OCR
RECOGNISING ACHIEVEMENT

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced GCE

PHYSICS B (ADVANCING PHYSICS) 2865/01

Advances in Physics

Monday **26 JANUARY 2004** Morning 1 hour 30 minutes

Candidates answer on the question paper.
Additional materials:
Insert (Advance Notice Article for this question paper)
Data, Formulae and Relationships Booklet
Electronic calculator

Candidate Name	Centre Number	Candidate Number

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Write your answers in the spaces provided on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Show clearly the working in all calculations, and give answers to only a justifiable number of significant figures.

INFORMATION FOR CANDIDATES

- Section A (questions 1–7) is based on the Advance Notice article, a copy of which is included as an insert. You are advised to spend about 60 minutes on Section A.
- The number of marks is given in brackets [ ] at the end of each question or part question.
- There are four marks for the quality of written communication on this paper.
- The values of standard physical constants are given in the Data, Formulae and Relationships booklet. Any additional data required are given in the appropriate question.

FOR EXAMINER'S USE		
Qu	Max.	Mark
1	8	
2	10	
3	6	
4	14	
5	6	
6	8	
7	6	
8	17	
9	11	
QWC	4	
TOTAL	90	

This question paper consists of 19 printed pages and 1 blank page.

Jan04/erratum10

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Monday **26 JANUARY 2004** Morning 1 hour 30 minutes

ERRATUM NOTICE

For the attention of the Examinations Officer

Please read the following corrections to candidates at the start of the examination.

Look at the **Front Cover**.

The statement relating to the number of pages of the question paper should read:

'This question paper consists of 19 printed pages, 1 blank page and an **insert**'

For Examiner's Use

Answer **all** the questions.

Section A

The questions in this section are based on the Advance Notice article.
You are advised not to spend more than 60 minutes on this section.

1 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) Explain the meaning of the word 'tough' as applied to a strong material.

[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.

[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.)

[2]

(c) Jellies are made from gelatin. With reference to the structure of gelatin (Fig. 1 and lines 24–28 in the article), explain

(i) why the density of a jelly is almost identical to the density of water

[1]

(ii) why it melts at a relatively low temperature.

[1]

[Total: 8]

For Examiner's Use

2 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 32 in the article.)

Avogadro constant $N_A = 6.0 \times 10^{23} mol^{-1}$

[2]

(b) In the table below, E is the activation energy of a Maillard reaction (1.2×10^{-19} J).

	freezer	refrigerator	cool oven	boiling water	hot oven
temperature T/K	255	275	363	373	500
$kT/10^{-21}$ J	3.52	3.80	5.01	5.15	6.90
$\frac{E}{kT}$	34.1	31.6	24.0	23.3	17.4
Boltzmann factor $f_B = e^{-\frac{E}{kT}}$	1.55×10^{-15}	1.85×10^{-14}	3.95×10^{-11}	7.51×10^{-11}	2.80×10^{-8}

(i) Explain why the third row of the table, for $\frac{E}{kT}$, has no units.

[2]

(ii) Explain in terms of the values of $\frac{E}{kT}$ why these reactions will occur readily at temperatures of 500 K but not at 255 K.

[2]

(c) A useful rule for many chemical reactions in the temperature range above is that the rate of a reaction approximately doubles for every 10 K rise in temperature. (Lines 36–39 in the article.)

(i) Use the Boltzmann factor f_B at temperatures of 363 K and 373 K to check this rule.

[2]

(ii) Explain why the rate of a reaction is affected by the Boltzmann factor f_B.

[2]

[Total: 10]

3 This question is about a simple electronic thermometer using a thermocouple. (Lines 50–54 in the article.) A thermocouple is made from two different metals, connected at two junctions at different temperatures, as shown in Fig. 3.1. This generates an emf ε which depends on the temperature difference ΔT between the two junctions.

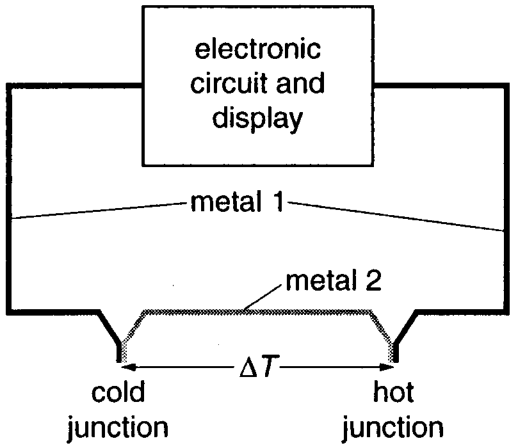

Fig. 3.1

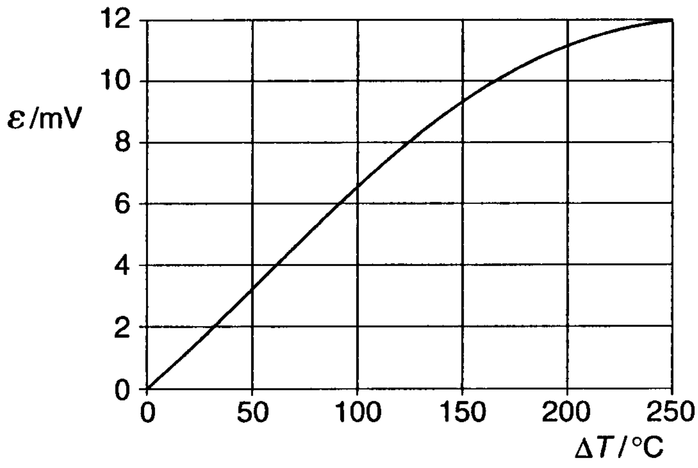

Fig. 3.2

(a) Many thermometers consist of coloured alcohol in glass. Suggest why such a thermometer would not be suitable for measuring the temperature of food during cooking in the oven.

[1]

(b) 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. 3.2 and explain why an amplifier is needed.

[1]

(c) A temperature difference $\Delta T = 250\,°C$ gives a reading of 2.50 V on the display of the thermometer. Look at the graph of Fig. 3.2 and explain why a temperature difference $\Delta T = 125\,°C$ may not give a reading of 1.25 V.

[2]

(d) Is the sensitivity of this thermometer greater near 0 °C or near 250 °C? Explain your answer.

[2]

[Total: 6]

For Examiner's Use

4 This question is about electron movement in a magnetron. (Figs. 4 and 5 and lines 89–96 in the article.)

(a) Fig. 4.1 shows the electric field inside a magnetron.

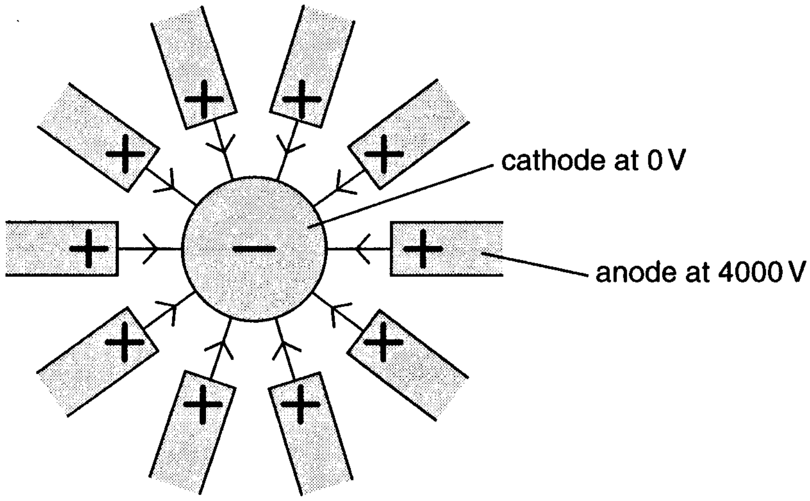

Fig. 4.1

(i) State how, from the diagram, you can tell that the electric field becomes weaker as the electron moves outwards from the cathode.

[1]

(ii) Using data from Fig. 4.1, show that the maximum kinetic energy (in joule) that an electron can gain when moving to the anode is about 6×10^{-16} J.

electronic charge $e = 1.6 \times 10^{-19}$ C

[2]

(iii) The microwave output of the magnetron is 650 W. Estimate the least number of electrons that must be emitted by the cathode each second.

least number of electrons s^{-1} = ... [2]

(iv) Suggest **one** reason why the actual number of electrons emitted is likely to be larger than your answer to **(iii)**.

[1]

For Examiner's Use

(b) Fig. 4.2 shows the path of an electron in the magnetic field inside a magnetron.

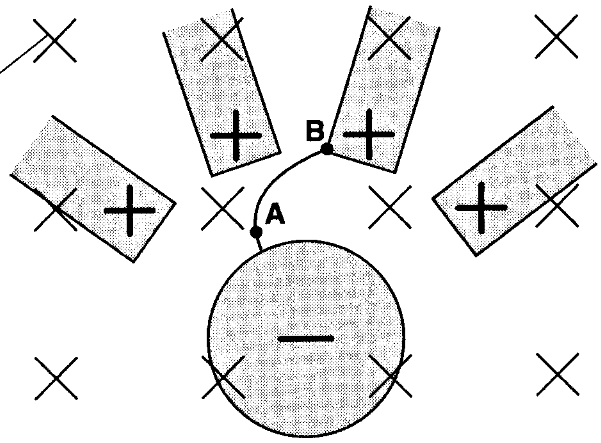

Fig. 4.2

Draw an arrow at the point marked **A** on Fig. 4.2 to show the direction of the **magnetic** force acting on the electron. [2]

(c) Here are two steps in a mathematical treatment of a particle of mass m and charge q moving at speed v perpendicular to a magnetic field of flux density B. The particle is travelling in an arc of radius r.

$$qvB = \frac{mv^2}{r} \qquad \textbf{equation 1}$$

$$r = \frac{mv}{qB} \qquad \textbf{equation 2}$$

(i) Explain carefully the meaning of the term qvB in **equation 1**.

[2]

(ii) Explain carefully the meaning of the term $\frac{mv^2}{r}$ in **equation 1**.

[2]

(iii) Use **equation 2** to explain why the path of the electron is curved at **A**, but becomes nearly straight as it approaches **B**.

[2]

[Total: 14]

[Turn over

For Examiner's Use

5 This question compares the conduction of heat with the conduction of electricity. (Fig. 3 and lines 59–72 in the article.)

Fig. 5.1 shows heat conducting into an egg, cooking in a frying pan without oil or fat. An electrical circuit, which is being used to model it, is shown in Fig. 5.2.

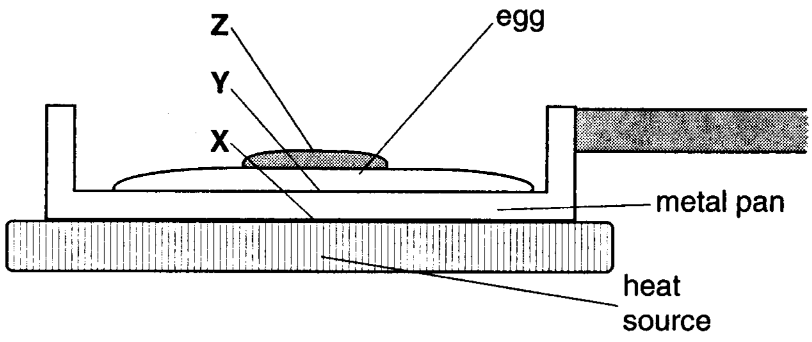

Fig. 5.1

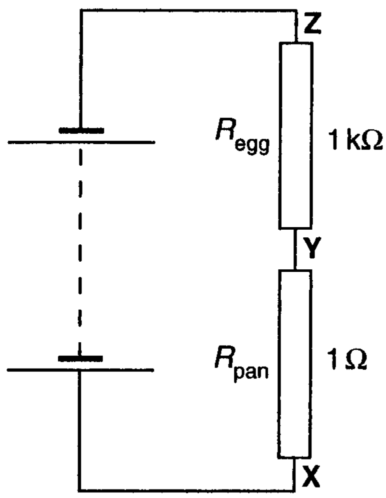

Fig. 5.2

(a) The thermal conductance of the base of the frying pan is much greater than the thermal conductance of the egg. The **electrical resistance** R_{pan} modelling the pan base must be much less than the **electrical resistance** R_{egg} modelling the egg. Explain why.

[2]

(b) Use the electrical circuit of Fig. 5.2 to explain why the temperature difference across the pan base is very much less than the temperature difference across the egg.

[2]

For Examiner's Use

(c) The temperature at **X**, the bottom of the pan, is about 400 °C. Explain why you might expect the bottom of the egg, at **Y**, to over-cook and blacken.

[2]

[Total: 6]

6 This question is about the absorption of microwaves as they penetrate deeper into food. (Lines 123–129 in the article.)

(a) Show that the energy of a 2.45 GHz microwave photon is about 2×10^{-24} J.

Planck constant $h = 6.63 \times 10^{-34}$ J s

[2]

For Examiner's Use

(b) The table below shows the intensity of microwaves reaching different depths in the food being cooked.

depth into food / mm	0	4	8	12	16
intensity of microwaves in food / arbitrary units	24	19	15	12	10

(i) State a simple numerical test that you could apply to the data to see whether the intensity of the microwaves goes down exponentially with the depth they penetrate into the food.

[1]

(ii) Apply the test to the data in the table and state your conclusion.

[2]

(iii) Show that the intensity of the microwaves at a depth of 48 mm in the food is about 1.5 arbitrary units.

[1]

(c) Explain why it is not true that 'microwaves heat food from the middle out'. (Line 129 in the article.)

[2]

[Total: 8]

7 This question is about resonance in microwave ovens. (Lines 130–135 in the article.)

(a) Show that the wavelength of 2.45 GHz microwaves is about 12 cm.

speed of light $c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$

[3]

(b) The interior walls of a microwave oven are made from metal. State what happens to the microwaves when they meet the metal surface.

[1]

(c) Fig. 7.1 shows the interior of a small microwave oven, which uses 2.45 GHz microwaves.

Sketch on Fig. 7.1 a standing wave pattern that might be set up across the width of this oven.

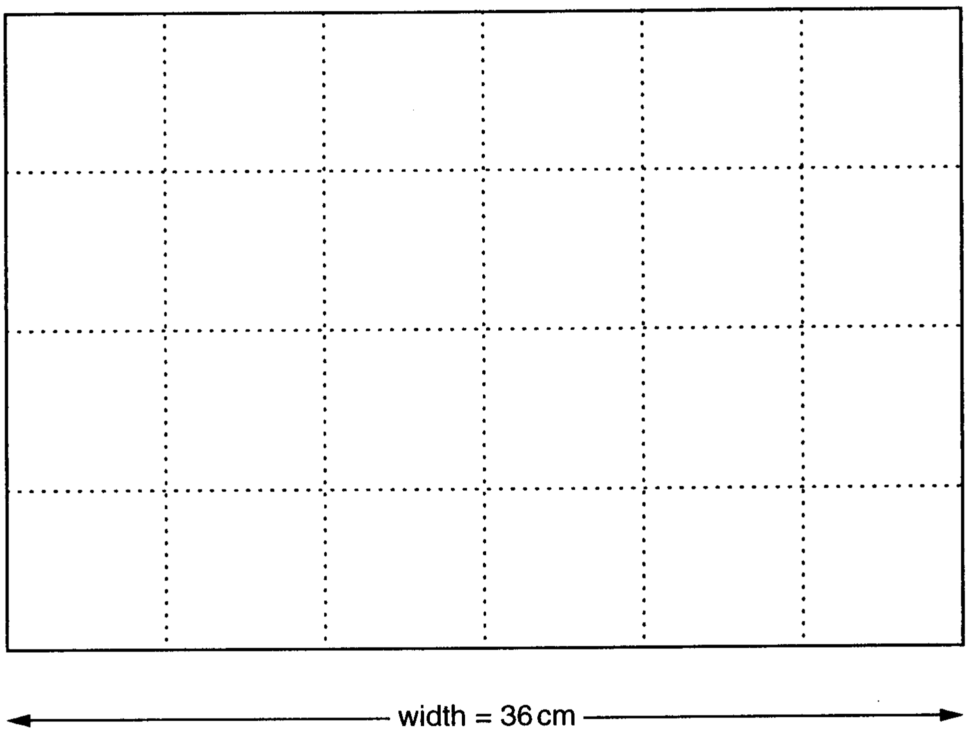

Fig. 7.1

[2]

[Total: 6]

For Examiner's Use

Section B

8 This question is about asteroids. These are rocky objects in orbit around the Sun, which are too small to be considered as planets.

(a) The table below gives some data about two of the largest asteroids, both discovered at the beginning of the nineteenth century.

name	volume / m^3	mass / kg	orbital period / year
Ceres	4.3×10^{17}	8.7×10^{20}	4.6
Vesta	7.8×10^{16}	3.0×10^{20}	3.6

(i) Use the data in the table to calculate the densities of these asteroids.

density of Ceres = ... kg m^{-3} density of Vesta = ... kg m^{-3} [2]

(ii) Comment on the composition of the two asteroids Ceres and Vesta.

[1]

(b) The speed, v, of a satellite in a circular orbit of radius r about a central object is given by

$$v = \sqrt{\frac{GM}{r}}$$

where G is the universal gravitational constant and M is the mass of the central object.

(i) Use this equation to show that the orbital period, T, of the satellite is given by

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}.$$

[3]

For Examiner's Use

(ii) State and explain which asteroid, Ceres or Vesta, has the larger orbital speed around the Sun, assuming that both orbits are circular.

[2]

(c) NASA's Shoemaker spacecraft was placed in an orbit of radius 35 000 m around the small asteroid Eros in February 2000.

Use the equation from **(b)(i)** to show that the spacecraft took nearly a day to orbit the asteroid Eros.

universal gravitational constant $G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
mass of Eros $M = 6.69 \times 10^{15}\,\mathrm{kg}$

[2]

(d) After a year in orbit, a controlled descent to the surface was planned. At the time, Eros was about $3 \times 10^{11}\,\mathrm{m}$ from the Earth.

(i) Calculate the time it took for a control signal to travel from the Earth to the spacecraft.

speed of light $c = 3.0 \times 10^{8}\,\mathrm{m\,s^{-1}}$

time = ... s [1]

(ii) What problems might this have posed in controlling the descent?

[2]

[Turn over

For Examiner's Use

(e) The image of Fig. 8.1 was taken during the descent of the Shoemaker spacecraft.

Fig. 8.1

(i) This image, which consists of 398 x 303 pixels at 8 bits per pixel, was stored in 10 576 bytes of computer memory.

Why does this suggest that some kind of data compression was used?

[2]

(ii) Once on the surface, the spacecraft continued to function even though it had not been designed to make a landing. Data was transmitted back to Earth at a rate of 10 bits per second.

How long would it have taken to transmit the data for the image above?

time to transmit data = ... s [2]

[Total: 17]

For Examiner's Use

9 This question is about modelling simple harmonic motion.

Fig. 9.1 shows a trolley of mass 1.0 kg tethered between two extended springs. The springs obey Hooke's Law.

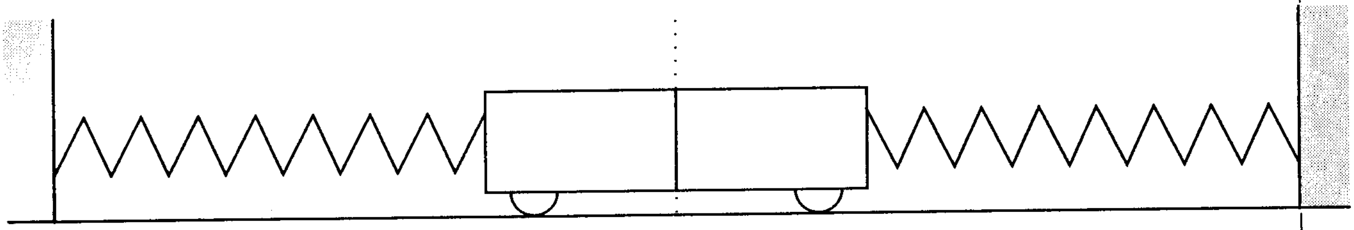

Fig. 9.1

Fig. 9.2 shows the trolley displaced 0.10 m to the right. Both springs are still in tension.

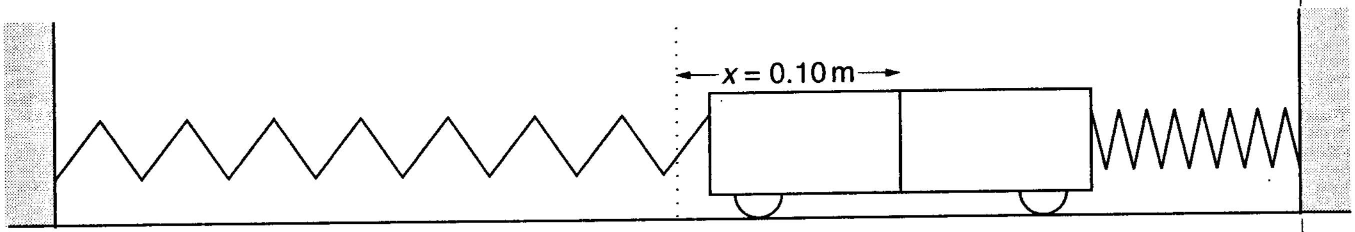

Fig. 9.2

(a) In Fig. 9.2, the resultant force on the trolley is 4.0 N to the left. Show that the spring constant of the system is $40\,\mathrm{N\,m^{-1}}$.

[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.

(i) Explain why the acceleration a is proportional to the displacement x for this spring/trolley system.

[2]

(ii) Explain the significance of the minus sign in the equation $a \propto -x$.

[2]

[Turn over

(c) A modelling program produced the graph of Fig. 9.3. 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.

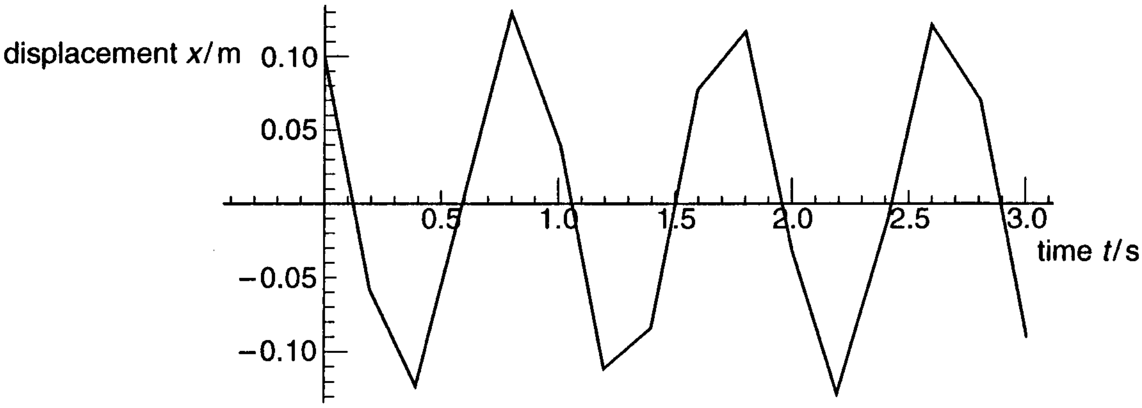

Fig. 9.3

Use the graph of Fig. 9.3 to estimate the period of the motion predicted by the model.

period = ... s [1]

(d) Theory gives the following equation for the period T of a spring/trolley system of mass m and spring constant k.

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

(i) Calculate the period of a spring/trolley system of mass 1.0 kg and spring constant 40 N m^{-1}.

period = ... s [2]

(ii) Suggest **one** reason why the value of the period T from the graph is different from the value of the period T calculated from the equation.

[1]

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

[2]

[Total: 11]

Quality of Written Communication [4]