INTERNATIONAL BACCALAUREATE
BACCALAURÉAT INTERNATIONAL
BACHILLERATO INTERNACIONAL

PHYSICS
HIGHER LEVEL
PAPER 2

Monday 8 May 2000 (afternoon)

2 hours 15 minutes

Name

Number

INSTRUCTIONS TO CANDIDATES

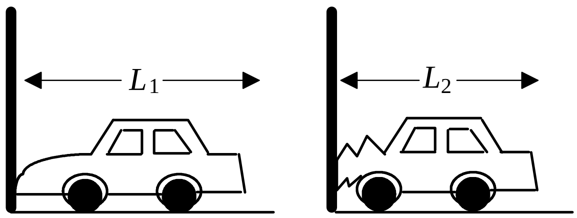
- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: Answer all of Section A in the spaces provided.
- Section B: Answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the Section B questions answered in the boxes below.

QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/35	/35	/35
SECTION B QUESTION QUESTION		 /30 /30	 /30 /30	 /30 /30
		TOTAL /95	TOTAL /95	TOTAL /95

SECTION A

*Candidates must answer **all** questions in the spaces provided.*

A1. This question is about finding the force that acts upon a car when it is in a head on collision.



In order to measure collision forces a car is crashed head-on into a flat, rigid barrier and the resulting crush distance d is measured. The crush distance is the amount that the car collapses in coming to rest. In the above diagram the crush distance $d = L_1 - L_2$.

(a) Show that the average crush force exerted on a car of mass m with impact speed v is equal to $\frac{mv^2}{2d}$. *[2]*

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(b) The table below gives values of the crush distance, d, for different impact speeds v, of cars of the same make. (Uncertainties in measurement are not given.)

$v\,/\,\mathrm{m\,s^{-1}}$	$d\,/\,\mathrm{m}$	$\frac{v^2}{d}\,/\,\mathrm{m\,s^{-2}}$
0	0	0
3.0	0.08	. . . .
10.0	0.35	. . . .
15.0	0.65	. . . .
20.0	1.02	. . . .

Complete the last column of the table. *[1]*

(This question continues on the following page)

(Question A1 continued)

(c) On the grid below plot a graph of $\frac{v^2}{d}$ against v. *[4]*

(d) Consider the situation in which a car of mass 1200 kg has an impact speed of 12 $m\,s^{-1}$. Use information from the graph you have drawn to find the average force exerted on the car during the collision as it is brought to rest. *[2]*

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(e) Calculate the time it takes this car to come to rest from the moment of impact. *[1]*

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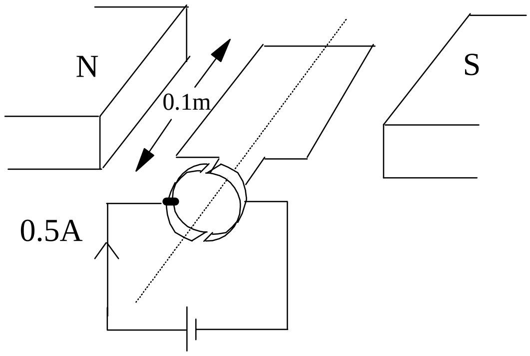
A2. This question is about the simple d.c. electric motor.

The diagram below shows a sketch of a simple d.c. electric motor.



(a) What is the direction of rotation of the armature coil? *[1]*

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(b) The loop is a square of side 0.1 m and is in an uniform magnetic field of strength 0.02 T. If the current in the loop is 0.5 A, calculate the torque acting on the loop when it is in the position shown in the diagram. *[2]*

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(c) It is noted that when the loop is first connected to the battery the initial current measured in the loop is greater than the current measured when the loop is rotating at a steady speed. Explain this. *[4]*

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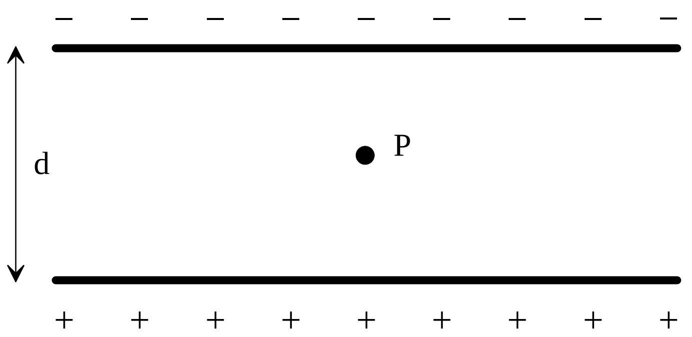
A3. This question is about the forces acting on a charged oil drop.

Two horizontal, parallel metal plates are a distance d apart and charged as shown in the diagram below. A small oil drop P is introduced between the plates. When there is a potential difference V_1 between the plates the drop is observed to be stationary. When the potential difference is changed to V_2 the drop is observed to move upwards with a constant velocity v.



(a) What is the sign of the charge carried by the drop? *[1]*

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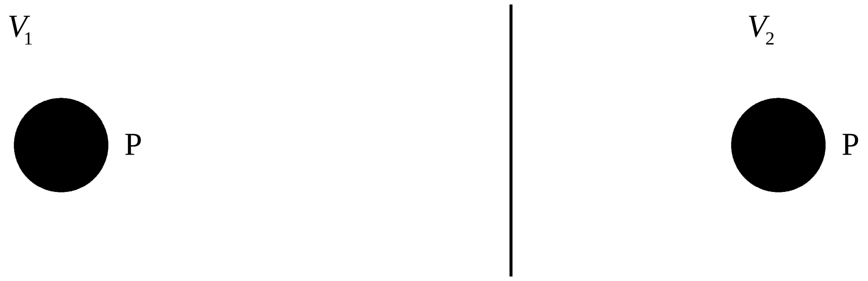
(b) On the two diagrams below draw and name the forces acting on the oil drop showing their directions and their relative magnitudes when the potential difference between the plates is V_1 and when the potential difference between the plates is V_2. *[5]*



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(Question A3 continued)

(c) When a small sphere moves through the air with a low speed *v* it experiences a resistive force given by *kv* where *k* is a constant. If the oil drop carries a charge of magnitude *q*, show that when the potential difference between the plates is V_2 the speed *v* with which the drop moves upwards is given by *[4]*

$$v = \frac{q}{kd}(V_2 - V_1).$$

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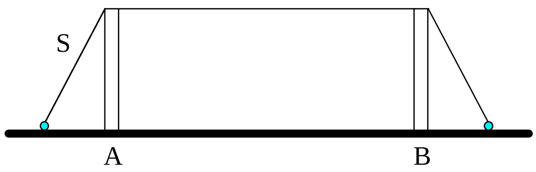
A4. This question is about standing waves in a string.

The diagram below shows a string S which is stretched between two supports A and B.



(a) Sketch on the diagram the shape of the standing wave pattern produced when the string is set to vibrate at its fundamental frequency. *[1]*

(b) State **three** independent parameters that effect the fundamental frequency of vibration of the string. *[3]*

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(c) By what factor can each parameter be altered independently in order that the fundamental frequency of vibration be doubled? *[3]*

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(d) When the distance between the supports A and B is 100 cm the tension in the string is 50.0 N. If the mass per unit length of the string is 5.0×10^{-3} kg m^{-1} calculate the frequency of the fundamental vibration of the string. *[1]*

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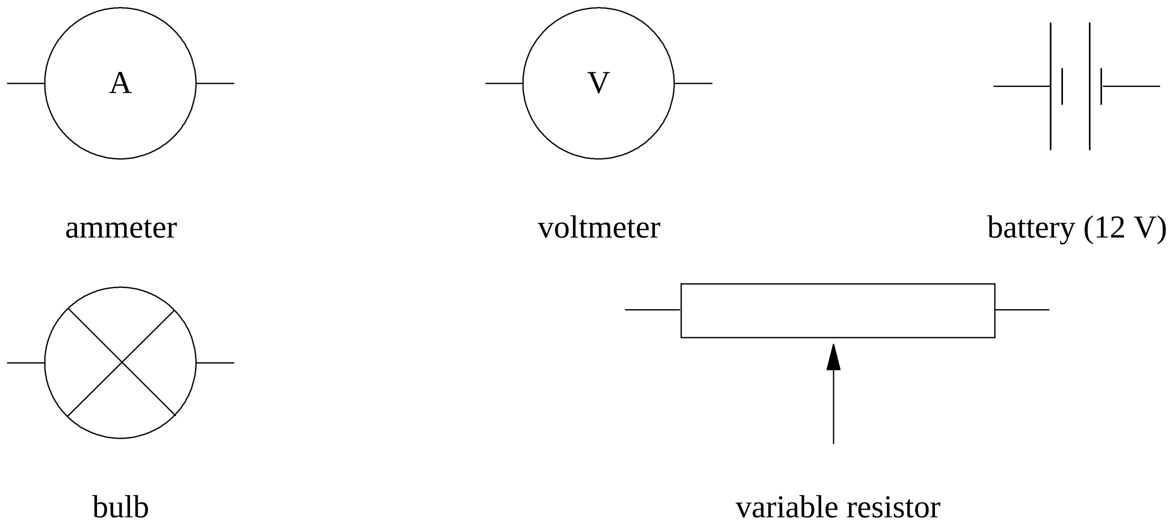
SECTION B

*This section consists of four questions: B1, B2, B3 and B4. Answer any **two** questions in this section.*

B1. This question is in **two** parts. **Part 1** is about electrical circuits and **Part 2** (the shorter part) is about the Carnot Cycle and Entropy.

Part 1. Electrical circuits

(a) You are given the apparatus shown below which is also identified by the appropriate circuit symbol. The 12 V battery has negligible internal resistance.



Draw a circuit diagram showing how this apparatus should be connected so that the current through the bulb can be measured as the potential difference across the bulb is varied from **zero** to 12 V. *[4]*

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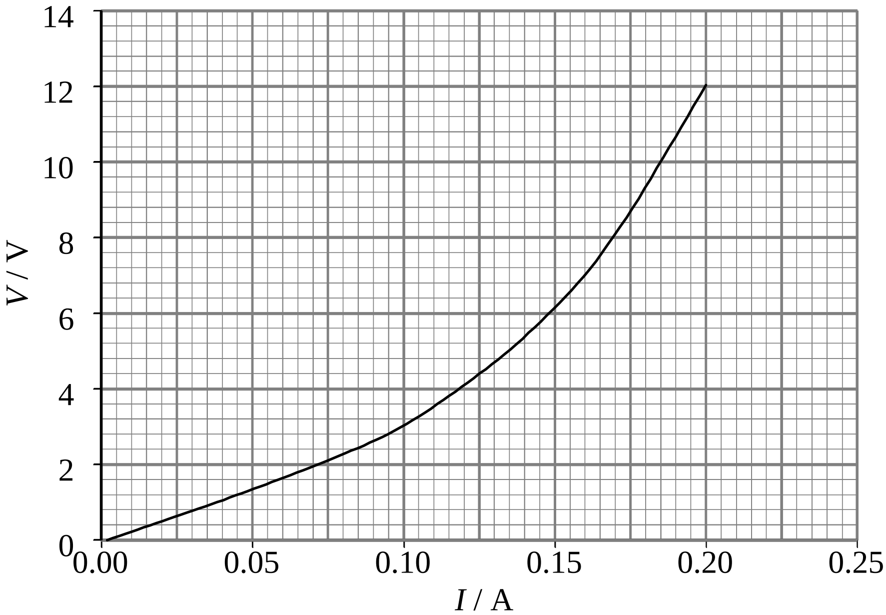
(Question B1 Part 1 continued)

(b) The graph below shows the relationship between the current I through a particular filament lamp and the potential difference V across it.



(i) State whether or not the filament of the lamp obeys Ohm's law. *[1]*

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(ii) What is the resistance of the lamp when the potential difference across it is very small? *[2]*

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(iii) How much power is dissipated in the lamp when the potential difference across it is 12 V? *[2]*

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(This question continues on the following page)

(Question B1 Part 1 continued)

(c) A student connects a filament lamp to a dry battery via a switch. A high resistance voltmeter connected across the battery reads 12 V when the switch is open. When the switch is closed the voltmeter reads 10.8 V.

(i) Suggest why this might be. *[2]*

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(ii) On measuring the current through the lamp the student finds it to be 0.18 A. Calculate the internal resistance of the battery. *[3]*

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(This question continues on the following page)

(Question B1 Part 1 continued)

(d) A 60 W filament lamp is operated from an alternating current supply. The RMS voltage of the supply is 240 V at a frequency of 50 Hz.

(i) Calculate the maximum current in the filament. *[2]*

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(ii) Show that the maximum power dissipated in the lamp is 120 W. *[1]*

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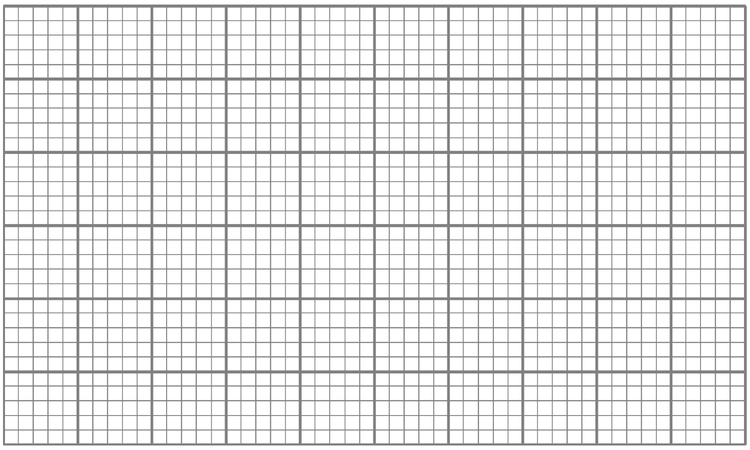
(iii) On the grid below sketch a graph to show how the power dissipated in the filament varies with time over **one** complete cycle. *[3]*



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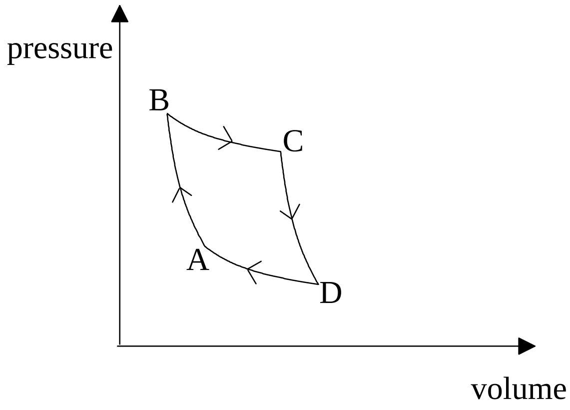
(Question B1 continued)

Part 2. The Carnot Cycle and Entropy

The diagram below shows the pressure–volume relationship for a fixed mass of an ideal gas that undergoes a Carnot cycle.



The process from B $\rightarrow$ C takes place at a constant temperature of 1000 K and the process from D $\rightarrow$ A takes place at a constant temperature of 500 K.

(a) During which of the four processes is work done

(i) **by** the gas? *[2]*

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(ii) **on** the gas? *[2]*

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(b) How can the total work done during a cycle be determined from the graph? *[1]*

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(c) Calculate the efficiency of the cycle. *[1]*

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(This question continues on the following page)

(Question B1 Part 2 continued)

(d) The Second law of Thermodynamics can be stated as "*all irreversible processes increase the entropy of the Universe*".

Explain from a molecular point of view how the following changes lead to an entropy increase of the Universe:

(i) a bouncing ball that comes to rest. *[2]*

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(ii) the collapse of a toy balloon when it is pricked by a pin. *[2]*

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B2. This question is about the motion of a firework rocket.

A firework rocket is fired vertically upwards from the ground. It accelerates uniformly from rest with an acceleration of 8.0 $m\,s^{-2}$ for 5.0 s after which time the fuel of the rocket has all been used.

(a) (i) Sketch below a graph to show how the **velocity** of the rocket changes with time from the moment it leaves the ground until the moment that it returns to the ground. Mark on your sketch the time t_1 at which the fuel has run out, the time t_2 at which the rocket reaches its maximum height and the time t_3 at which it reaches the ground. *[6]*

(Note that you are not expected to give any quantitative values of velocity and time and air resistance can be ignored.)

(ii) Comment on the area(s) under the graph that you have drawn. *[2]*

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(This question continues on the following page)

(Question B2 continued)

In the following calculations you may ignore any effects of air resistance and take the acceleration due to gravity, $g = 10\ m\,s^{-2}$.

(b) Calculate the

(i) speed of the rocket when the fuel runs out. *[2]*

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(ii) height that the rocket reaches when the fuel has just run out. *[2]*

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(iii) maximum height reached by the rocket. *[3]*

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(iv) time it takes the rocket to reach its maximum height. *[2]*

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(v) time that it takes to fall from its maximum height to the ground. *[2]*

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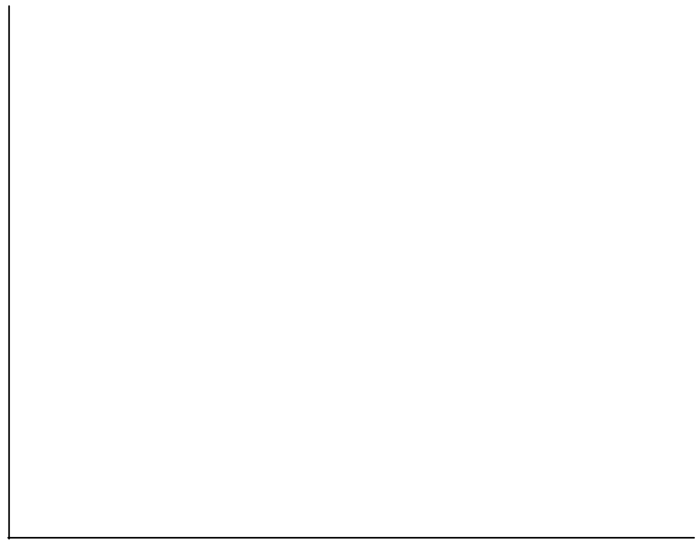
(This question continues on the following page)

(Question B2 continued)

(c) (i) On the axes below sketch graphs to show how the gravitational potential energy and the kinetic energy of the rocket varies as it moves from the ground to its maximum height. *[4]*

(Note that this is only a sketch graph; you do not need to add any numerical values.)



(ii) State **one** assumption, other than ignoring air resistance, that you have made in sketching the above graph. *[1]*

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(d) The rocket plus fuel initially have a mass of 0.16 kg. If the initial mass of the fuel is 0.02 kg, calculate the maximum kinetic energy of the rocket when all the fuel has been used. *[2]*

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(e) Calculate the power delivered to the rocket by the rocket fuel. *[2]*

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(f) Describe **two** consequences on the motion of the rocket as a result of air resistance acting on the rocket. *[2]*

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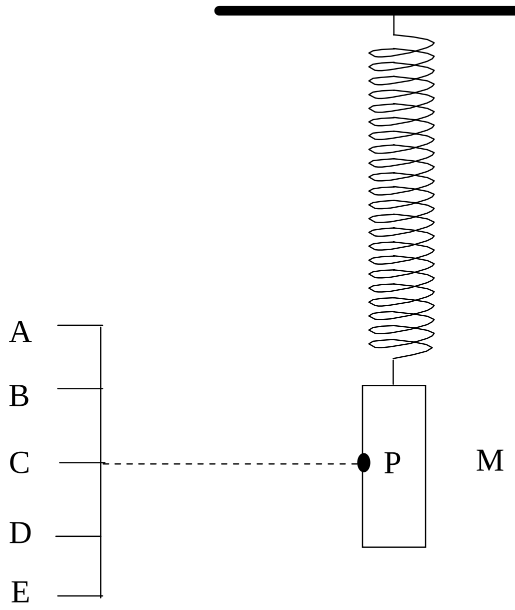
B3. This question is about an oscillating magnet.

The diagram below shows a magnet M suspended vertically from a spring. When the magnet is in equilibrium its mid-point P coincides with the line C on the adjacent scale. The magnet is pulled down such that P is now opposite E. It is then released.



(a) What conditions must be satisfied by the acceleration of the magnet in order for its motion after release to be **simple harmonic**? *[2]*

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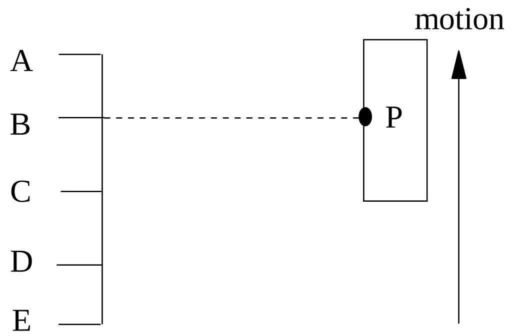
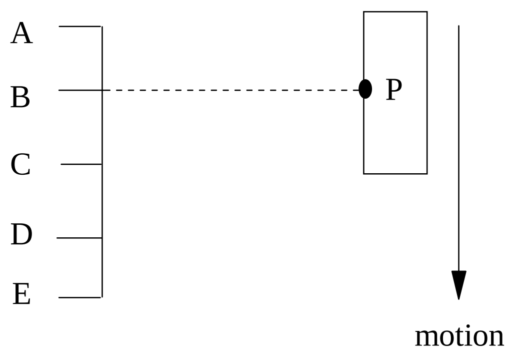
(Question B3 continued)

(b) (i) On the diagram below the magnet is moving up at the moment the point P is opposite B. Draw and name the forces acting on the magnet, showing both magnitude and direction. *[3]*



(ii) On the diagram below draw and name the forces acting on the magnet when the magnet is in the same position but moving downwards. Show the magnitude and direction of the forces. *[2]*



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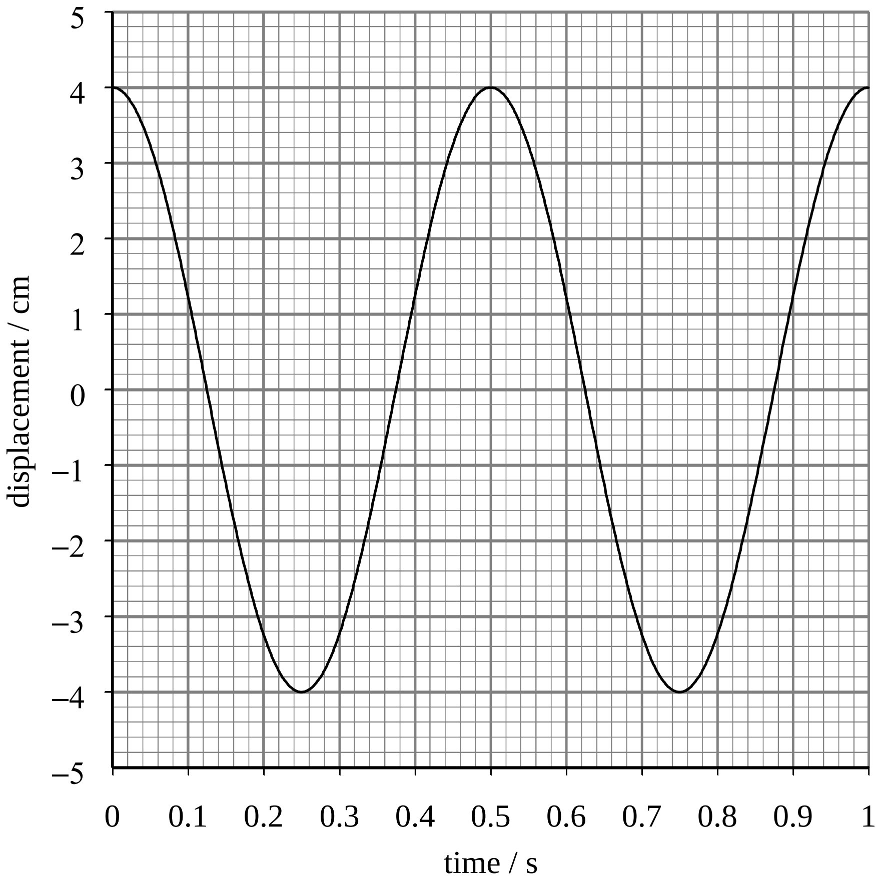
(Question B3 continued)

(c) The graph below shows how the displacement of the magnet varies with time for two oscillations.



Using information from this graph and the fact that the mass of the magnet is 0.30 kg calculate the

(i) value of the spring constant. *[3]*

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(ii) maximum kinetic energy of the magnet. *[4]*

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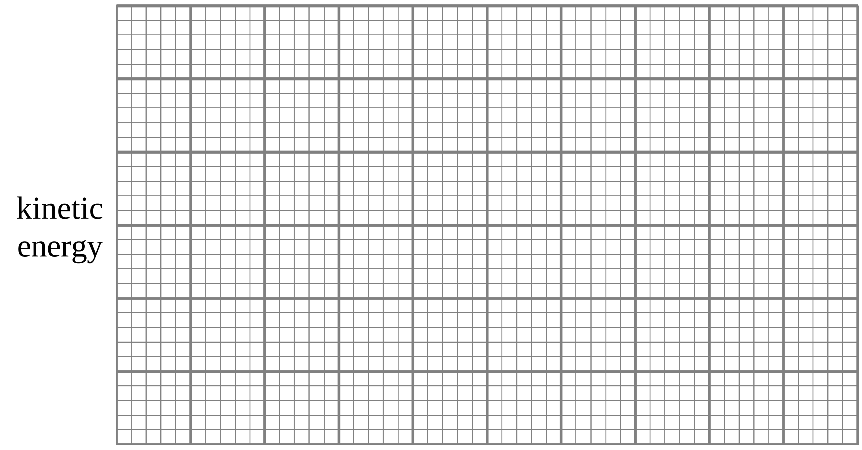
(Question B3 continued)

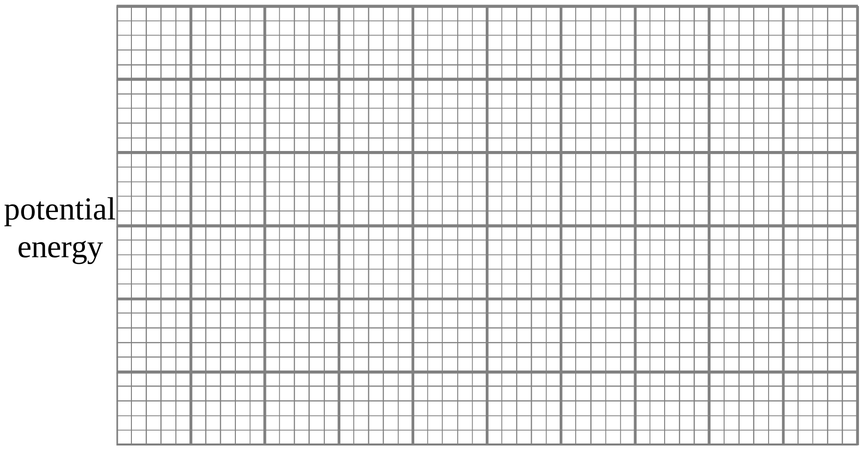
(d) On the two grids below sketch

(You do not need to give any values of energies on either graph.)

(i) a graph to show how the kinetic energy of the magnet varies with time for **one** complete oscillation. *[2]*



(ii) a graph to show how the elastic potential energy of **the spring** varies with time for **one** complete oscillation. *[3]*



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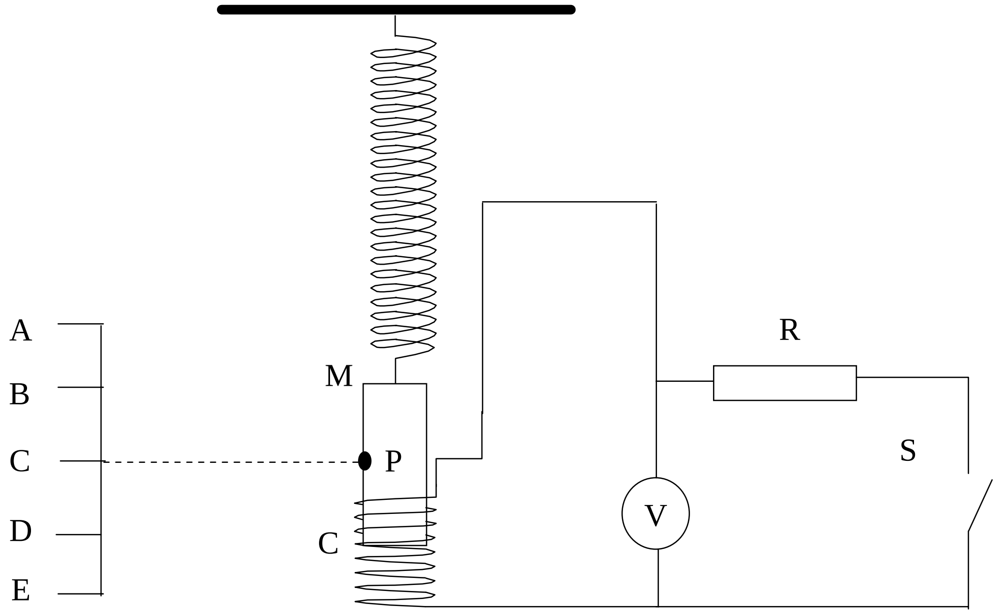
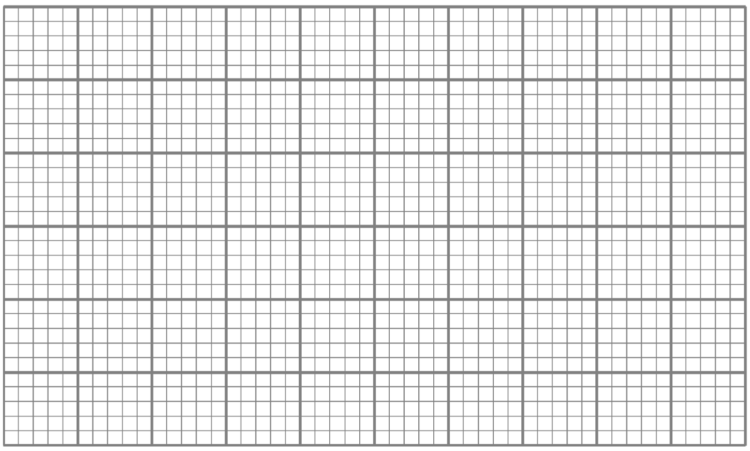
(Question B3 continued)

(e) The apparatus is now arranged such that the magnet is suspended inside a coil C that is connected to an electrical circuit as shown in the diagram below. The magnet is again set into oscillation by pushing it down such that point P is opposite D and then releasing it.



(i) On the grid below sketch a graph to show how you would ideally expect the reading on the voltmeter to vary with time for several complete oscillations of the magnet when the switch S is open. *(Note that this is only a sketch graph; you do not need to add values to the axes.)* *[1]*



(ii) Label on your sketch graph **one** point corresponding to a time when the magnet is stationary and **one** point corresponding to a time when it is moving with maximum velocity. *[2]*

(iii) State **three** factors that determine the maximum reading on the voltmeter when the switch S is open. *[3]*

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(This question continues on the following page)

(Question B3 continued)

(f) (i) On the grid below sketch a graph to show how the voltmeter reading varies with time when the switch S is closed. *(Again note that this is only a sketch graph, you do not need to add values to the axes.)* *[2]*

(ii) Explain why this sketch graph is different to the graph you have sketched in (e) (i) above. *[3]*

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B4. This question is in **two** parts. The first part is about Chadwick's discovery of the neutron and the second part is about the wave properties of particles.

Part 1 Chadwick and the discovery of the neutron

(a) Chadwick carried out an experiment in which he bombarded beryllium ($^{9}_{4}Be$) with α-particles. He found that a very penetrating radiation was produced and also another element. He postulated that this penetrating radiation consisted of the so far, undiscovered neutron.
Assuming that neutrons are produced in this interaction, write down the equation for the interaction of an α-particle with a nucleus of beryllium and identify the other element produced. *[2]*

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(b) In order to determine the mass of the particles making up the unknown radiation he carried out two further experiments.

(i) In the first of these Chadwick bombarded a slab of paraffin wax with the unknown radiation produced in the above reaction. The radiation ejected protons from the wax. Describe briefly the principle by which Chadwick measured the velocity of these ejected protons. *[3]*

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(ii) In the second experiment Chadwick allowed the unknown radiation to enter a nitrogen cloud chamber. He observed tracks that he assumed were produced by ionised nitrogen atoms being "knocked on" by collision with the neutrons.

Describe briefly how Chadwick determined the velocity of the nitrogen atoms. *[3]*

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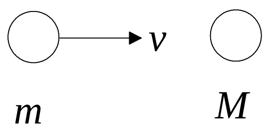
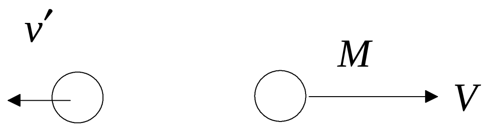
(Question B4 Part 1 continued)

(c) Chadwick now applied the ideas of conservation of momentum and energy to the data he obtained from the recoil experiments.

The diagram below shows a neutron mass m moving with speed v about to collide head on with another particle of mass M.



The collision takes place along a line joining the two particles. After the collision the neutron rebounds with a speed v' and the other particle moves off with a speed V as shown in the diagram below. The collision is perfectly elastic.



Write down an equation in terms of the respective masses and velocities of the two particles that expresses the

(i) conservation of momentum. *[2]*

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(ii) conservation of mechanical energy. *[2]*

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(This question continues on the following page)

(Question B4 Part 1 continued)

(d) It can be shown that in such a collision

$$V = \frac{2m}{m+M}v.$$

In the experiments with protons and nitrogen in 1936 Chadwick obtained the following data:

maximum speed of the protons ejected from paraffin wax	=	$3.3\times10^{7}\ \mathrm{m\,s^{-1}}$
maximum speed of the nitrogen atoms in the cloud chamber	=	$4.7\times10^{6}\ \mathrm{m\,s^{-1}}$

If the mass of a nitrogen atom is 14 m_p where m_p is the mass of a proton show, using the above equation and this data, that a value for the mass of the neutron m_n is determined as

$$m_n = 1.16\, m_p$$ *[5]*

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(Question B4 continued)

Part 2. The wave properties of particles.

(a) State the de Broglie hypothesis. *[2]*

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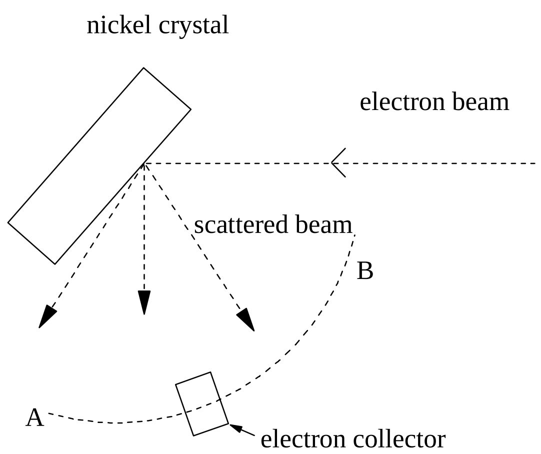
(b) In 1926 Davisson and Germer carried out an experiment in which an electron beam was scattered by a single nickel crystal.

A schematic diagram of the apparatus is shown below.



The electron collector is moved along the arc AB. It is found that electrons are only detected at certain positions along the arc.

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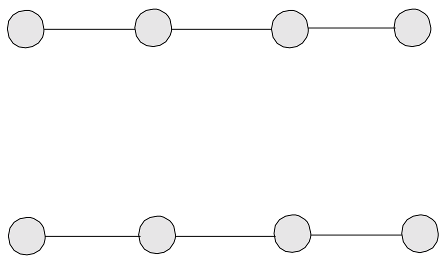
(Question B4 Part 2 (b) continued)

The diagram below represents two layers of ions in the nickel crystal. With the aid of this diagram explain how the results of the experiment help verify the de Broglie hypothesis. *[6]*



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(c) (i) Show that an electron accelerated through a potential difference of 150 V will have a de Broglie wavelength equal to about 10^{-10} m. *[4]*

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(ii) Why would such electrons with energy 150 eV be suitable for use in the Davisson and Germer experiment? *[1]*

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