Candidate Name	Centre Number					Candidate Number				
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A LEVEL

PHYSICS

A2 UNIT 3
Oscillations and Nuclei

SPECIMEN PAPER

(2 hours 15 minutes)

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1.**	12	
	2.	18	
	3.	8	
	4.	12	
	5.	8	
	6.	16	
	7	6	
Section B	**8.**	20	
	Total	100	

ADDITIONAL MATERIALS

In addition to this examination paper, you will require a calculator and a **Data Booklet**.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen.
Answer **all** questions.
Write your name, centre number and candidate number in the spaces at the top of this page. Write your answers in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

This paper is in 2 sections, **A** and **B**.
Section **A**: 80 marks. Answer **all** questions. You are advised to spend about 1 hour 35 minutes on this section.
Section **B**: 20 marks; Comprehension. You are advised to spend about 40 minutes on this section.

The number of marks is given in brackets at the end of each question or part-question.
The assessment of the quality of extended response (QER) will take place in question 8*(a).*

SECTION A
*Answer **all** questions*

1. *(a)* According to the kinetic theory of gases, the pressure, p, of a gas in a container of volume V is given by:

$$pV = \frac{1}{3}Nm\overline{c^2}$$

(i) State the meaning of: [1]

N ....

m ....

(ii) Hence show clearly that an equivalent form of the equation is: [2]

$$p = \frac{1}{3}\rho\overline{c^2}$$

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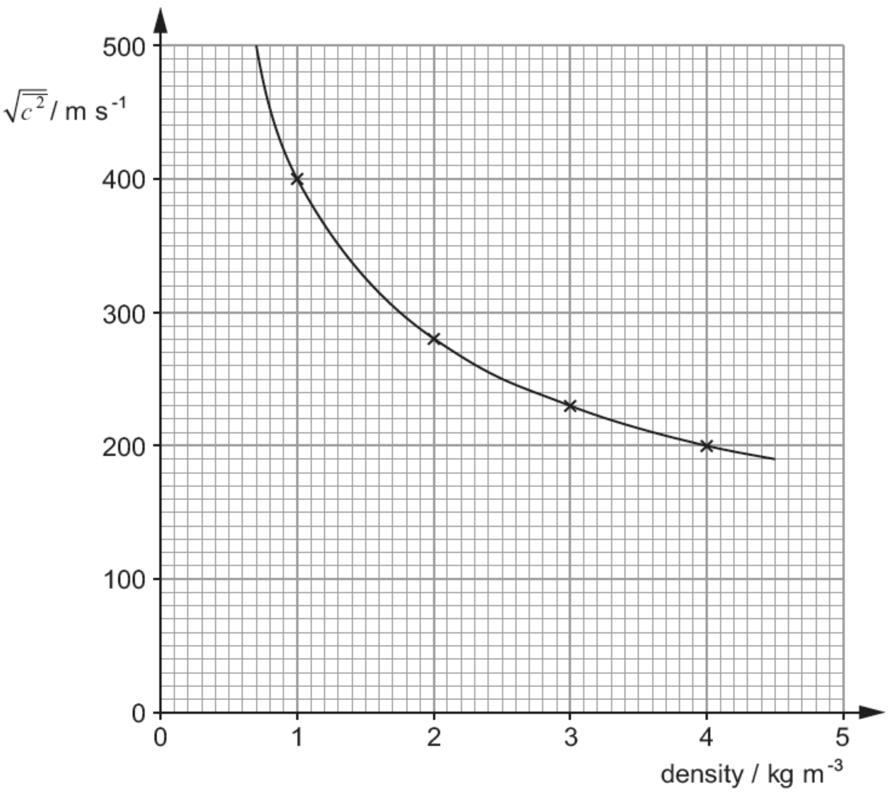
An experiment is carried out at constant pressure. The rms speed of molecules is obtained for gases of different density. The following results are obtained.



(iii) Explain briefly whether or not the results agree with the equation:

$$p = \tfrac{1}{3}\rho\overline{c^2}$$ [3]

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(b) A cylinder of volume 0.050 m^3 contains 0.025 kg of helium gas (relative molecular mass 4.00) at a pressure of 3.0×10^5 Pa. Calculate:

(i) the rms speed of the molecules; [2]

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(ii) the mean kinetic energy per molecule. [4]

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2. *(a)* In an electric storage heater, special bricks are heated overnight by passing electric current through wires embedded in the bricks. The bricks are surrounded by thermal insulation.

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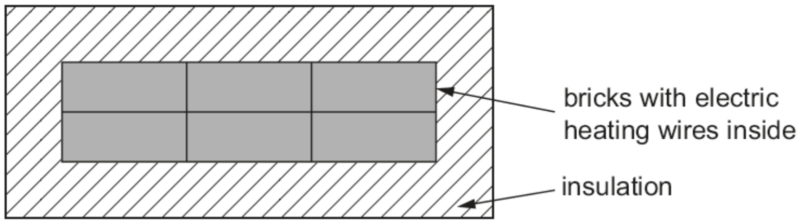

The wires convert energy at a rate of 2.0 kW for a time of 7.0 hours. During this time the temperature of the bricks rises from 20 °C to 320 °C. The total mass of the bricks is 84 kg and their specific heat capacity is 1 600 J kg^{-1} °C^{-1}.

The makers of the heater claim that less than a quarter of the energy supplied is given off as heat during the 7.0 hour overnight period. Investigate this claim, setting out your reasoning and calculations clearly. [6]

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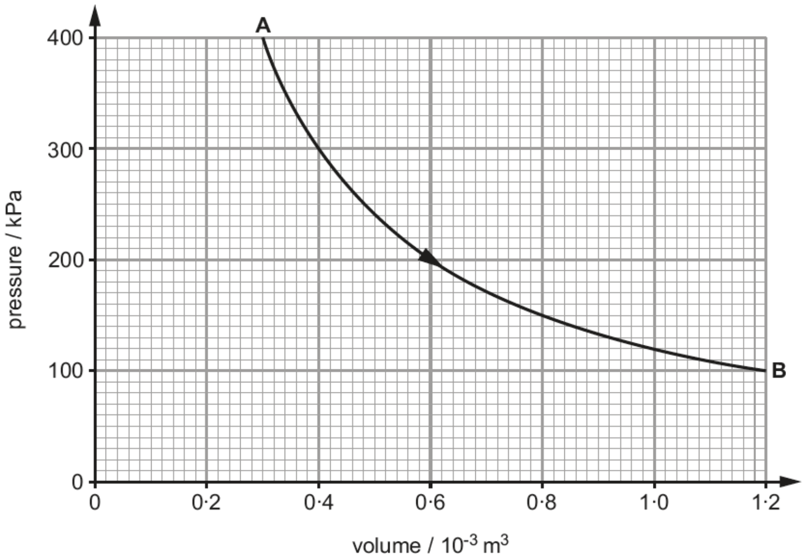
(b) 0.050 mole of helium gas is contained in a cylinder fitted with a leak-proof piston. The piston moves slowly outwards, resulting in the variation of pressure shown in the graph.



(i) Verify that the temperature of the gas does not change, and calculate this temperature. Evaluate to what extent the curve is a true isothermal. [5]

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(ii) By approximating the curve on the graph to a straight line, or by any other method, calculate approximately how much work is done by the gas as it expands from A to B, explaining whether your result is likely to be too high or too low. [4]

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(iii) The first law of thermodynamics may be written as:

$$\Delta U = Q - W$$

State the meanings of: [1]

ΔU ....

Q ....

W ....

(iv) State the values of these terms (ΔU, Q, W) for the expansion AB (your answer to *(b)*(ii) should be one of these. [2]

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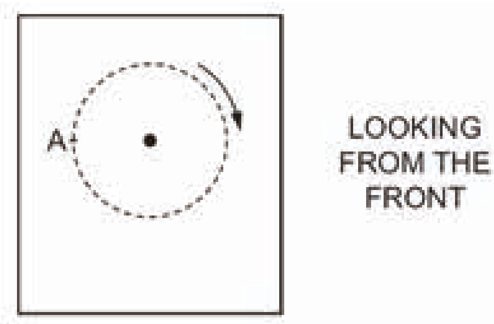
3. The drum of a washing machine is a hollow perforated cylinder with an inside radius of 0.45 m. On its 'spin cycle' it rotates (about the axis of the cylinder) at a rate of 2 400 revolutions per minute.



(a) Calculate the angular velocity of the drum in radians per second. [2]

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(b) (i) Calculate the force that must act on a wet sock of mass 0.080 kg in contact with the cylinder wall. Neglect gravitational forces. [2]

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(ii) Investigate whether or not it is justifiable to neglect gravitational forces. [2]

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(c) (i) State the direction of the force on the sock. [1]

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(ii) A water drop escapes through a hole in the cylinder at A. **Draw on the diagram** the first part of the path of the drop when it is free of the cylinder. [1]

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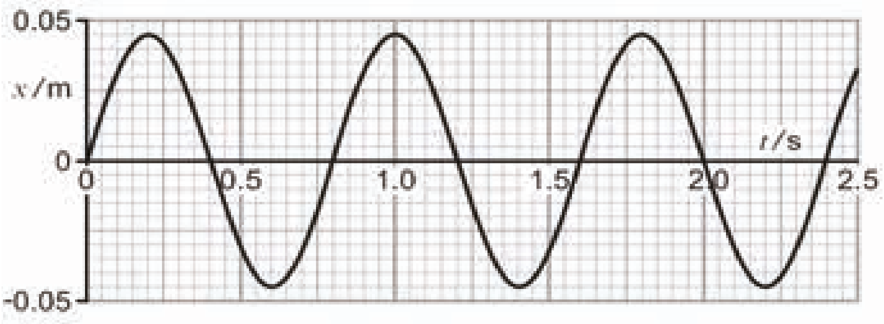
4. A graph of displacement (x) against time (t) is given for a body performing simple harmonic motion in a vertical direction.



(a) Consider the body at a time of 0.10 s. Use the graph to determine the next time at which the body achieves the same:

(i) speed; .... [1]

(ii) velocity. .... [1]

(b) The relationship between x and t is of the form: $x = A\sin(\omega t + \varepsilon)$. Use the graph to determine the values of:

(i) A .... [1]

(ii) ω .... [2]

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(iii) ε .... [1]

(c) (i) **Sketch, on the same grid** as the graph above, a graph of acceleration against time for the body. No scale is needed on the vertical (acceleration) axis. [2]

(ii) A grain of sand is placed on top of the body when it is at its lowest point. Investigate whether or not it will separate from the body as it oscillates. [4]

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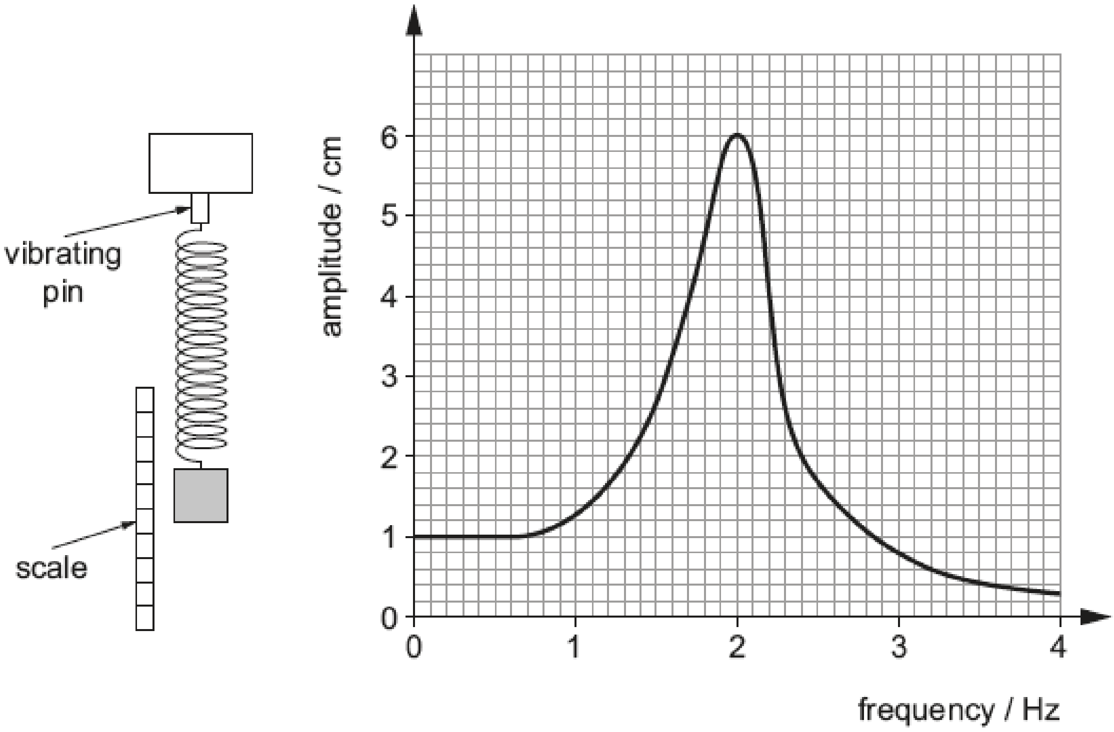
5. A helical spring, loaded with a mass of 0.10 kg, hangs from the moving pin of a vibration generator which is powered by a signal generator. The amplitude of the (vertical) oscillations of the mass is measured at several frequencies of the vibration generator. The results are shown in the graph.



(a) Explain what is meant by resonance in a mechanical system. [2]

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(b) Determine the spring stiffness, k (the force per unit extension). [4]

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(c) Suppose that the experiment were now to be repeated with greater damping on the mass-spring system. Sketch on the same grid a possible new graph of amplitude against frequency. [2]

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6. Radon gas ($^{222}_{86}\mathrm{Ra}$) is radioactive and can be a significant health hazard in some areas of Mid Wales that have a high natural concentration of the gas. Radon decays to a stable form of lead (Pb) via 4 alpha decays and 4 beta decays and radon has a half-life of 3.8 days.

(a) (i) Calculate the mass number and atomic number of this stable isotope of lead (Pb). [2]

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(ii) Radon gas is known to be carcinogenic because it caused increased cancer rates in an experiment carried out on rats. State some benefits and ethical issues related to this experiment. [3]

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(b) Calculate the time taken for the number of radon gas particles to decrease to 9.0% of their initial number. [4]

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(c) When radon gas is kept in a lead lined container for 3.8 days, the number of radon gas particles halves. However, the activity inside the container is considerably higher than half the original activity. Suggest a reason why. [1]

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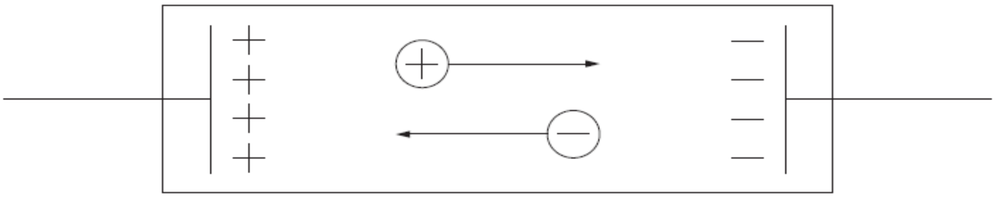
(d) The radon gas produces 250 alpha particles in a detector per second. Each of these alpha particles produces 1.15×10^6 ionised molecules on average. These ions provide a current between the plates. Calculate this current, stating any assumption that you make. [3]



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(e) $$^{222}_{86}\text{Ra} \rightarrow {}^{218}_{84}\text{Po} + {}^{4}_{2}\text{He} + 5.59\,\text{MeV}$$

When a radon-222 nucleus emits an alpha particle the energy emitted in the reaction is 5.59 MeV. Calculate the mass of a polonium-218 nucleus to 7 significant figures. [3]

(mass of $^{222}_{86}\text{Ra}$ nucleus = 221.9773 u; mass of $^{4}_{2}\text{He}$ nucleus = 4.0015 u;
1 u = 931 MeV)

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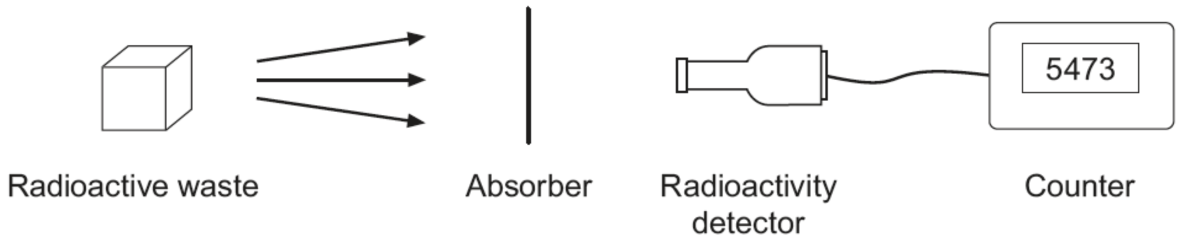
7. A student devises an experiment to determine which radiations α, β, and γ are emitted by a sample of radioactive waste. The student measures and records the detected count rate using the set-up below.



The results obtained are summarised in the table.

Absorber	**Count rate / s^{-1}**
None	8 894
3 sheets of paper	5 473
None	8 921
0.5 mm of aluminium foil	5 455
None	8 860
10 cm of lead	439
None	8 888

(a) Explain which types of radiation are present in the radioactive waste. [4]

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(*b*) Suggest two reasons why the student measured the count rate without an absorber several times. [2]

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SECTION B
*Answer **all** questions*

Read through the following article carefully.

Freely adapted from:

What If I Double It?
By Thomas Humphrey

Why does size matter?

To find out more, let's cook a turkey.

Suppose you are responsible for cooking a turkey. You have a 9 kg turkey, but your cookbook only tells you how long it takes to cook a 4·5 kg turkey.

How long do you cook your turkey?

Since the 9 kg turkey is twice the size of a 4·5 kg bird, at first the answer might seem obvious. Simply double the cooking time suggested for a 4·5 kg turkey. But is that really the right thing to do?

The way I see it, there are three ways to answer this question:

(a) you can call and ask your grandmother;
(b) you can get a new cookbook;
(c) you can thumb through your physics books for the turkey equation.

I began by gathering cookbook data. My cookbook says that when you double the weight of a turkey, you don't have to double the cooking time. You only have to increase it from 4 hours for the small bird to 6 ½ hours for the big one. So even though the 9 kg turkey is twice the weight of the 4·5 kg turkey, you only have to cook it about 1·6 times as long. Why would that be?

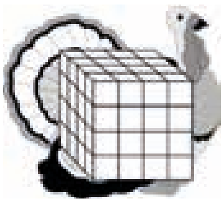
Let's take a more detailed look at our question. What is the "it" that we are doubling? What kind of "its" does a turkey have?

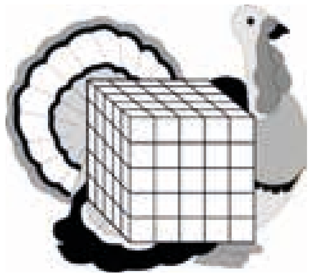
The turkey has a width, a surface area, a volume, and a weight. It has a density, a thermal conductivity (how well it transfers the oven's heat into its interior), and a specific heat capacity (how much heat it needs to climb one degree Celsius in temperature). A turkey has a lot of "its." How do some of these factors change in going from a 4·5 kg turkey to a 9 kg turkey?

Let's imagine that my turkey is shaped like a cube. This will make it easier to see how the various factors change.

Take a look at the cubical turkeys on the next page. Try to figure out how the weight, surface area, and width differ. If you count the number of small cubes in the 4·5 kg turkey, you will find that there are 4 × 4 × 4, or 64 cubes. The number of cubes in the 9 kg turkey is 5 × 5 × 5, or 125 cubes. That's not exactly double, but it's pretty close. So now we know that the 9 kg cube turkey is about twice the volume of the 4·5 kg cube turkey (that is, it has twice as many little cubes), and therefore it weighs about twice as much.

But when you double the size of a turkey, what happens to its width and surface area? Do they double, too?





If you look at the cube turkeys above, you can see that the widths of the two turkeys are 4 and 5 blocks respectively. So the bigger turkey is about 25 percent wider than the smaller one. It did not double.

If we look at surface area, the small turkey has 6 sides × 16 blocks per side, or 96 blocks. The surface area of the big turkey has 6 sides × 25 blocks per side, or 150 blocks. That means the big turkey has about 50 percent more blocks in it than the small turkey. So that measurement didn't double, either. More precisely, on a real turkey, the width and all the other linear dimensions increase by a factor of 1·26 and the surface area increase by a factor of 1·59.

How do some of these "its" – weight, surface area, and thickness – influence the turkey's cooking time?

Well, first of all, the 9 kg turkey, because it has doubled in volume, has twice as much stuff (including stuffing) to heat up, so we need to put twice as much heat into it. Fair enough. How does the heat get in? It is transferred across the surface of the turkey, and it must travel all the way into the centre of the bird. The bigger turkey has more surface. That should speed up the transfer of heat, but the heat must travel a longer way to the centre. That will slow things down. The net result is that it doesn't take twice as long to cook the twice-as-heavy turkey. The physicists agree with the home economist.

Increase in cooking time If you put the three factors together, the cooking time increases by 2 × 0·63 × 1·26 = 1·59. (4 hrs. × 1·59 = 6·4 hrs.) My cook book says to increase the time to 6·5 hours, or by a factor of 1·62. (6·5 hrs. / 4 hrs. = 1·62). That's pretty close!

So now we know how to cook a turkey. But in this little foray into the physics of cooking we discovered that the seemingly innocuous question, "What happens if you double it?" has turned out to be quite complex. We must be very specific about which feature of the turkey we are doubling because we don't seem to be able to double everything at once!

The fact that we cannot double every feature of the turkey at the same time is one example of a very general behaviour in nature, a behaviour that leads to consequences even more important than the difference between a perfect turkey and an overcooked one. When we compare similar objects, one large and one small, not all features of the object are magnified or reduced by the same ratio. This has dramatic consequences for natural behaviour.

8. Answer the following questions in your own words. Direct quotes from the original article will not be awarded marks.

   (a) Explain how the three factors of weight (mass), surface area, and thickness affect the cooking time of the turkey. Include in your answers scientific reasons for these variations (see lines 42-47). [6 QER]

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   (b) An important factor is missing from the explanation of specific heat capacity. Modify the statement to make it accurate (lines 21-22). [1]

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   (c) The smaller (4.5 kg) turkey has a width of 22 cm. Calculate the width of the larger (9.0 kg) turkey (lines 36-40). [1]

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   (d) The larger turkey (9.0 kg) has a surface area of 0.46 m^2. Calculate the surface area of the smaller (4.5 kg) turkey (lines 36-40). [1]

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(e) The turkeys are considered to be cooked when their mean temperature has risen 90 ^{o}C.

(i) How much thermal energy does this require for the 9.0 kg turkey? (Specific heat capacity of turkey = 3 200 J kg ^{o}C^{-1}.) [2]

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(ii) The electrical power supplied to the cooking oven was 2 200 W. If all this energy was transferred as thermal energy to the turkey, how long should the 9.0 kg turkey have taken to cook? [2]

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(iii) Why is there such a large difference between the answer to *(e)*(ii) and the time given in the passage? [2]

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(iv) Determine the efficiency of the cooking process for the 9.0 kg turkey. [2]

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(v) Would you expect the efficiency of the cooking process for the 4.5 kg turkey to be greater than, less than or the same as that of the 9.0 kg turkey? Justify your answer using data from the article. [3]

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