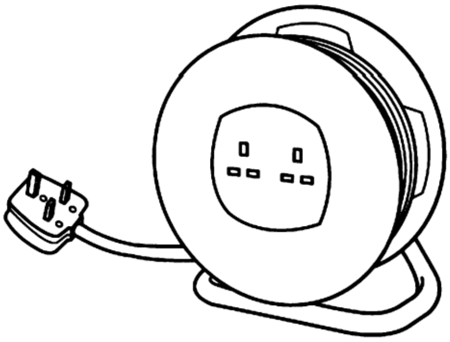
.... **[3]**

(b)* The cable is stored tightly wound on a reel as shown. The manufacturer recommends that if the cable is used coiled on its reel, the current must be significantly less than 13 A to prevent overheating.



Use your answers to part **(a)** to calculate the power dissipated by the cable. Make further estimates and calculations to show why the current should be kept significantly less than 13 A when the cable is wound on a reel.

specific thermal capacity of copper = 390 J kg^{-1} K^{-1}
density of copper = 9000 kg m^{-3}

[6]

SECTION C

This section is based on the Advance Notice article, which is an Insert.

7 This question is about the physical properties of cooked and uncooked food.

(a) The biological molecules found in meat, or in uncooked vegetables, are **long-chain polymer molecules** (lines 6 – 7 in the article).

With the aid of a simple sketch, indicate the basic structure of a long-chain polymer molecule.

[1]

(b) 'The term 'tough' is used rather differently in describing strong materials such as metals.' (lines 22 - 23 in the article).

(i) State the meaning of the word 'tough' as applied to a strong material.

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....**[1]**

(ii) Referring to the structure of collagen (Fig. 1 and lines 19 – 20 in the article), suggest why raw meat is tough to eat.

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....**[2]**

(iii) What happens to the structure of collagen during cooking to make meat tender and cause it to fall apart? (lines 20 – 22 in the article)

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....**[2]**

(c) Jellies are made from gelatine. With reference to the structure of gelatine (Fig. 1 and lines 25 – 29 in the article), explain why the density of a jelly is almost identical to the density of water.

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....**[1]**

8* In lines 10 -12 the Article states, 'The important applications of physics in the kitchen – particularly heat transfer – are ways in which we can control and accelerate these processes.'

Thermal conductivity *k* is analogous to electrical conductivity σ, with the energy per second *P* conducted through a conductor (such as the bottom of a pan) of area *A* and thickness *d* given by the equation

$$P = \frac{kA}{d}\Delta T$$

where ΔT is the temperature difference between the hot and cold ends of the conductor.

metal	aluminium	steel	copper
thermal conductivity *k* /W m^{-1} K^{-1}	220	48	380

Saucepans can be made from aluminium, stainless steel or copper. Discuss how the cooking of food in a saucepan can be can be controlled and accelerated by a suitable choice of materials and dimensions of the pan.

[6]

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9 This question is about the effect of temperature on the rate of chemical reactions.

(a) Show that 70 kJ mol^{-1} is about 1.2×10^{-19} J per molecule. (line 33 in the article)

[1]

(b) The table below shows how the Boltzmann factor for a typical Maillard reaction varies with temperature.

	freezer	**refrigerator**	**cool oven**	**boiling water**	**warm oven**	**hot oven**
temperature *T*/K	255	275	360	373	410	
Boltzmann factor	1.55×10^{-15}	1.85×10^{-14}	3.23×10^{-11}	7.51×10^{-11}	6.15×10^{-10}	2.80×10^{-8}

(i) Use the value of the Boltzmann factor to calculate the temperature of the hot oven.

activation energy for a typical Maillard reaction $E = 1.2 \times 10^{-19}$ J

temperature = ... ^{o}C **[3]**

(ii) A useful approximate rule for many reactions in the temperature range shown in the table is that the rate of reaction approximately doubles for every 10 K rise in temperature.

Explain why the rate of reaction is affected by the Boltzmann factor.

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.... **[2]**

(iii) Test the rule that the rate of reaction doubles for every 10 K rise in temperature (lines 38 – 40 in the article) for the temperature range between a cool oven and a warm oven (a temperature difference of 50 K). Comment on your answer.

[3]

10 This question is about a simple electronic thermometer using a thermocouple (lines 51 – 54 in the article). A thermocouple is made from two different metals, connected at two junctions at different temperatures, as shown in Fig. 10.1. This generates an e.m.f. $\mathcal{E}$ which depends on the temperature difference ΔT between the two junctions

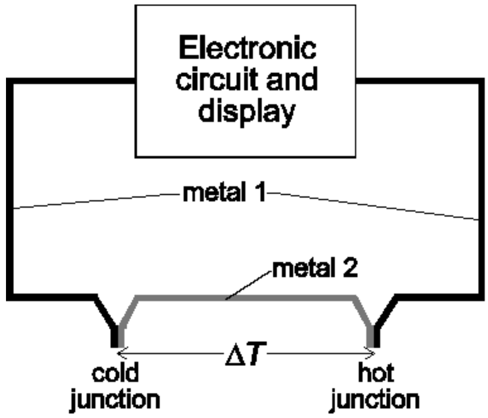

Fig. 10.1

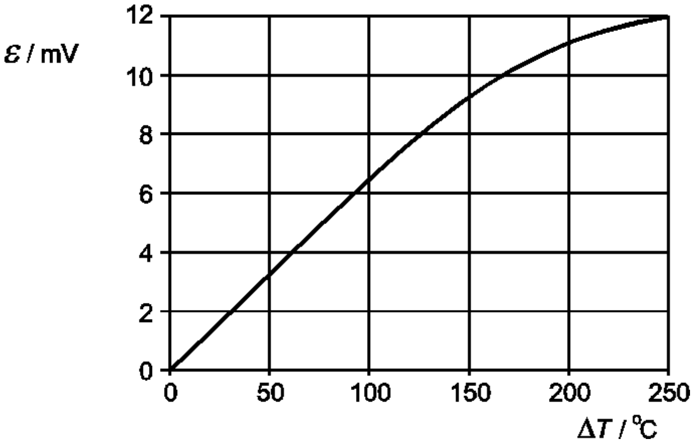

Fig. 10.2

(a) The display for the electronic thermometer is a voltmeter of full-scale deflection 2.50 V. The thermometer is designed to have a range of 0 °C to 250 °C. Look at the graph of Fig. 10.2 and state why an amplifier is needed.

....

....**[1]**

(b) A temperature difference ΔT = 250 °C gives a reading of 2.50 V on the display of the thermometer.

Use the graph of Fig. 10.2 to explain why a temperature difference ΔT = 125 °C may not give a reading of 1.25 V.

[2]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).