Diploma Programme
Programme du diplôme
Programa del Diploma

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Physics
Higher level
Paper 2

Thursday 28 April 2022 (morning)

Candidate session number

2 hours 15 minutes

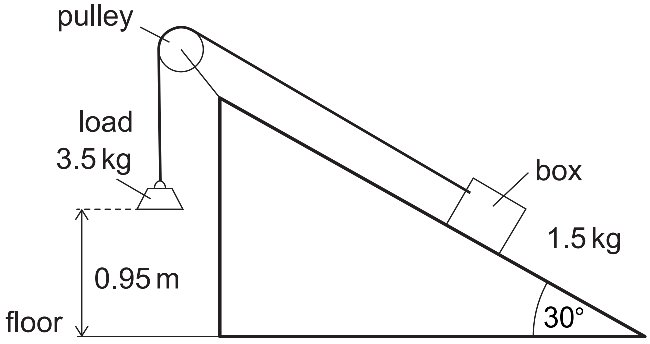
Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Answers must be written within the answer boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[90 marks]**.

2222 – 6508

Answer **all** questions. Answers must be written within the answer boxes provided.

1. A student uses a load to pull a box up a ramp inclined at 30°. A string of constant length and negligible mass connects the box to the load that falls vertically. The string passes over a pulley that runs on a frictionless axle. Friction acts between the base of the box and the ramp. Air resistance is negligible.



The load has a mass of 3.5 kg and is initially 0.95 m above the floor. The mass of the box is 1.5 kg.

The load is released and accelerates downwards.

(a) Outline **two** differences between the momentum of the box and the momentum of the load at the same instant. [2]

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(b) The vertical acceleration of the load downwards is $2.4\,m\,s^{-2}$.

Calculate the tension in the string. [2]

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(Question 1 continued)

(c) Show that the speed of the load when it hits the floor is about $2.1\,m\,s^{-1}$. [2]

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(d) After the load has hit the floor, the box travels a further 0.35 m along the ramp before coming to rest. Determine the average frictional force between the box and the surface of the ramp. [4]

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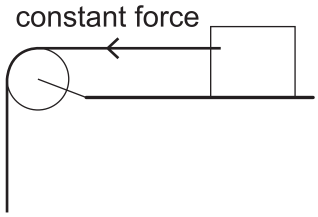
(Question 1 continued)

(e) The student then makes the ramp horizontal and applies a constant horizontal force to the box. The force is just large enough to start the box moving. The force continues to be applied after the box begins to move.



Explain, with reference to the frictional force acting, why the box accelerates once it has started to move. [3]

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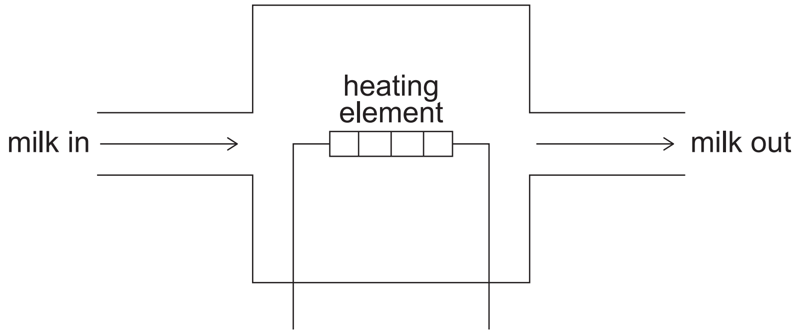
2. Cold milk enters a small sterilizing unit and flows over an electrical heating element.



The temperature of the milk is raised from 11 °C to 84 °C. A mass of 55 g of milk enters the sterilizing unit every second.

Specific heat capacity of milk = $3.9\,\text{kJ}\,\text{kg}^{-1}\,\text{K}^{-1}$

(a) Estimate the power input to the heating element. State an appropriate unit for your answer. [2]

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(b) Outline whether your answer to (a) is likely to overestimate or underestimate the power input. [2]

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(c) Discuss, with reference to the molecules in the liquid, the difference between milk at 11 °C and milk at 84 °C. [2]

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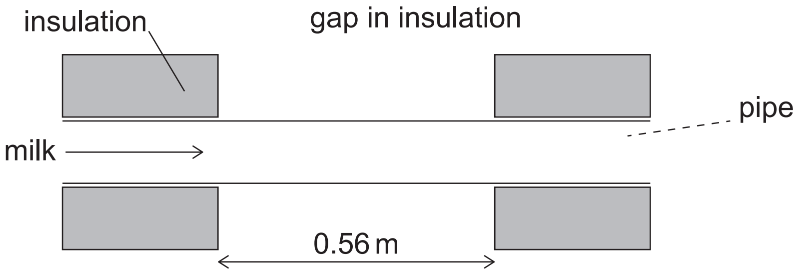
(Question 2 continued)

(d) The milk flows out through an insulated metal pipe. The pipe is at a temperature of 84 °C. A small section of the insulation has been removed from around the pipe.

diagram not to scale



(i) State how energy is transferred from the inside of the metal pipe to the outside of the metal pipe. [1]

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(ii) The missing section of insulation is 0.56 m long and the external radius of the pipe is 0.067 m. The emissivity of the pipe surface is 0.40. Determine the energy lost every second from the pipe surface. Ignore any absorption of radiation by the pipe surface. [3]

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(iii) Describe **one** other method by which significant amounts of energy can be transferred from the pipe to the surroundings. [2]

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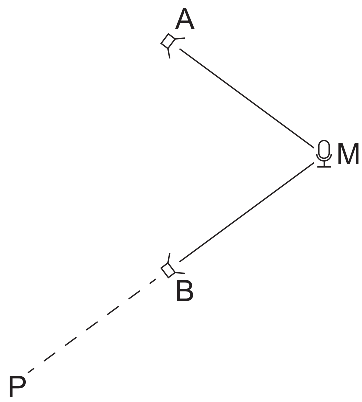
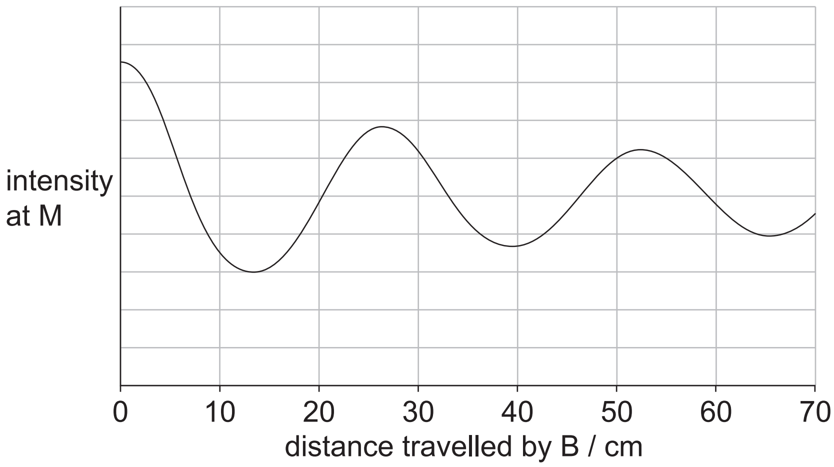
3. Two loudspeakers A and B are initially equidistant from a microphone M. The frequency and intensity emitted by A and B are the same. A and B emit sound in phase. A is fixed in position.



B is moved slowly away from M along the line MP. The graph shows the variation with distance travelled by B of the received intensity at M.



(a) Explain why the received intensity varies between maximum and minimum values. [3]

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(Question 3 continued)

(b) State and explain the wavelength of the sound measured at M. [2]

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(c) B is placed at the first minimum. The frequency is then changed until the received intensity is again at a maximum.

Show that the lowest frequency at which the intensity maximum can occur is about 3 kHz.

Speed of sound $= 340\,\text{m s}^{-1}$ [2]

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(d) Loudspeaker A is switched off. Loudspeaker B moves away from M at a speed of $1.5\,\text{m s}^{-1}$ while emitting a frequency of 3.0 kHz.

Determine the difference between the frequency detected at M and that emitted by B. [2]

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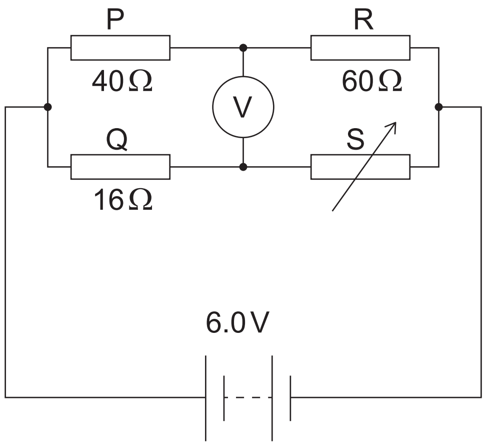
4. A power supply is connected to three resistors P, Q and R of fixed value and to an ideal voltmeter. A variable resistor S, formed from a solid cylinder of conducting putty, is also connected in the circuit. Conducting putty is a material that can be moulded so that the resistance of S can be changed by re-shaping it.



The resistance values of P, Q and R are 40 Ω, 16 Ω and 60 Ω respectively. The emf of the power supply is 6.0 V and its internal resistance is negligible.

(a) Calculate the potential difference across P. [2]

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(b) The voltmeter reads zero. Determine the resistance of S. [3]

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(Question 4 continued)

(c) All the putty is reshaped into a solid cylinder that is four times longer than the original length.

(i) Deduce the resistance of this new cylinder when it has been reshaped. [3]

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(ii) Outline, without calculation, the change in the total power dissipated in Q and the new cylinder after it has been reshaped. [2]

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5. (a) Describe the quark structure of a baryon. [2]

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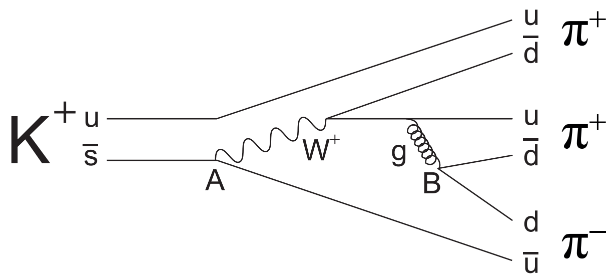
(b) The Feynman diagram shows a possible decay of the K^+ meson.



Identify the interactions that are involved at points A and B in this decay. [2]

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(c) The K^+ meson can decay as

$$K^+ \rightarrow \mu^+ + \nu_\mu.$$

State and explain the interaction that is responsible for this decay. [2]

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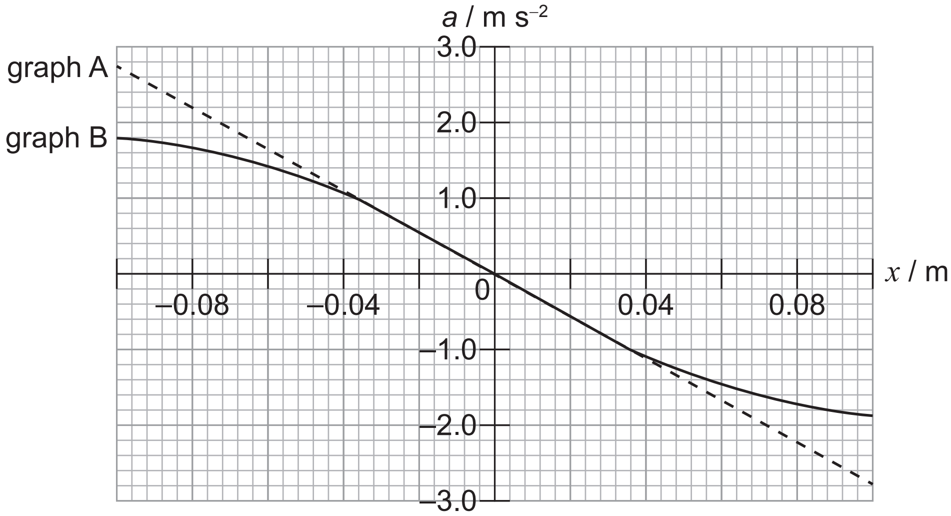
6. A mass–spring system oscillates horizontally on a frictionless surface. The mass has an acceleration *a* when its displacement from its equilibrium position is x.

The variation of *a* with x is modelled in two different ways, A and B, by the graphs shown.



(a) Outline **two** reasons why both models predict that the motion is simple harmonic when *a* is small. [2]

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(b) Determine the time period of the system when *a* is small. [4]

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(Question 6 continued)

(c) Outline, without calculation, the change to the time period of the system for the model represented by graph B when *a* is large. [2]

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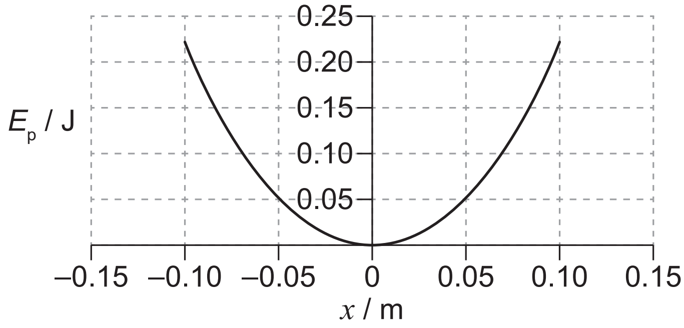
(d) The graph shows for model A the variation with x of elastic potential energy E_p stored in the spring.



Describe the graph for model B. [2]

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7. Two identical positive point charges X and Y are placed 0.30 m apart on a horizontal line. O is the point midway between X and Y. The charge on X and the charge on Y is +4.0 μC.

(a) Calculate the electric potential at O. [3]

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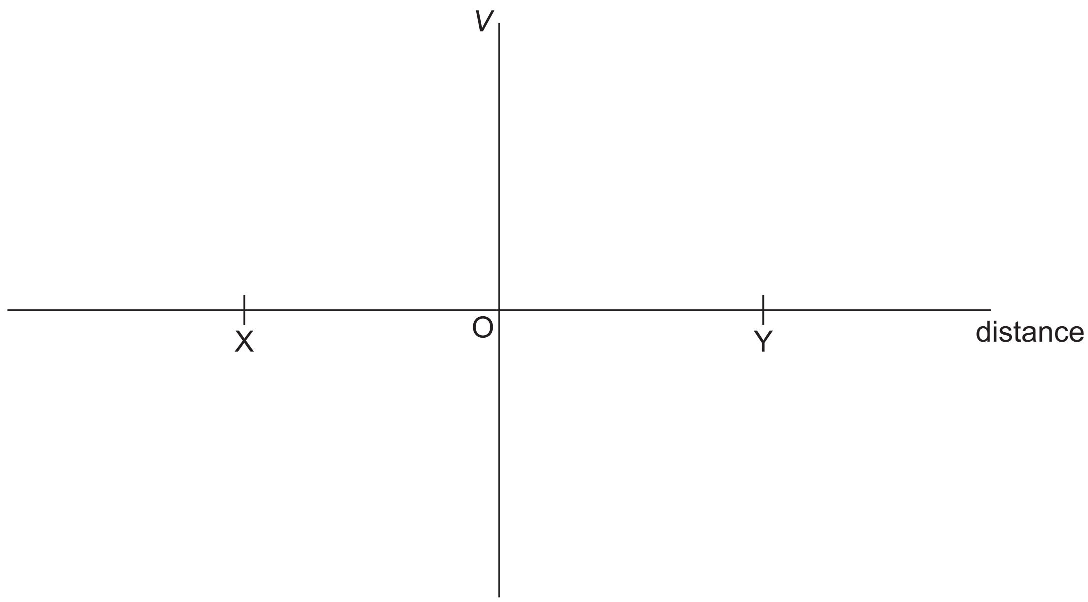
(b) Sketch, on the axes, the variation of the electric potential V with distance between X and Y. [2]



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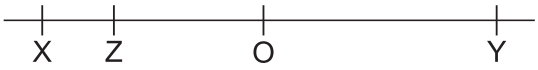
(Question 7 continued)

(c) A positive charge Z is released from rest 0.010 m from O on the line between X and Y. Z then begins to oscillate about point O.



(i) Identify the direction of the resultant force acting on Z as it oscillates. [2]

(ii) Deduce whether the motion of Z is simple harmonic. [2]

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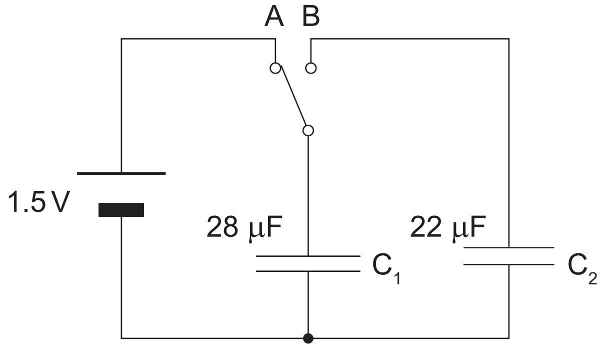
8. Two capacitors C_1 and C_2 of capacitance 28 μF and 22 μF respectively are connected in a circuit with a two-way switch and a cell of emf 1.5 V with a negligible internal resistance. The capacitors are initially uncharged. The switch is then connected to position A.



(a) Show that the charge stored on C_1 is about 0.04 mC. [1]

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(b) The switch is moved to position B.

(i) Calculate the energy transferred from capacitor C_1. [4]

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(ii) Explain why the energy gained by capacitor C_2 differs from your answer in (b)(i). [1]

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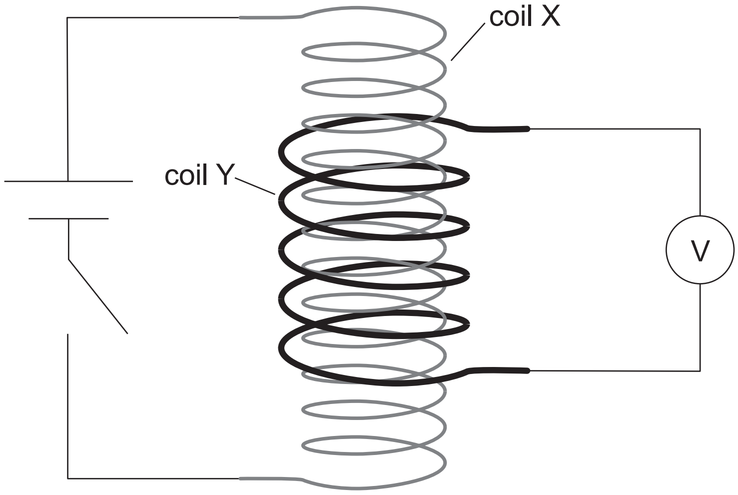
(Question 8 continued)

(c) A cell is now connected by a switch to a coil X. A second coil Y of cross-sectional area $6.4\,cm^2$ with 5 turns is looped around coil X and connected to an ideal voltmeter.



(i) The switch is closed at time $t = 0$. Explain how the voltmeter reading varies after the switch is closed. [2]

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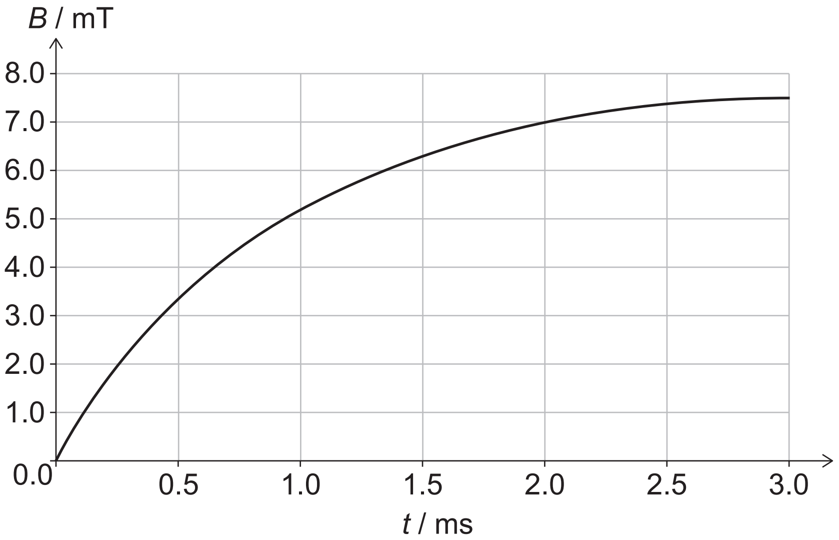
(Question 8 continued)

The graph shows the variation with t of the magnetic flux density B in coil Y.



(ii) Determine the average emf induced across coil Y in the first 3.0 ms. [3]

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9. Potassium-40 ($^{40}_{19}K$) decays by two processes.

The first process is that of beta-minus (β^-) decay to form a calcium (Ca) nuclide.

(a) Write down the equation for this decay. [2]

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(b) Potassium-40 decays by a second process to argon-40. This decay accounts for 11 % of the total decay of the potassium-40.

Rocks can be dated by measuring the quantity of argon-40 gas trapped in them. One rock sample contains 340 μmol of potassium-40 and 12 μmol of argon-40.

(i) Show that the initial quantity of potassium-40 in the rock sample was about 450 μmol. [2]

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(ii) The half-life of potassium-40 is 1.3×10^9 years. Estimate the age of the rock sample. [3]

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(Question 9 continued)

(c) Outline how the decay constant of potassium-40 was determined in the laboratory for a pure sample of the nuclide. [3]

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References:

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