88096502

International Baccalaureate
Baccalauréat International
Bachillerato Internacional

PHYSICS
HIGHER LEVEL
PAPER 2

Monday 16 November 2009 (afternoon)

2 hours 15 minutes

Candidate session number

0	0							

INSTRUCTIONS TO CANDIDATES

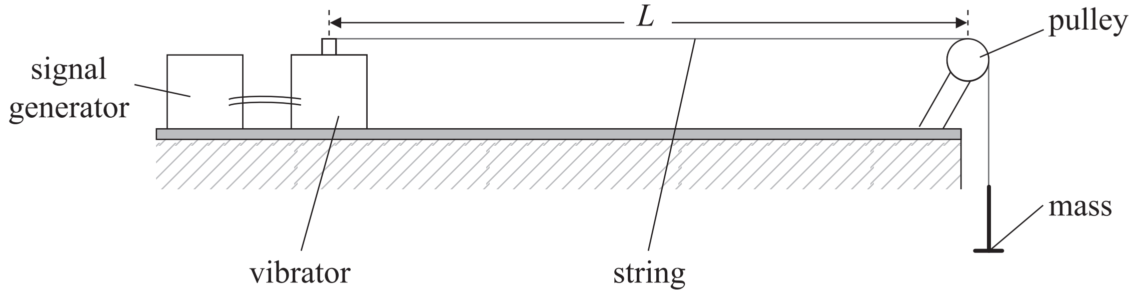
- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: answer all of Section A in the spaces provided.
- Section B: answer two questions from Section B in the spaces provided.
- At the end of the examination, indicate the numbers of the questions answered in the candidate box on your cover sheet.

SECTION A

*Answer **all** the questions in the spaces provided.*

A1. Data analysis question.

The frequency f of the fundamental vibration of a standing wave of fixed length is measured for different values of the tension T in the string, using the apparatus shown.



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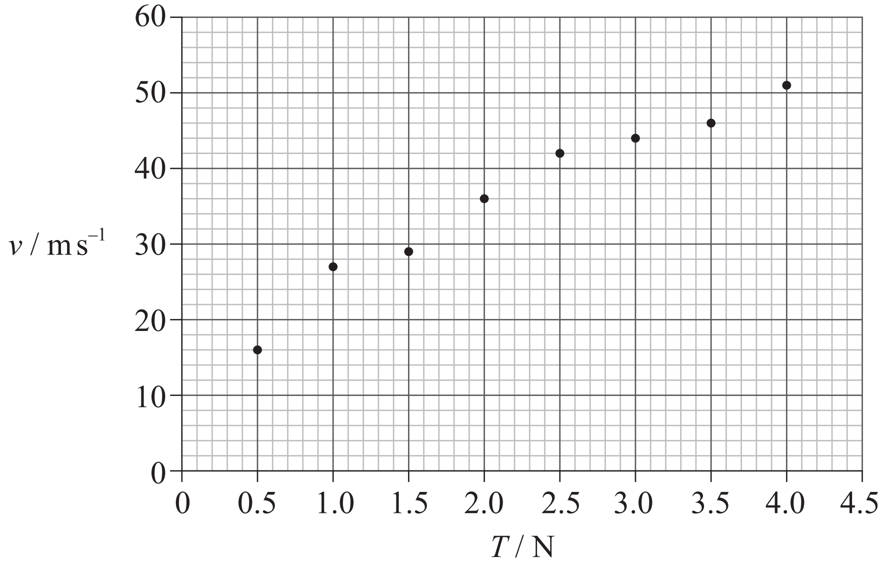
(Question A1 continued)

In order to find the relationship between the speed v of the wave and the tension T in the string, the speed v is calculated from the relation

$$v = 2fL$$

where L is the length of the string.

The data points are shown plotted on the axes below. The uncertainty in v is $\pm 5\,\text{m s}^{-1}$ and the uncertainty in T is negligible.



(a) Draw error bars on the first and last data points to show the uncertainty in speed v. *[1]*

(b) The original hypothesis is that the speed is directly proportional to the tension T. Explain why the data do **not** support this hypothesis. *[2]*

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(This question continues on the following page)

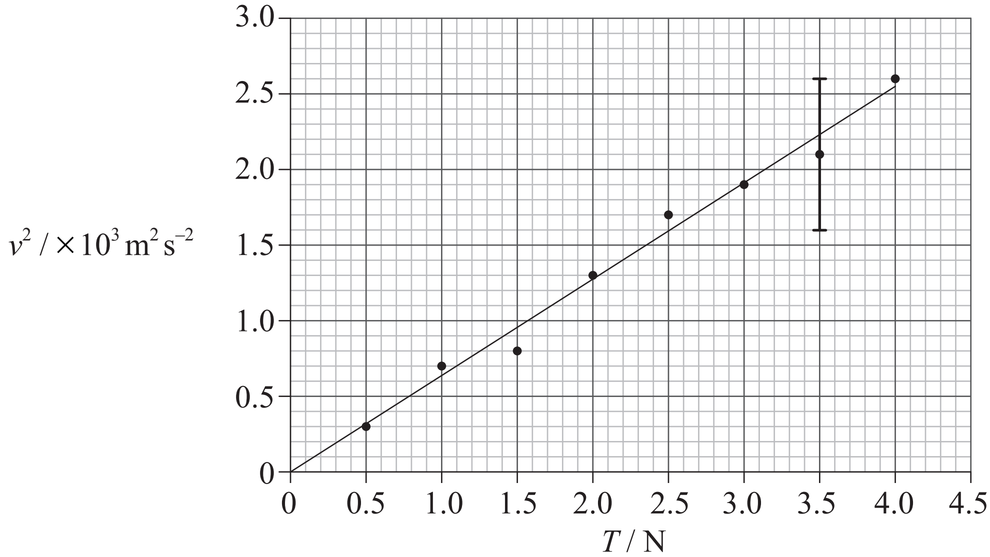
(Question A1 continued)

(c) It is suggested that the relationship between speed and tension is of the form

$$v = k\sqrt{T}$$

where k is a constant.

To test whether the data support this relationship, a graph of v^2 against T is plotted as shown below.



The best-fit line shown takes into account the uncertainties for each data point. The uncertainty in v^2 for $T = 3.5$ N is shown as an error bar on the graph.

(i) State the value of the uncertainty in v^2 for $T = 3.5$ N. *[1]*

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(ii) At $T = 1.0$ N the speed $v = 27 \pm 5$ m s^{-1}. Calculate the uncertainty in v^2. *[3]*

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(Question A1 continued)

(d) Use the graph in (c) to determine *k* without its uncertainty. *[4]*

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A2. This question is about thermal energy transfer.

(a) A piece of copper is held in a flame until it reaches thermal equilibrium. The time it takes to reach thermal equilibrium will depend on the thermal capacity of the piece of copper.

(i) Define *thermal capacity*. *[1]*

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(ii) Outline what is meant by thermal equilibrium in this context. *[1]*

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(b) The piece of copper is transferred quickly to a plastic cup containing water. The thermal capacity of the cup is negligible. The following data are available.

Mass of copper	= 0.12 kg
Mass of water	= 0.45 kg
Rise in temperature of water	= 30 K
Final temperature of copper	= 308 K
Specific heat capacity of copper	= 390 J kg K^{-1}
Specific heat capacity of water	= 4200 J kg K^{-1}

(i) Use the data to calculate the temperature of the flame. *[3]*

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(ii) Explain whether the temperature of the flame is likely to be greater or less than your answer to (b)(i). *[2]*

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A3. This question is about gravitational and electric fields.

(a) The equation for the magnitude of the gravitational field strength due to a point mass may be written as below.

$$Y = \frac{KX}{s^2}$$

The equation for the magnitude of the electric field strength can also be written in the same form.

In the table identify the symbols used in the equation. *[4]*

Symbol	Gravitational field quantity	Electrical field quantity
Y		
K		
X		
s		

(b) The magnitude of the electrostatic force between the proton and electron in a hydrogen atom is F_E. The magnitude of the gravitational force between them is F_G.

Determine the ratio $\frac{F_E}{F_G}$. *[3]*

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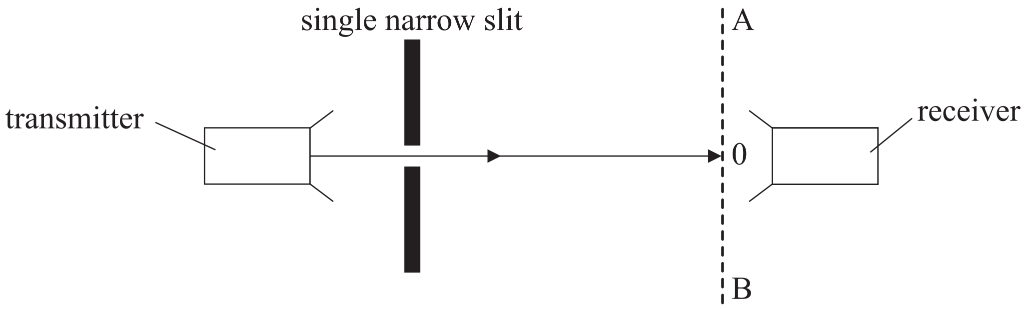
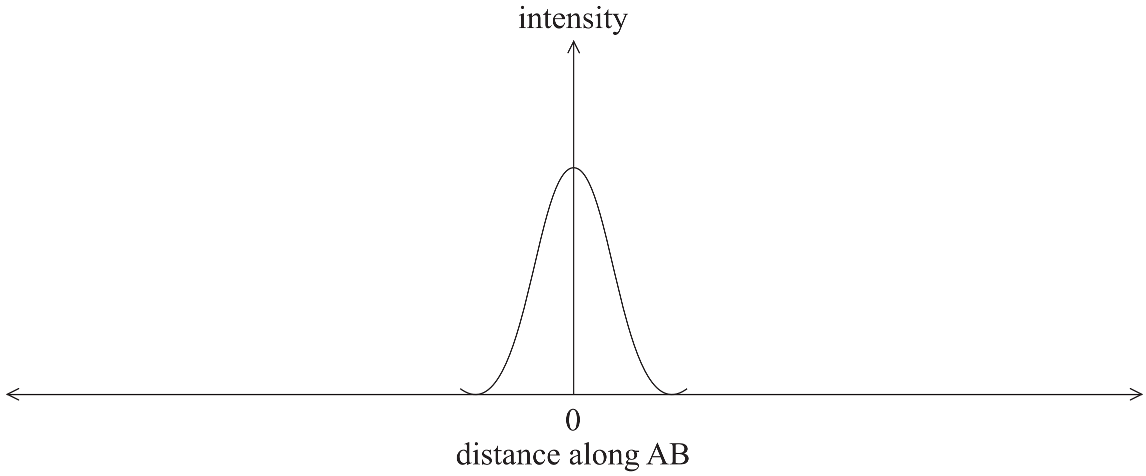
A4. This question is about microwaves.

(a) Radiation from a microwave transmitter passes through a single narrow slit. A receiver is placed several metres beyond the slit. The receiver can be moved between point A and point B along a line parallel to the slit.



(i) On the axes below, sketch a graph to show the variation of intensity of the microwave radiation with distance along line AB. The graph has been started for you. *[3]*



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(Question A4 continued)

(ii) The width of the narrow slit is reduced. State and explain **two** effects on the intensity distribution you have shown in (a)(i). *[4]*

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Explanation: . . . .

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Effect: . . . .

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(b) Standing waves are formed in microwave ovens. Suggest why it is desirable that food is rotated whilst being cooked in the microwave. *[3]*

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A5. This question is about forces.

A solid iron ball of mass 770 kg is used on a building site. The ball is suspended by a rope from a crane. The distance from the point of suspension to the centre of mass of the ball is 12 m.

(a) Calculate the tension in the rope when the ball hangs vertical and stationary. *[1]*

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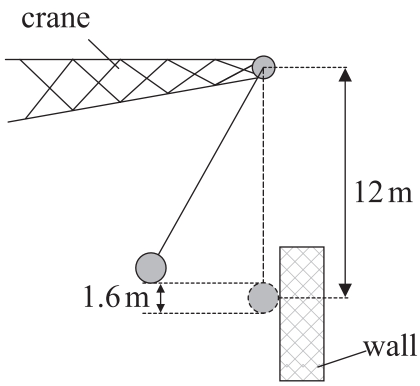
(b) The ball is pulled back from the vertical and then released. It falls through a vertical height of 1.6 m and strikes a wall.



(i) Calculate the speed of the ball just before impact. *[2]*

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(ii) Calculate the tension in the rope just before impact. *[3]*

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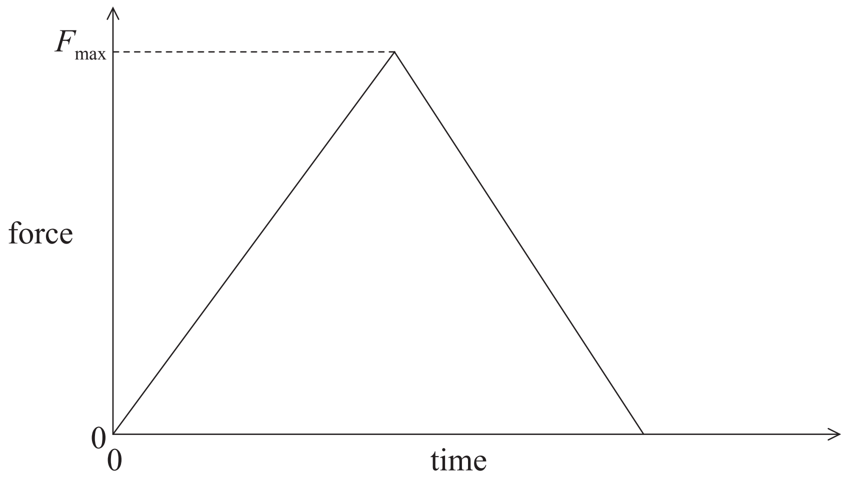
(This question continues on the following page)

(Question A5 continued)

(c) The ball is brought to rest in 0.15 s. The sketch graph below shows how the force the ball exerts on the wall varies with time.



(i) State what quantity is represented by the area under the graph. *[1]*

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(ii) Determine the maximum force F_{max} exerted by the ball on the wall. *[3]*

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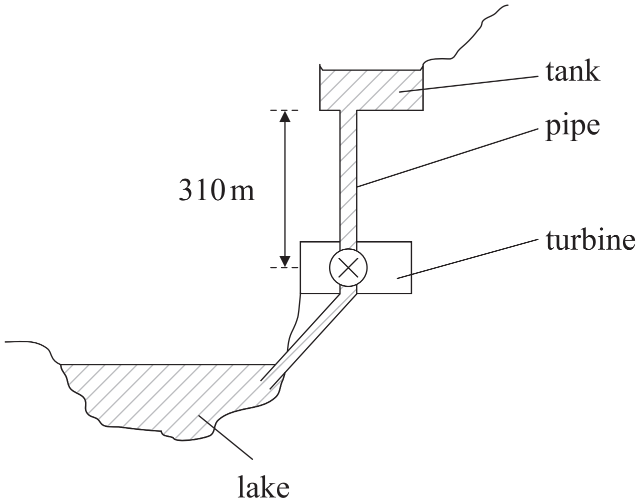
SECTION B

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

B1. This question is about the generation of electrical energy and global warming.

(a) The diagram, not to scale, shows a pumped-storage power station used for the generation of electrical energy.



Water stored in the tank is allowed to fall through a pipe to a lake via a turbine. The turbine is connected to an electrical generator. The pumped-storage ac generator system is reversible so that water can be pumped from the lake to the tank.

The tank is 50 m deep and has a uniform area of $5.0 \times 10^4\,m^2$. The height from the bottom of the tank to the turbine is 310 m. The density of water is $1.0 \times 10^3\,kg\,m^{-3}$.

(i) Show that the maximum energy that can be delivered to the turbine by the falling water is about $8 \times 10^{12}\,J$. *[3]*

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(ii) The flow rate of water in the pipe is $400\,m^3\,s^{-1}$. Calculate the power delivered by the falling water. *[2]*

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(This question continues on the following page)

(Question B1 continued)

(b) The energy losses in the power station are shown in the following table.

Source of energy loss	**Percentage loss of energy**
friction and turbulence of water in pipe	27
friction in turbine and ac generator	15
electrical heating losses	5

(i) Calculate the overall efficiency of the conversion of the gravitational potential energy of water in the tank into electrical energy. *[1]*

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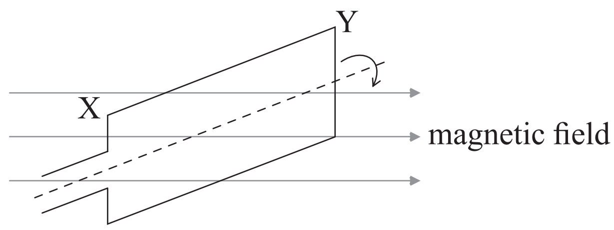
(ii) Sketch a Sankey diagram to represent the energy conversion in the power station. *[2]*

(This question continues on the following page)

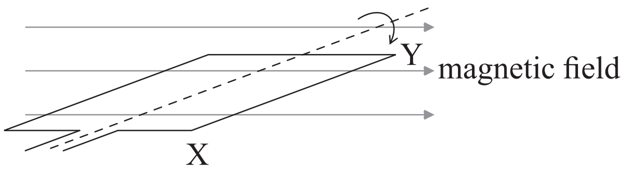
(Question B1 continued)

(c) An ac generator is connected to the turbine used in the pumped-water power station. The diagrams show two positions of one winding of the coil in the generator. The magnetic field acts horizontally in the direction shown. The coil rotates clockwise.

Position 1



Position 2



(i) By considering the motion of XY, explain why the emf induced between X and Y has a maximum value in position 2. *[3]*

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(ii) In position 2 the vertical speed of XY is $160\,m\,s^{-1}$. The magnetic field strength is 0.015 T and XY = 1.5 m. Determine the induced emf between X and Y at this position. *[2]*

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(iii) Side XY is part of the rectangular generator coil that has 1500 windings connected in series. Calculate the total emf across the ends of the coil at the moment when XY moves vertically downwards at 90° to the magnetic field direction. *[2]*

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(This question continues on the following page)

(Question B1 continued)

(d) The electrical power produced at the power station is transmitted by cables to the consumer.

(i) Outline how the energy losses in transmission are minimized. *[3]*

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(ii) State **one** advantage and **one** disadvantage that a pumped-storage system has compared to a tidal water storage system. *[2]*

Advantage: . . . .

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Disadvantage: . . . .

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(e) One effect of global warming is to melt the Antarctic ice sheet. The following data are available for the Antarctic ice sheet and the Earth's oceans.

Area of ice sheet	$= 1.4 \times 10^{7}\,\text{km}^{2}$
Average thickness of ice	$= 1.5 \times 10^{3}\,\text{m}$
Density of ice	$= 920\,\text{kg}\,\text{m}^{-3}$
Density of water	$= 1000\,\text{kg}\,\text{m}^{-3}$
Area of Earth's oceans	$= 3.8 \times 10^{8}\,\text{km}^{2}$

Using the data, determine the

(i) mass of the Antarctic ice. *[2]*

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(ii) change in mean sea level if all the Antarctic ice sheet were to melt and flow into the oceans. *[3]*

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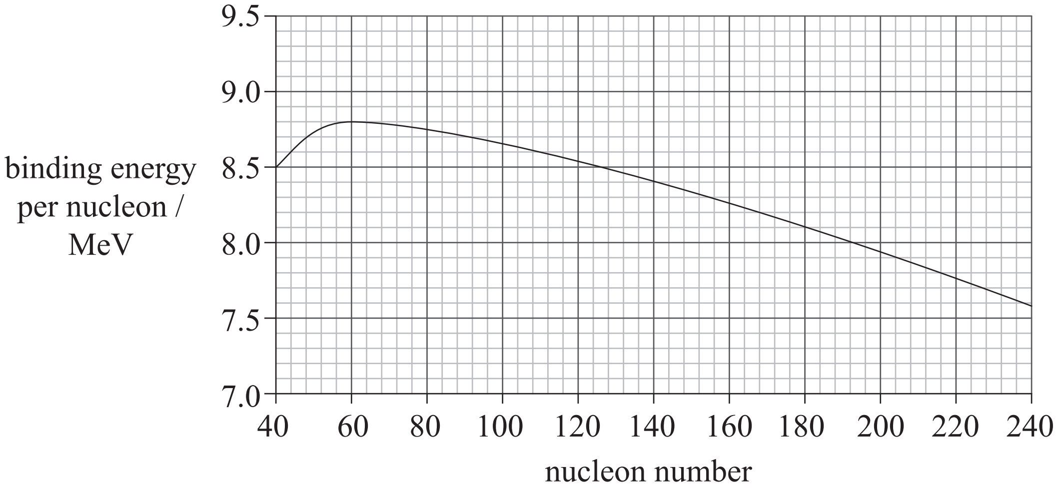
B2. This question is in **two** parts. **Part 1** is about nuclear fission and fusion. **Part 2** is about charge-coupled devices (CCD).

Part 1 Nuclear fission and fusion

(a) The graph shows the variation of binding energy per nucleon for nuclides with a nucleon number greater than 40.



(i) Define *binding energy*. *[1]*

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(ii) On the graph, label with the letter S the position of the most stable nuclide. *[1]*

(iii) State why the nuclide you have labelled is the most stable. *[1]*

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(This question continues on the following page)

(Question B2, part 1 continued)

(b) In a nuclear reactor, a nucleus of uranium(U)-235 fissions into barium(Ba)-141 and krypton(Kr)-92. The equation for this fission is

$$^{235}_{92}\text{U} \rightarrow {}^{141}_{56}\text{Ba} + {}^{92}_{36}\text{Kr} + x\,{}^{1}_{0}\text{n}.$$

(i) Use the graph to show that the fission of one nucleus of uranium-235 will release about 200 MeV of energy. *[4]*

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(ii) State the value of x in the equation. *[1]*

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(iii) The mass defect in this reaction is 3.1×10^{-28} kg. Calculate the number of uranium-235 nuclei that must fission in order to release 1.0 kJ of energy. *[2]*

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(iv) Outline how this fission reaction can lead to a chain reaction. *[2]*

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(This question continues on the following page)

(Question B2, part 1 continued)

(c) Intensive scientific effort is devoted to developing nuclear fusion as a future energy source. Discuss what could be the social and environmental benefits of using nuclear fusion as compared with nuclear fission as an energy source. *[3]*

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(This question continues on the following page)

(Question B2 continued)

Part 2 Charge-coupled devices (CCD)

(a) State the condition necessary for two points on an image to be resolved by a CCD. *[1]*

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(b) The following data are for a CCD in a camera.

Dimensions of CCD $= 24\,\text{mm} \times 16\,\text{mm}$
Number of pixels $= 10.2 \times 10^6$

(i) Each pixel on the CCD is square and they all have the same dimensions. Show that the length of one side of a pixel is about $6\,\mu\text{m}$. *[2]*

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(ii) The pixels have quantum efficiency of 80 % and a capacitance of 35 pF. Photons are incident on a pixel at a rate of $1.6 \times 10^8\,\text{s}^{-1}$. Calculate the potential difference across a pixel after 12 ms. *[3]*

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(iii) A photograph is taken of a distant building using the camera. The magnification of the CCD is 2.2×10^{-6}. Two windows on the building are separated by 2.5 m. Determine whether the images of the windows can be resolved by the CCD. *[2]*

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(This question continues on the following page)

(Question B2, part 2 continued)

(c) In terms of data storage, state **two** advantages of using a digital camera as compared to an analogue camera that uses film. *[2]*

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B3. This question is in **two** parts. **Part 1** is about simple harmonic motion. **Part 2** is about thermodynamics.

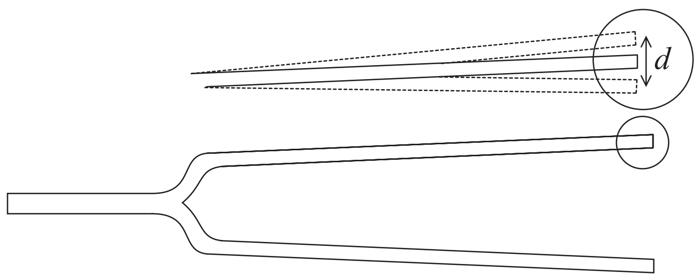
Part 1 Simple harmonic motion

(a) In terms of the acceleration, state **two** conditions necessary for a system to perform simple harmonic motion. *[2]*

1. . . . .

2. . . . .

(b) A tuning fork is sounded and it is assumed that each tip vibrates with simple harmonic motion.



The extreme positions of the oscillating tip of one fork are separated by a distance d.

(i) State, in terms of d, the amplitude of vibration. *[1]*

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(ii) On the axes below, sketch a graph to show how the displacement of one tip of the tuning fork varies with time. *[1]*

(iii) On your graph, label the time period T and the amplitude a. *[2]*

(This question continues on the following page)

(Question B3, part 1 continued)

(c) The frequency of oscillation of the tips is 440 Hz and the amplitude of oscillation of each tip is 1.2 mm. Determine the maximum

(i) linear speed of a tip. *[2]*

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(ii) acceleration of a tip. *[2]*

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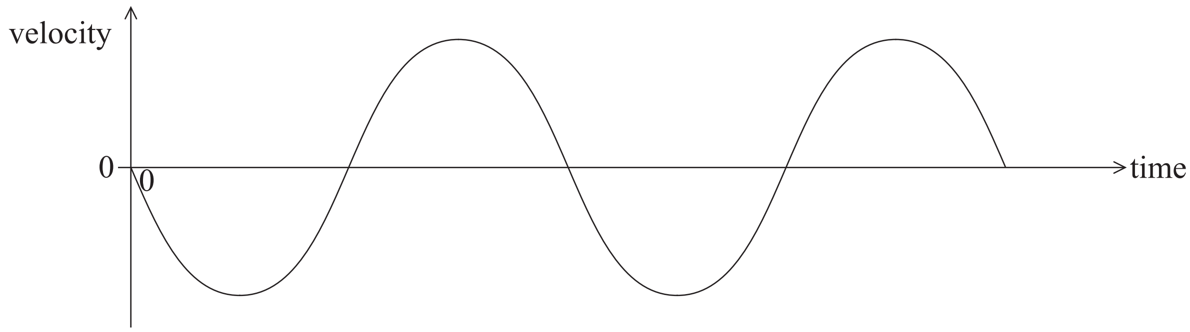
(d) The sketch graph below shows how the velocity of a tip varies with time.



On the axes, sketch a graph to show how the acceleration of the tip varies with time. *[2]*

(This question continues on the following page)

(Question B3, part 1 continued)

(e) In practice, the motion of the tips of the tuning fork is damped.

(i) Describe what is meant by damped motion. *[1]*

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(ii) Suggest **one** reason why the motion of the tips is damped. *[1]*

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(This question continues on the following page)

(Question B3 continued)

Part 2 Thermodynamics

(a) The first law of thermodynamics can be written as the following equation.

$$Q = \Delta U + W$$

Identify the symbols in this equation. *[3]*

Q . . . .

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ΔU . . . .

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W . . . .

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(This question continues on the following page)

(Question B3, part 2 continued)

(b) A fixed mass of an ideal gas is contained in a cylinder by a piston. The friction between the piston and cylinder wall is negligible.

Two procedures are carried out on the gas. The thermal energy input to the gas is the same in both procedures.

Procedure 1 The gas is heated and expands at constant pressure with the piston free to move. The temperature of the gas increases by 21 K.

Procedure 2 The gas is now brought back to its initial state and again heated with the piston fixed in position. The temperature of the gas increases by 35 K.

(i) State the name of the process in procedure 2. *[1]*

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(ii) Explain why the temperature change is greater in procedure 2 than in procedure 1. *[4]*

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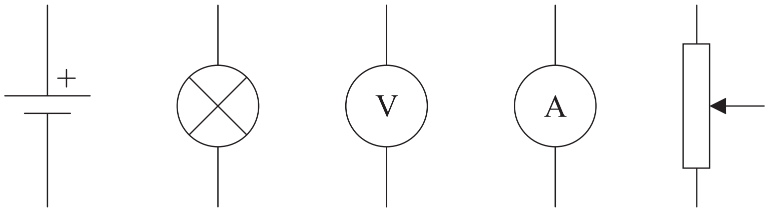
(iii) In procedure 1, ΔU changes by +120 J. Use the first law of thermodynamics to calculate the missing values in the table below. *[3]*

	ΔU / J	**W / J**	**Q / J**
Procedure 1	+120		+200
Procedure 2			+200

B4. This question is in **two** parts. **Part 1** is about electric circuits. **Part 2** is about electrons.

Part 1 Electric circuits

The components shown below are to be connected in a circuit to investigate how the current I in a tungsten filament lamp varies with the potential difference V across it.



(a) Construct a circuit diagram to show how these components should be connected together in order to obtain as large a range as possible for values of potential difference across the lamp. *[4]*

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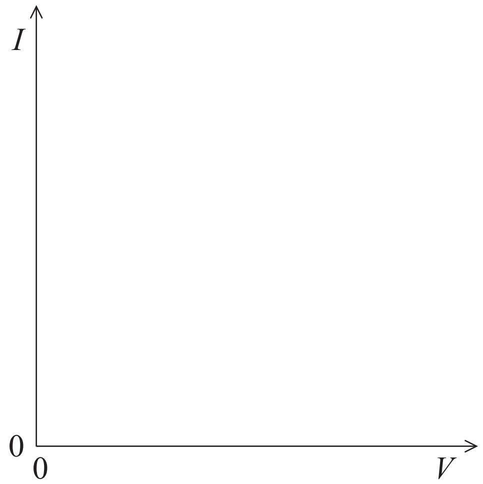
(Question B4, part 1 continued)

(b) On the axes, sketch a graph of I against V for a filament lamp in the range $V = 0$ to its normal working voltage. *[2]*



(c) The lamp is marked with the symbols "1.25 V, 300 mW". Calculate the current in the filament when it is working normally. *[1]*

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(d) The resistivity of tungsten at the lamp's working temperature is $4 \times 10^{-7}\ \Omega\,\text{m}$. The total length of the tungsten filament is 0.80 m. Estimate the radius of the filament. *[4]*

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(e) The cell is connected to two identical lamps connected in parallel. The lamps are rated at 1.25 V, 300 mW. The cell has an emf of 1.5 V and an internal resistance of 1.2 Ω. Determine whether the lamps will light normally. *[4]*

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(Question B4 continued)

Part 2 Electrons

(a) In 1924, Davisson and Germer carried out an experiment in which electrons were accelerated through a potential difference of 54 V. The electrons were scattered at the surface of a nickel crystal.

(i) Outline how the results of the experiment suggested that electrons exhibit wave properties. *[2]*

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(ii) Calculate the de Broglie wavelength of the electrons. *[3]*

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(b) Explain how the de Broglie hypothesis is used with the "electron in a box" model to understand the origin of atomic energy levels in the atom. *[5]*

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