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PHYSICS
STANDARD LEVEL
PAPER 2

Candidate session number

Wednesday 7 May 2014 (morning)

1 hour 15 minutes

Examination code

2	2	1	4	–	6	5	1	1

INSTRUCTIONS TO CANDIDATES

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all questions.
- Section B: answer one question.
- Write your answers in the 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 *[50 marks]*.

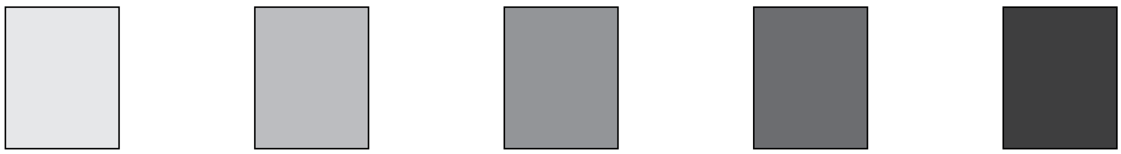
28 pages

SECTION A

Answer ***all*** *questions. Write your answers in the boxes provided.*

1. Data analysis question.

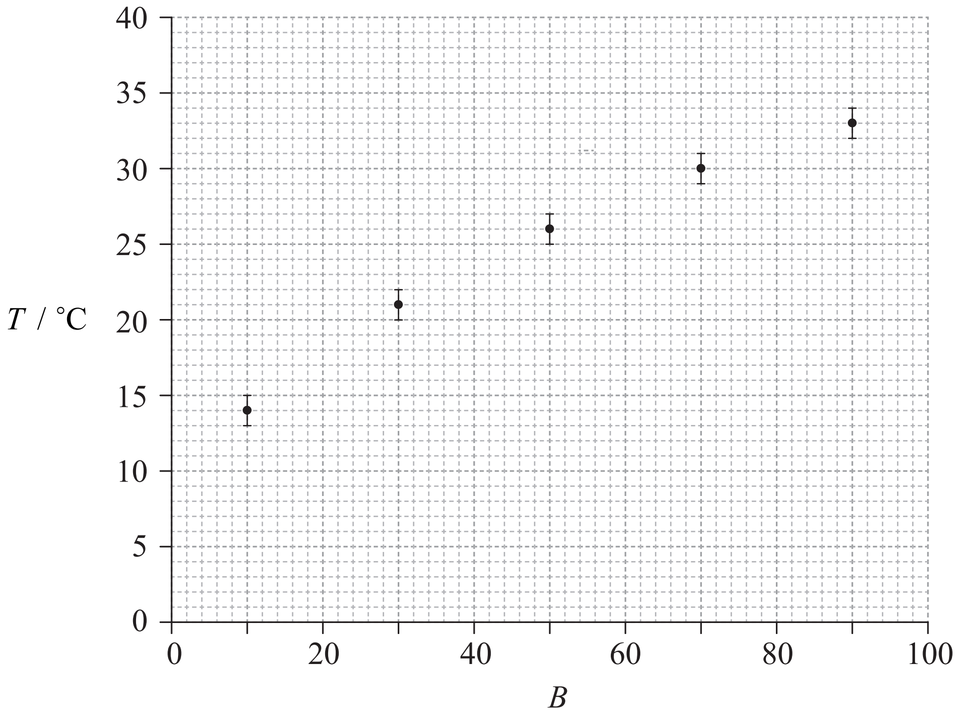
Connie and Sophie investigate the effect of colour on heat absorption. They make grey paint by mixing black and white paint in different ratios. Five identical tin cans are painted in five different shades of grey.



10 % black paint 30 % black paint 50 % black paint 70 % black paint 90 % black paint

Connie and Sophie put an equal amount of water at the same initial temperature into each can. They leave the cans under a heat lamp at equal distances from the lamp. They measure the temperature increase of the water, T, in each can after one hour.

(a) Connie suggests that T is proportional to B, where B is the percentage of black in the paint. To test this hypothesis, she plots a graph of T against B, as shown on the axes below. The uncertainty in T is shown and the uncertainty in B is negligible.



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(Question 1 continued)

(i) State the value of the absolute uncertainty in T. *[1]*

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(ii) Comment on the fractional uncertainty for the measurement of T for $B=10$ and the measurement of T for $B=90$. *[2]*

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(iii) On the graph opposite, draw a best-fit line for the data. *[1]*

(iv) Outline why the data do not support the hypothesis that T is proportional to B. *[2]*

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(This question continues on the following page)

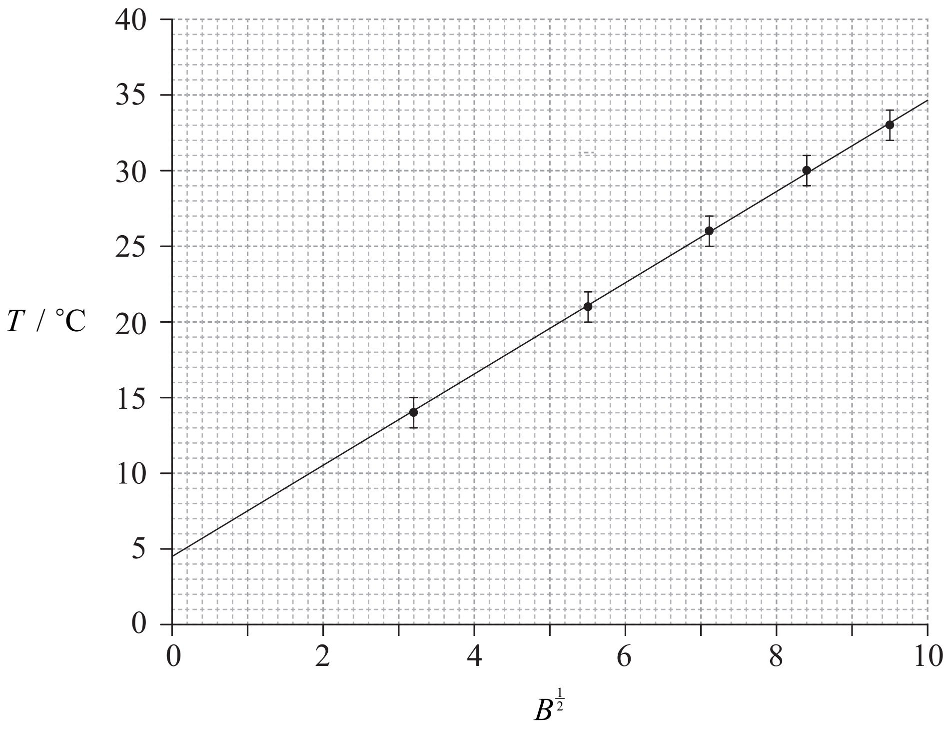
(Question 1 continued)

(b) Sophie suggests that the relationship between T and B is of the form

$$T = kB^{\frac{1}{2}} + c$$

where k and c are constants.

To test whether or not the data support this relationship, a graph of T against $B^{\frac{1}{2}}$ is plotted as shown below. The uncertainty in T is shown and the uncertainty in $B^{\frac{1}{2}}$ is negligible.



(i) Use the graph to determine the value of c with its uncertainty. *[4]*

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(This question continues on the following page)

(Question 1 continued)

(ii) State the unit of *k*. *[1]*

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2. This question is about a tidal power station.

A tidal power station is built for a coastal town. Sea water is stored in a tidal basin behind a dam at high tide and released in a controlled manner between high tides, so that it passes through turbines to generate electricity.

The following data are available.

Difference between high and low tide water level	$= 1.8\,\text{m}$
Density of sea water	$= 1.1\times10^{3}\,\text{kg}\,\text{m}^{-3}$
Surface area of basin	$= 1.4\times10^{5}\,\text{m}^{2}$
Overall efficiency of power station	$= 24\,\%$

(a) (i) Show that the mass of sea water released between successive high and low tides is about $2.8\times10^{8}\,\text{kg}$. *[2]*

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(ii) Calculate the electrical energy produced between successive high and low tides. *[3]*

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(Question 2 continued)

(b) (i) Identify **one** mechanism through which energy is transferred to the surroundings during the electricity generation process. *[1]*

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(ii) State why the energy transferred to the surroundings is said to be degraded. *[1]*

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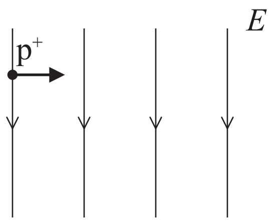
3. This question is about electric and magnetic fields.

A proton travelling to the right with horizontal speed $1.6 \times 10^{4}\,\text{m}\,\text{s}^{-1}$ enters a uniform electric field of strength E. The electric field has magnitude $2.0 \times 10^{3}\,\text{N}\,\text{C}^{-1}$ and is directed downwards.



(a) Calculate the magnitude of the electric force acting on the proton when it is in the electric field. *[2]*

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(b) A uniform magnetic field is applied in the same region as the electric field. A second proton enters the field region with the same velocity as the proton in (a). This second proton continues to move horizontally.

(i) Determine the magnitude and direction of the magnetic field. *[3]*

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(Question 3 continued)

(ii) An alpha particle enters the field region at the same point as the second proton, moving with the same velocity. Explain whether or not the alpha particle will move in a straight line. *[2]*

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SECTION B

This section consists of three questions: 4, 5 and 6. Answer ***one*** *question. Write your answers in the boxes provided.*

4. This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	7.0×10^{8} m
Surface temperature of Sun	T	5.8×10^{3} K
Distance from Sun to Earth	d	1.5×10^{11} m
Stefan-Boltzmann constant	σ	$5.7\times10^{-8}\,\text{W m}^{-2}\,\text{K}^{-4}$

(a) State the Stefan-Boltzmann law for a black body. *[2]*

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(b) Deduce that the solar power incident per unit area at distance d from the Sun is given by

$$\frac{\sigma R^2 T^4}{d^2}.$$ *[2]*

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(Question 4, part 1 continued)

(c) Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2]*

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(d) State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2]*

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2: . . . .

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(e) The average power absorbed per unit area at the Earth's surface is $240\,W\,m^{-2}$. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250 K. *[2]*

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(This question continues on the following page)

(Question 4, part 1 continued)

(f) Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3]*

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(g) Outline why the burning of fossil fuels may lead to an increase in the average surface temperature of the Earth. *[2]*

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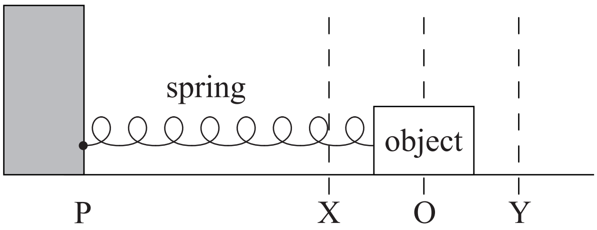
(Question 4 continued)

Part 2 A mass on a spring

An object is placed on a frictionless surface and attached to a light horizontal spring.



The other end of the spring is attached to a stationary point P. Air resistance is negligible. The equilibrium position is at O. The object is moved to position Y and released.

(h) Outline the conditions necessary for the object to execute simple harmonic motion. *[2]*

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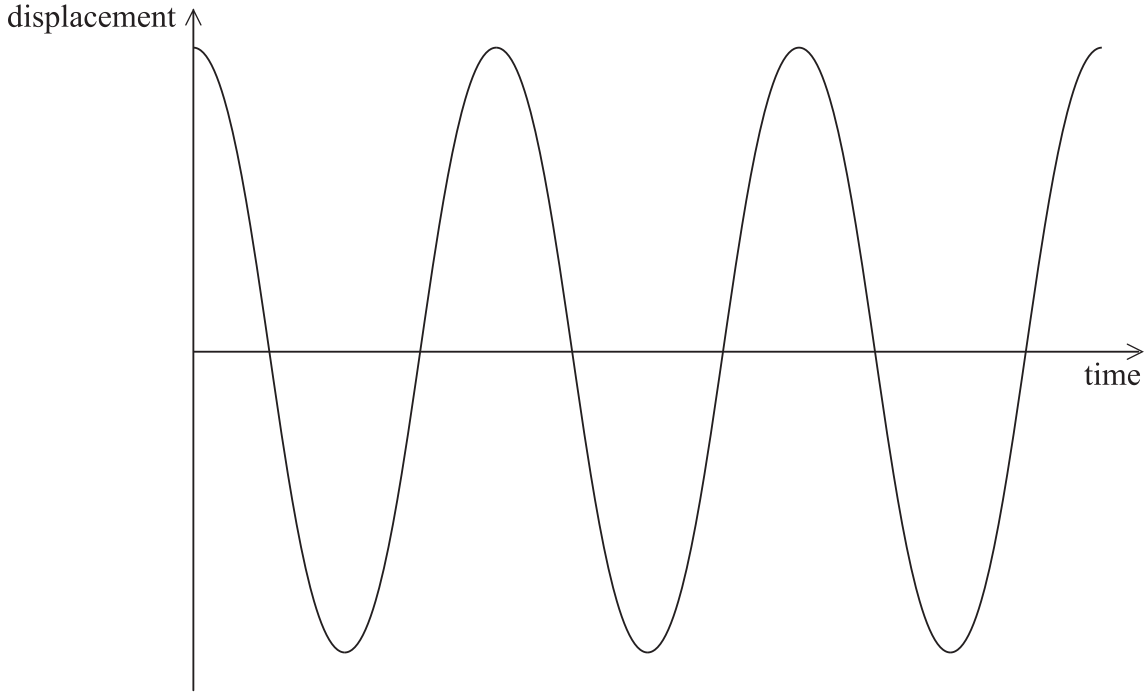
(Question 4, part 2 continued)

(i) The sketch graph below shows how the displacement of the object from point O varies with time over three time periods.



(i) Label with the letter A a point at which the magnitude of the acceleration of the object is a maximum. *[1]*

(ii) Label with the letter V a point at which the speed of the object is a maximum. *[1]*

(iii) Sketch on the same axes a graph of how the displacement varies with time if a **small** frictional force acts on the object. *[2]*

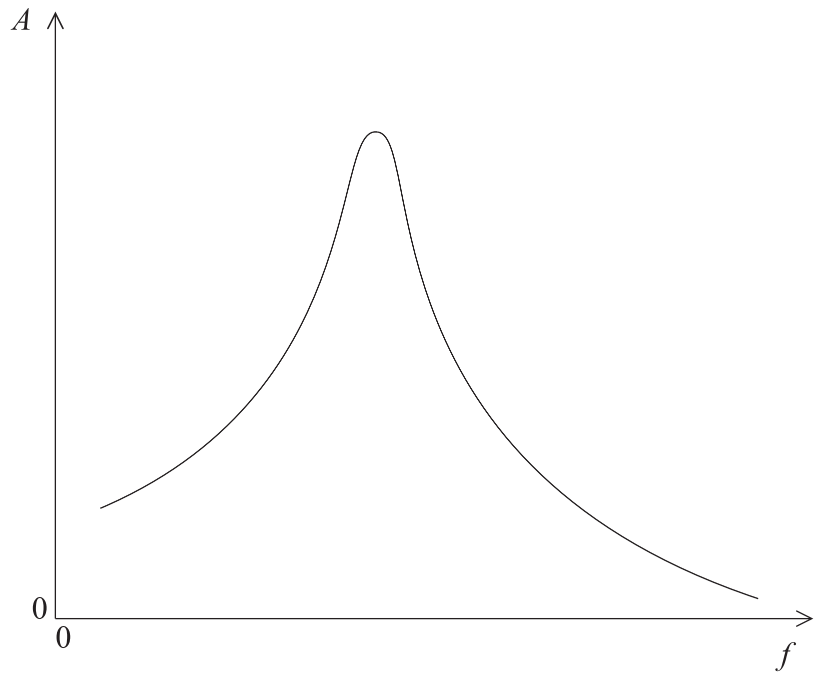
(This question continues on the following page)

(Question 4, part 2 continued)

(j) Point P now begins to move from side to side with a small amplitude and at a variable driving frequency *f*. The frictional force is still small.

At each value of *f*, the object eventually reaches a constant amplitude *A*.

The graph shows the variation with *f* of *A*.



(i) With reference to resonance and resonant frequency, comment on the shape of the graph. *[2]*

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(ii) On the same axes, draw a graph to show the variation with *f* of *A* when the frictional force acting on the object is increased. *[2]*

5. This question is in **two** parts. **Part 1** is about nuclear reactions. **Part 2** is about thermal energy transfer.

Part 1 Nuclear reactions

(a) (i) Define the term *unified atomic mass unit*. *[1]*

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(ii) The mass of a nucleus of einsteinium-255 is 255.09 u. Calculate the mass in $\text{MeV}\,c^{-2}$. *[1]*

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(b) Describe the phenomenon of artificial (induced) transmutation. *[2]*

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(c) When particle X collides with a stationary nucleus of calcium-40 (Ca-40), a nucleus of potassium (K-40) and a proton are produced.

$$^{40}_{20}\text{Ca} + \text{X} \rightarrow {}^{40}_{19}\text{K} + {}^{1}_{1}\text{p}$$

(This question continues on the following page)

(Question 5, part 1 continued)

The following data are available for the reaction.

Particle	**Rest mass / MeV c^{-2}**
calcium-40	37214.694
X	939.565
potassium-40	37216.560
proton	938.272

(i) Identify particle X. *[1]*

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(ii) Suggest why this reaction can only occur if the initial kinetic energy of particle X is greater than a minimum value. *[2]*

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(iii) Before the reaction occurs, particle X has kinetic energy 8.326 MeV. Determine the total combined kinetic energy of the potassium nucleus and the proton. *[3]*

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(Question 5, part 1 continued)

(d) Another isotope of potassium is potassium-38, which decays with a half-life of eight minutes.

(i) Define the term *radioactive half-life*. *[1]*

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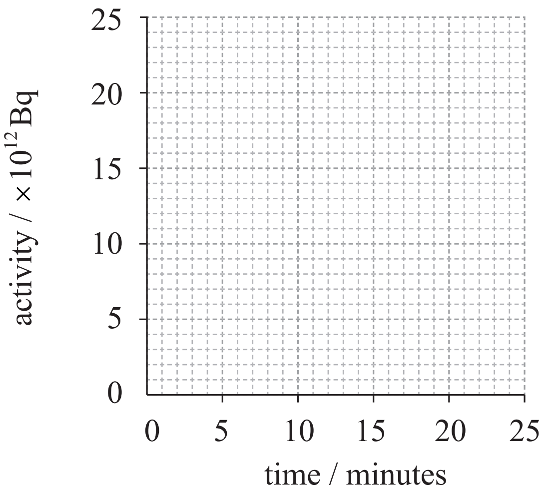
(ii) A sample of potassium-38 has an initial activity of 24×10^{12} Bq. On the axes below, draw a graph to show the variation with time of the activity of the sample. *[2]*



(iii) Determine the activity of the sample after 2 hours. *[2]*

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(Question 5 continued)

Part 2 Thermal energy transfer

(e) (i) Define the *specific latent heat* of fusion of a substance. *[2]*

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(ii) Explain, in terms of the molecular model of matter, the relative magnitudes of the specific latent heat of vaporization of water and the specific latent heat of fusion of water. *[3]*

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(Question 5, part 2 continued)

(f) A piece of ice is placed into a beaker of water and melts completely.

The following data are available.

Initial mass of ice	$= 0.020\,\text{kg}$
Initial mass of water	$= 0.25\,\text{kg}$
Initial temperature of ice	$= 0\,^{\circ}\text{C}$
Initial temperature of water	$= 80\,^{\circ}\text{C}$
Specific latent heat of fusion of ice	$= 3.3\times10^{5}\,\text{J}\,\text{kg}^{-1}$
Specific heat capacity of water	$= 4200\,\text{J}\,\text{kg}^{-1}\,\text{K}^{-1}$

(i) Determine the final temperature of the water. *[3]*

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(ii) State **two** assumptions that you made in your answer to part (f)(i). *[2]*

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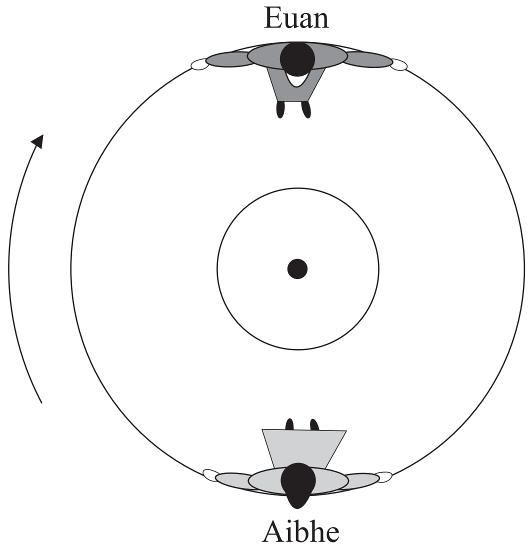
Please **do not** write on this page.

Answers written on this page
will not be marked.

6. This question is in **two** parts. **Part 1** is about two children on a merry-go-round. **Part 2** is about electric circuits.

Part 1 Two children on a merry-go-round

Aibhe and Euan are sitting on opposite sides of a merry-go-round, which is rotating at constant speed around a fixed centre. The diagram below shows the view from above.



Aibhe is moving at speed $1.0\,m\,s^{-1}$ relative to the ground.

(a) Determine the magnitude of the velocity of Aibhe relative to

(i) Euan. *[1]*

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(ii) the centre of the merry-go-round. *[1]*

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(This question continues on the following page)

(Question 6, part 1 continued)

(b) (i) Outline why Aibhe is accelerating even though she is moving at constant speed. *[2]*

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(ii) Draw an arrow on the diagram on page 22 to show the direction in which Aibhe is accelerating. *[1]*

(iii) Identify the force that is causing Aibhe to move in a circle. *[1]*

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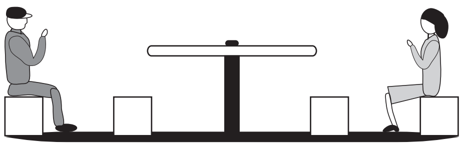
(iv) The diagram below shows a side view of Aibhe and Euan on the merry-go-round.



Explain why Aibhe feels as if her upper body is being "thrown outwards", away from the centre of the merry-go-round. *[2]*

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(Question 6, part 1 continued)

(c) Euan drags his foot along the ground to act as a brake. The merry-go-round comes to a stop after 4.0 rotations. The radius of the merry-go-round is 1.5 m. The average frictional force between his foot and the ground is 45 N. Calculate the work done. *[2]*

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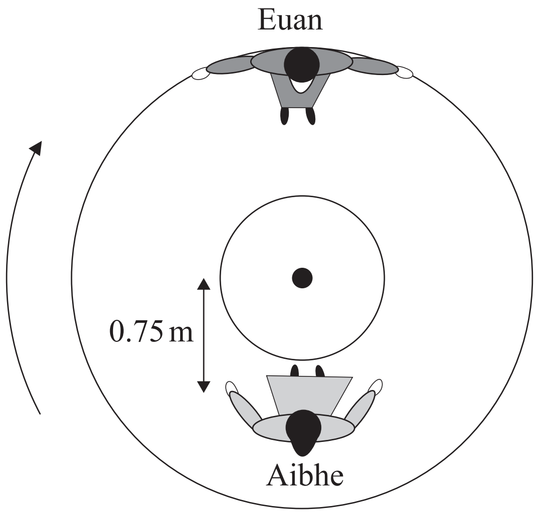
(Question 6, part 1 continued)

(d) Aibhe moves so that she is sitting at a distance of 0.75 m from the centre of the merry-go-round, as shown below.



Euan pushes the merry-go-round so that he is again moving at 1.0 m s^{-1} relative to the ground.

(i) Determine Aibhe's speed relative to the ground. *[3]*

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(ii) Calculate the magnitude of Aibhe's acceleration. *[2]*

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(Question 6 continued)

Part 2 Electric circuits

(e) Define the *electric resistance* of a wire. *[1]*

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(f) Using the following data, calculate the length of constantan wire required to make a resistor with a resistance of 6.0 Ω. *[3]*

Resistivity of constantan $= 5.0 \times 10^{-7}\,\Omega\,\text{m}$
Average radius of wire $= 2.5 \times 10^{-5}\,\text{m}$

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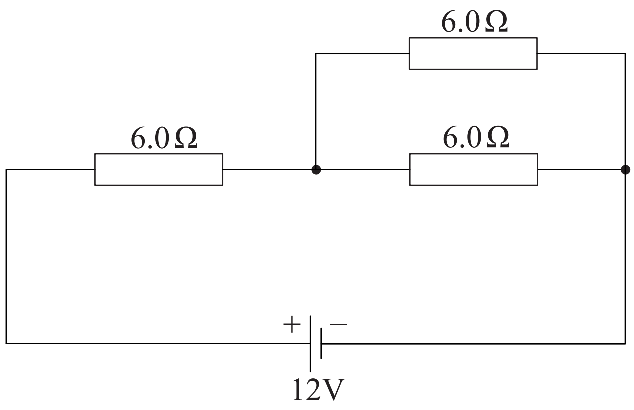
(Question 6, part 2 continued)

(g) Three resistors, each of resistance 6.0 Ω, are arranged in the circuit shown below. The cell has an emf of 12 V and negligible internal resistance.



Determine the total power supplied by the cell. *[3]*

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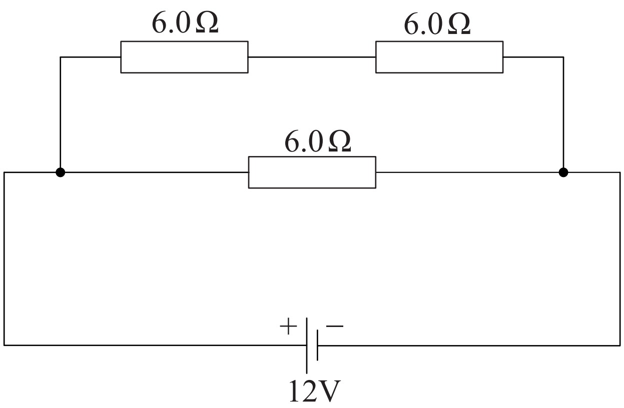
(Question 6, part 2 continued)

(h) The same resistors and cell are now re-arranged into a different circuit, as shown below.



Explain why the total power supplied by the cell is greater than for the circuit in (g). *[3]*

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