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International Baccalaureate®
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PHYSICS
HIGHER LEVEL
PAPER 2

Candidate session number

Wednesday 7 May 2014 (morning)

2 hours 15 minutes

Examination code

2 2 1 4 – 6 5 1 4

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 two questions.
- 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 *[95 marks]*.

36 pages

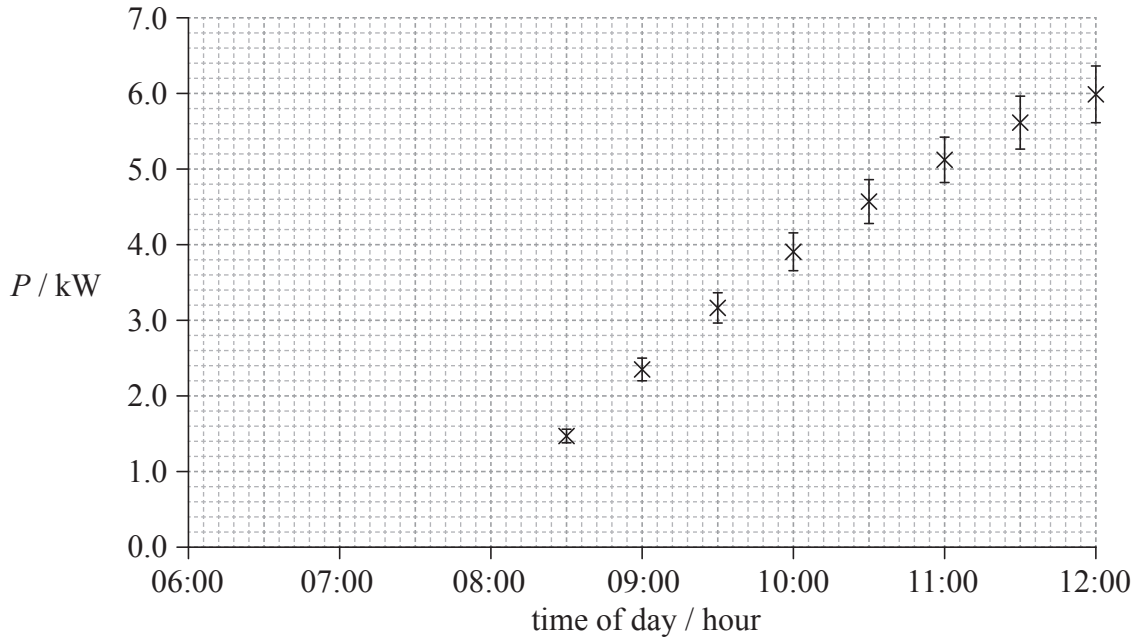
SECTION A

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

1. Data analysis question.

An array of photovoltaic cells is used to provide electrical energy for a house. When the array produces more power than is consumed in the house, the excess power is fed back into the mains electrical supply for use by other consumers.

The graph shows how the power P produced by the array varies with the time of day. The error bars show the uncertainty in the power supplied. The uncertainty in the time is too small to be shown.



(a) Using the graph, estimate the time of day at which the array begins to generate energy. *[2]*

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(This question continues on the following page)

(Question 1 continued)

(b) The average power consumed in the house between 08:00 and 12:00 is 2.0 kW. Determine the energy supplied by the array to the mains electrical supply between 08:00 and 12:00. *[3]*

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(c) The power P produced by the array is calculated from the generated emf V and the fixed resistance R of the array using the equation $\frac{V^2}{R}$. The uncertainty in the value of R is 2 %. Calculate the percentage uncertainty in V at 12:00. *[3]*

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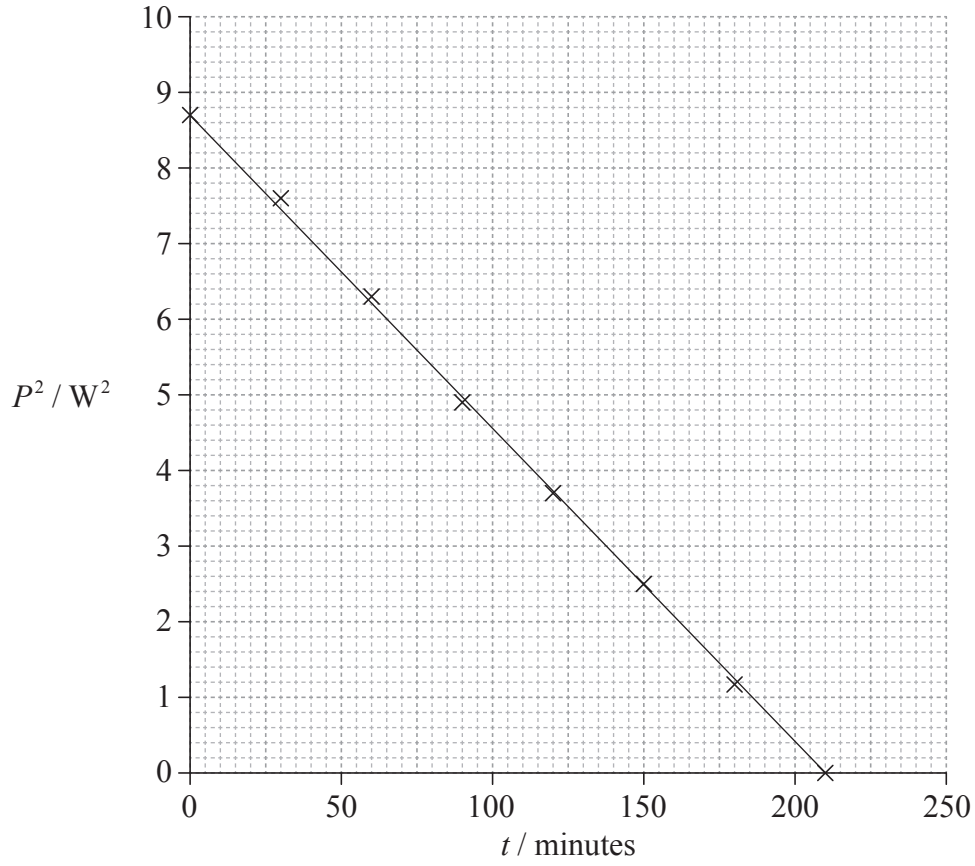
(Question 1 continued)

(d) Later that day a second set of data was collected starting at $t = 0$. The variation of P^2 with time t since the start of this second data collection is shown in the graph.



Using the graph, determine the relationship between P^2 and t. *[3]*

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2. This question is about energy.

At its melting temperature, molten zinc is poured into an iron mould. The molten zinc becomes a solid without changing temperature.

(a) Outline why a given mass of molten zinc has a greater internal energy than the same mass of solid zinc at the same temperature. *[3]*

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(b) The zinc is allowed to cool in the mould. The temperature of the iron mould was 20 °C before the molten zinc, at its melting temperature, was poured into it. The final temperature of the iron mould and the solidified zinc is 89 °C.

The following data are available.

Mass of iron mould	= 12 kg
Mass of zinc	= 1.5 kg
Specific heat capacity of iron	= 440 $J kg^{-1} K^{-1}$
Specific latent heat of fusion of zinc	= 113 $kJ kg^{-1}$
Melting temperature of zinc	= 420 °C

Using the data, determine the specific heat capacity of zinc. *[4]*

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3. This question is about binding energy and mass defect.

(a) State what is meant by mass defect. *[1]*

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(b) (i) The nuclear mass of the nuclide helium-3 $\left({}_{2}^{3}\mathrm{He}\right)$ is 3.014931 u. Show that the binding energy per nucleon for the nuclide is about 2.6 MeV. *[2]*

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(ii) The binding energy per nucleon for deuterium $\left({}_{1}^{2}\mathrm{H}\right)$ is 1.11 MeV. Calculate the energy change in the following reaction. *[2]*

$${}_{1}^{2}\mathrm{H} + {}_{1}^{1}\mathrm{H} \rightarrow {}_{2}^{3}\mathrm{He} + \gamma$$

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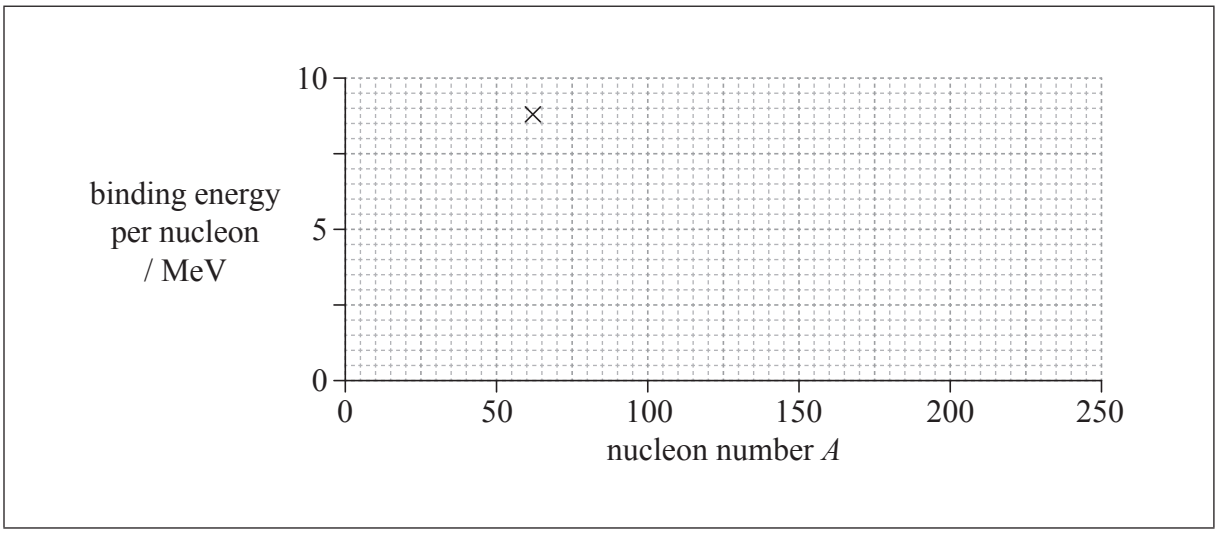
(Question 3 continued)

(iii) The cross on the grid shows the binding energy per nucleon and nucleon number A of the nuclide nickel-62.



On the grid, sketch a graph to show how the average binding energy per nucleon varies with nucleon number A. *[2]*

(iv) State and explain, with reference to your sketch graph, whether energy is released **or** absorbed in the reaction in (b)(ii). *[2]*

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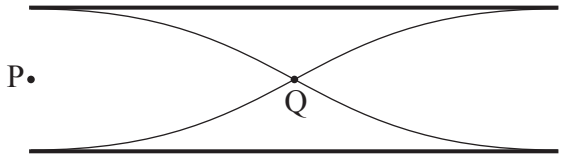
4. This question is about waves.

(a) The diagram represents a standing (stationary) wave in air in a pipe which is open at both ends.



Two points in the pipe are labelled P and Q.

(i) State the direction of oscillation of an air molecule at point P. *[1]*

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(ii) Compare the amplitude of oscillation of an air molecule at point P with that of an air molecule at point Q. *[2]*

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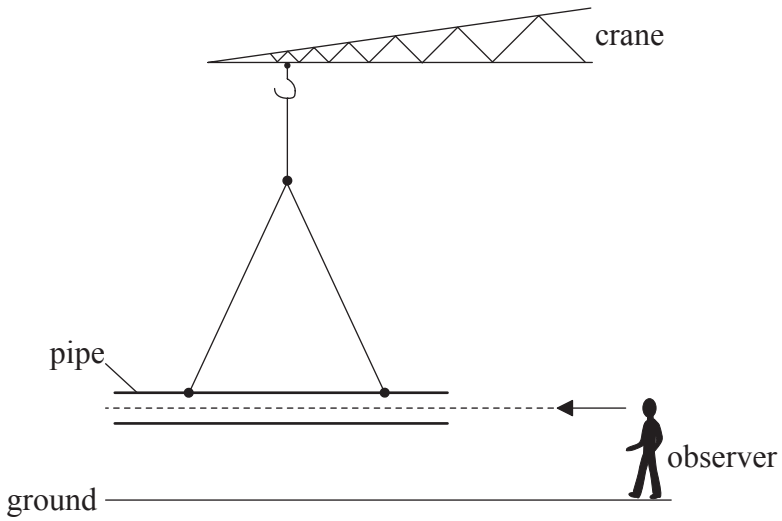
(Question 4 continued)

(b) A hollow pipe open at both ends is suspended just above the ground on a construction site.



(not to scale)

Wind blows across one end of the pipe. This causes a standing wave to form in the air of the pipe, producing the first harmonic (fundamental). The pipe has a length of 2.1 m and the speed of sound in air is $330\,m\,s^{-1}$.

Estimate the frequency of the first harmonic (fundamental) standing wave. *[2]*

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(Question 4 continued)

(c) The pipe is held stationary by the crane and an observer runs towards the pipe. Outline how the frequency of the sound measured by the observer is different from the frequency of the sound emitted by the pipe. *[3]*

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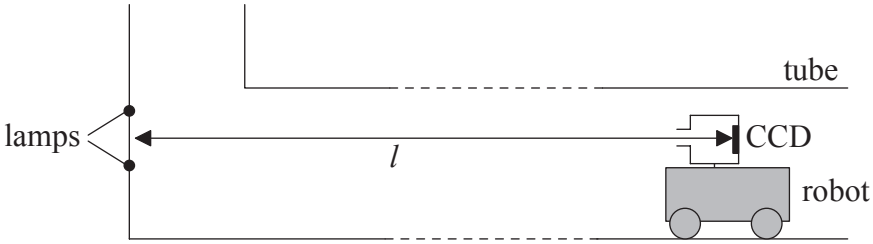
(Question 4 continued)

(d) The pipe is joined to other pipes to form a continuous tube that is used to transport gases. At one end of the tube is a pair of lamps 60 mm apart which guide a welding robot that moves along the tube. The lamps are detected by a charge-coupled device (CCD).



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(i) The square pixels in the CCD that senses the light are 6.7×10^{-4} mm on each side. Calculate the required magnification of the CCD so that images of the lamps can be resolved on the CCD. *[2]*

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(ii) In fact, the resolution of the system is limited by diffraction effects.

The CCD has an aperture diameter of 0.85 mm. The lamps emit light of wavelength 450 nm. At a certain distance l between the lamps and the CCD, the images of the lamps are just resolved according to the Rayleigh criterion. Determine l. *[2]*

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5. This question is about generating emfs.

(a) Define *magnetic flux*. *[1]*

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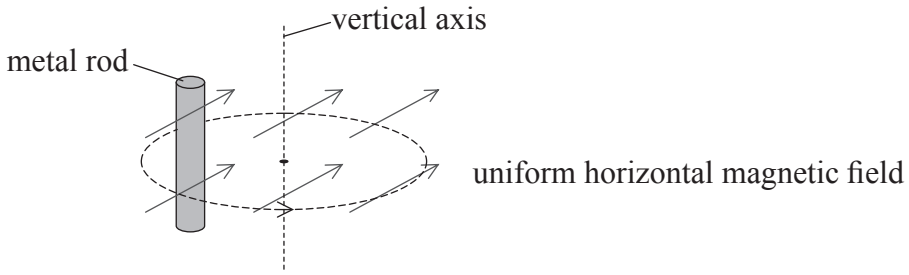
(b) A vertical metal rod of length 0.25 m moves in a horizontal circle about a vertical axis in a uniform horizontal magnetic field.



The metal rod completes one circle of radius 0.060 m in 0.020 s in the magnetic field of strength 61 mT.

(i) Determine the maximum emf induced between the ends of the metal rod. *[3]*

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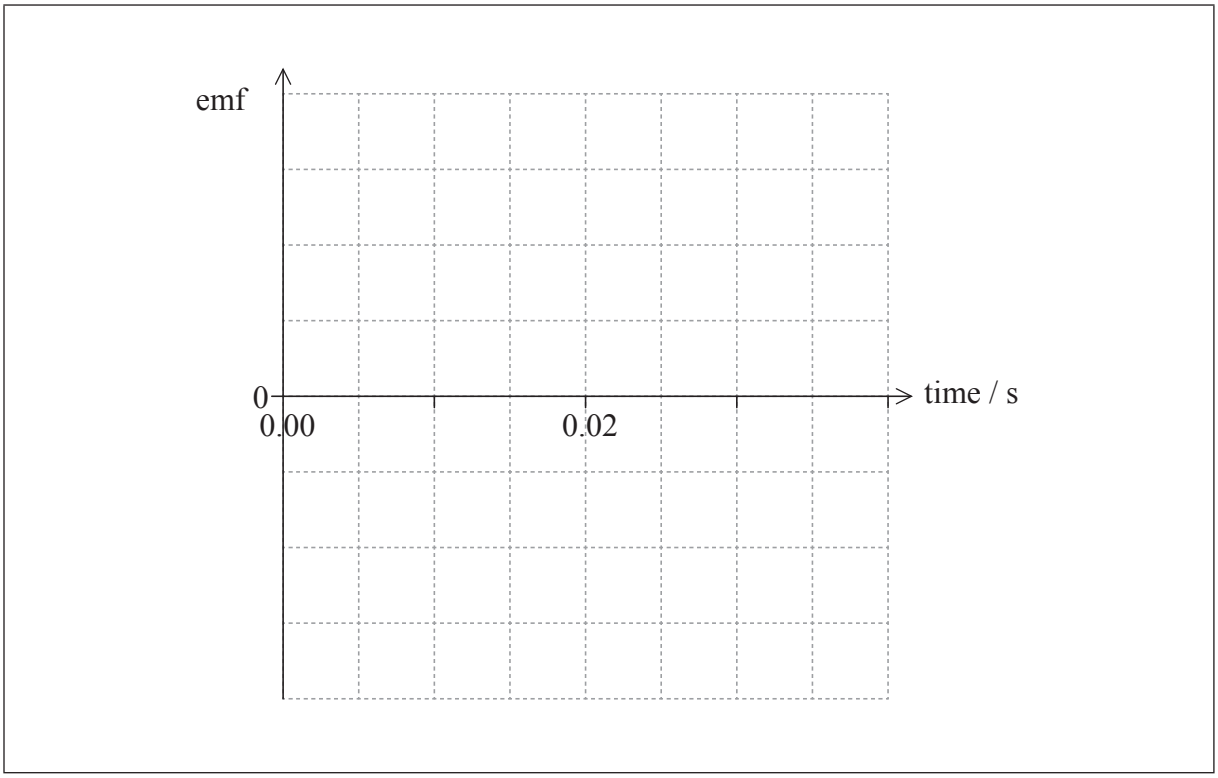
(Question 5 continued)

(ii) Using the axes, sketch a graph to show the variation with time of the emf of the metal rod. *[2]*



SECTION B

*This section consists of four questions: 6, 7, 8 and 9. Answer **two** questions. Write your answers in the boxes provided.*

6. This question is in **two** parts. **Part 1** is about the use of renewable energy sources. **Part 2** is about the gravitational potential of the Earth.

Part 1 Renewable energy sources

(a) State the difference between renewable and non-renewable energy sources. *[1]*

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(b) Electrical energy is obtained from tidal energy at La Rance in France.

Water flows into a river basin from the sea for six hours and then flows from the basin back to the sea for another six hours. The water flows through turbines and generates energy during both flows.

The following data are available.

Area of river basin	$= 22\,\text{km}^2$
Change in water level of basin over six hours	$= 6.0\,\text{m}$
Density of water	$= 1000\,\text{kg m}^{-3}$

(i) The basin empties over a six hour period. Show that about $6000\,\text{m}^3$ of water flows through the turbines every second. *[2]*

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(Question 6, part 1 continued)

(ii) Show that the average power that the water can supply over the six hour period is about 0.2 GW. *[3]*

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(iii) La Rance tidal power station has an energy output of 5.4×10^{8} kW h per year. Calculate the overall efficiency of the power station. Assume that the water can supply 0.2 GW at all times. *[3]*

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(Question 6, part 1 continued)

(c) Energy resources such as La Rance tidal power station could replace the use of fossil fuels. This may result in an increase in the average albedo of Earth.

(i) State **two** reasons why the albedo of Earth must be given as an average value. *[2]*

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(ii) Suggest, with reference to the enhanced greenhouse effect, why the reduction in the use of fossil fuels could lead to an increase in the average albedo of Earth. *[4]*

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(Question 6 continued from page 16)

Part 2 Gravitational potential of the Earth

(d) The table gives the gravitational potential V for various distances r from the **surface** of Earth. The radius of Earth is 6.4×10^3 km.

V / 10^7 J kg^{-1}	r / 10^3 km
−6.24	0
−3.84	4.0
−1.04	32

Show that the data are consistent with Earth acting as a point mass with its mass concentrated at its centre. *[3]*

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(Question 6, part 2 continued)

(e) A satellite of mass 780 kg is put into circular orbit 4.0×10^3 km above the surface of the Earth. It is then moved to a higher orbit 3.2×10^4 km above the surface.

Calculate, for the satellite as it is moved from the lower orbit to the higher orbit, the change in

(i) the gravitational potential energy. *[2]*

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(ii) kinetic energy. *[2]*

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(iii) total energy. *[3]*

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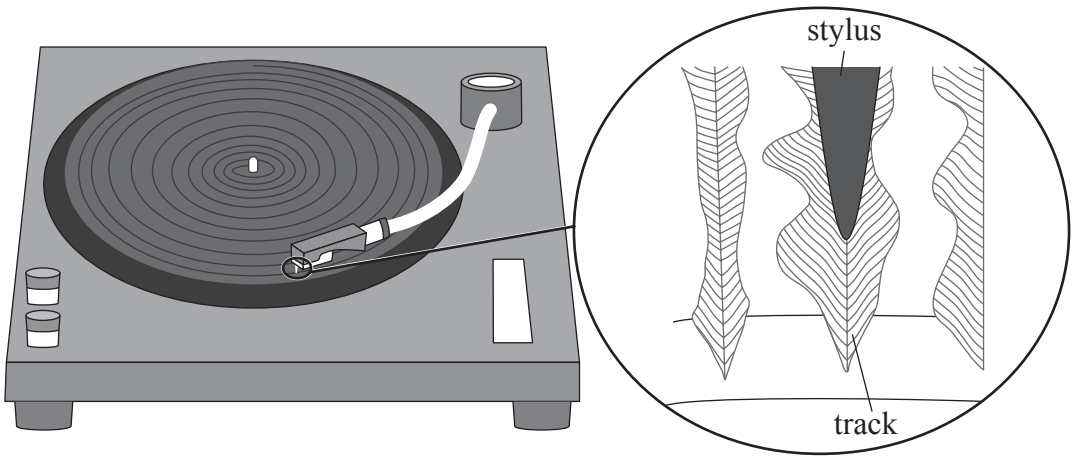
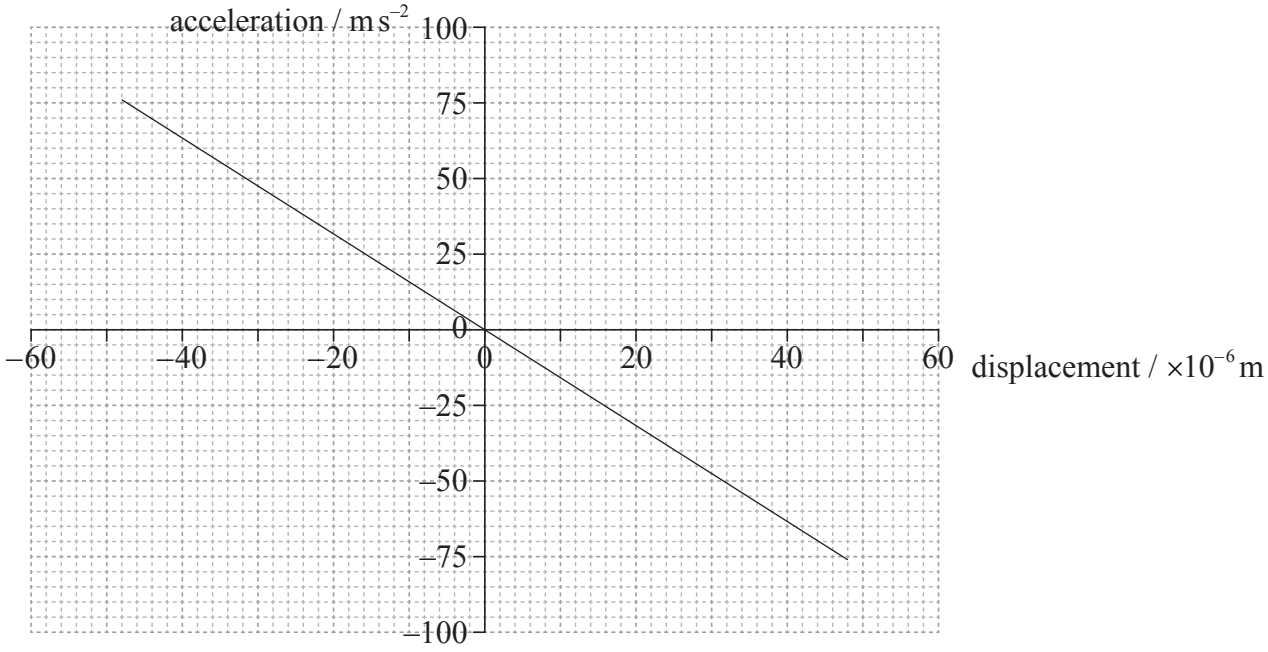
7. This question is about simple harmonic motion (SHM) and sound.

The diagram shows a section of continuous track of a long-playing (LP) record. The stylus (needle) is placed in the track of the record.



As the LP record rotates, the stylus moves because of changes in the width and position of the track. These movements are converted into sound waves by an electrical system and a loudspeaker.

A recording of a single-frequency musical note is played. The graph shows the variation in horizontal acceleration of the stylus with horizontal displacement.



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(Question 7 continued)

(a) Explain why the graph shows that the stylus undergoes simple harmonic motion. *[4]*

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(b) Using the graph on page 20, show that the frequency of the note being played is about 200 Hz. *[4]*

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(c) (i) The mass of the stylus is 5.5×10^{-4} kg. Determine the maximum kinetic energy of the stylus. *[2]*

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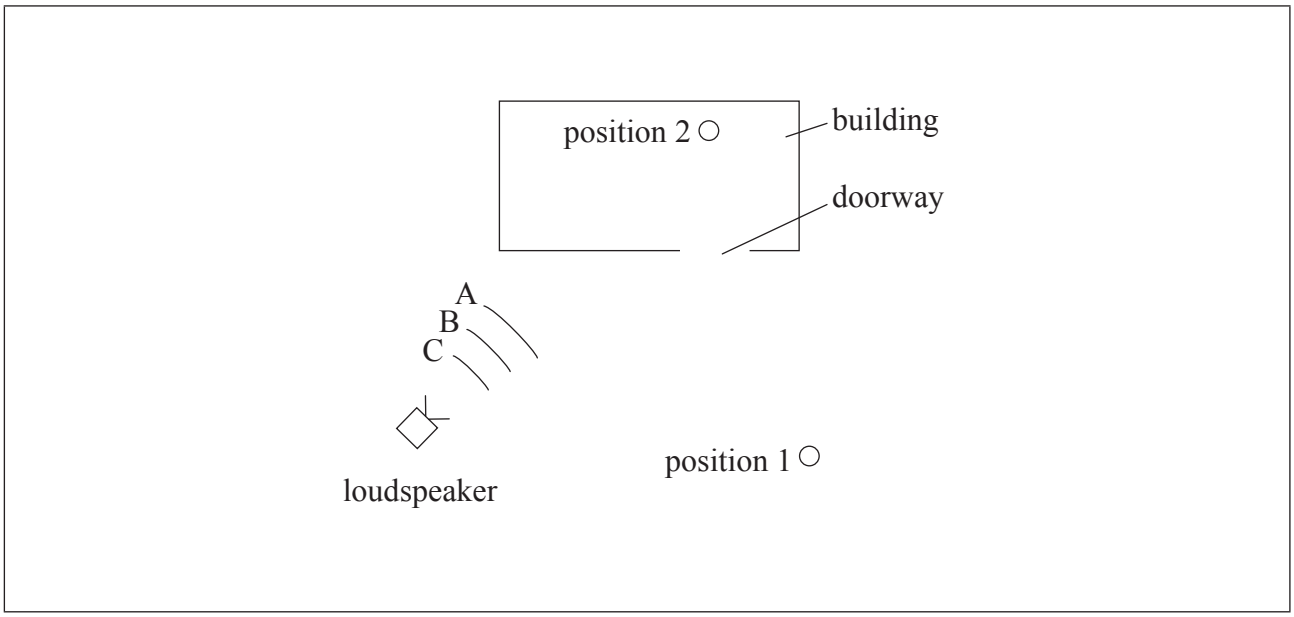
(ii) On the graph on page 20, identify, with the letter P, the position of the stylus at which the kinetic energy is at a maximum. *[1]*

(This question continues on the following page)

(Question 7 continued)

(d) The sound from the LP record is sent to a loudspeaker which is outside a building. The loudspeaker emits a sound wave that has the same frequency as the recorded note.

A person standing at position 1 outside the building and a person standing at position 2 inside the building both hear the sound emitted by the loudspeaker.



A, B and C are wavefronts emitted by the loudspeaker.

(i) Draw rays to show how the person at **position 1** is able to hear the sound emitted by the loudspeaker. *[1]*

(ii) The speed of sound in the air is $330\,m\,s^{-1}$. Calculate the wavelength of the note. *[1]*

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(This question continues on the following page)

(Question 7 continued)

(iii) The doorway to the building is 1.5 m wide. The internal walls of the building are designed to absorb all sound. Explain how the person at **position 2** is able to hear the sound emitted by the loudspeaker. *[3]*

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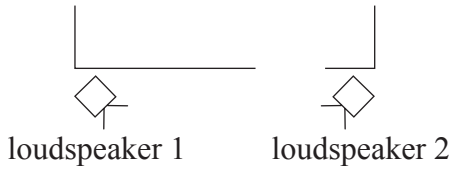
(e) The arrangement in (d) is changed and another loudspeaker is added. Both loudspeakers emit the same recorded note in phase with each other.



Outline why there are positions between the loudspeakers where the sound can only be heard faintly. *[3]*

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(Question 7 continued)

(f) The LP record used is an analogue storage device. State **one** other example of a device that stores audio information in an analogue form and outline how it stores information. *[2]*

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(g) The Digital Versatile Disc (DVD) stores both audio and video in a digital form. The video images are collected via a charge-coupled device (CCD) in which incident light causes charge to be stored on an array of pixels. Describe how a stored digital signal of the image can be obtained from the pixels. *[4]*

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(Section B continues on page 26)

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8. This question is in **two** parts. **Part 1** is about electric cells. **Part 2** is about atoms.

Part 1 Electric cells

(a) Cells used to power small electrical devices contain both conductors and insulators. Cells also have the property of internal resistance.

(i) Distinguish between an insulator and a conductor. *[2]*

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(ii) Outline what is meant by the internal resistance of a cell. *[2]*

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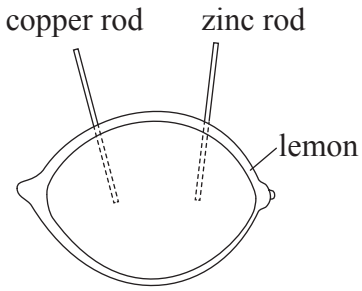
(b) A lemon can be used to make an electric cell by pushing a copper rod and a zinc rod into the lemon.



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(Question 8, part 1 continued)

A student constructs a lemon cell and connects it in an electrical circuit with a variable resistor. The student measures the potential difference V across the lemon and the current I in the lemon.

(i) Draw a circuit diagram of the experimental arrangement that will enable the student to collect the data for the graph. *[2]*

(ii) Show that the potential difference V across the lemon is given by

$$V = E - Ir$$

where E is the emf of the lemon cell and r is the internal resistance of the lemon cell. *[2]*

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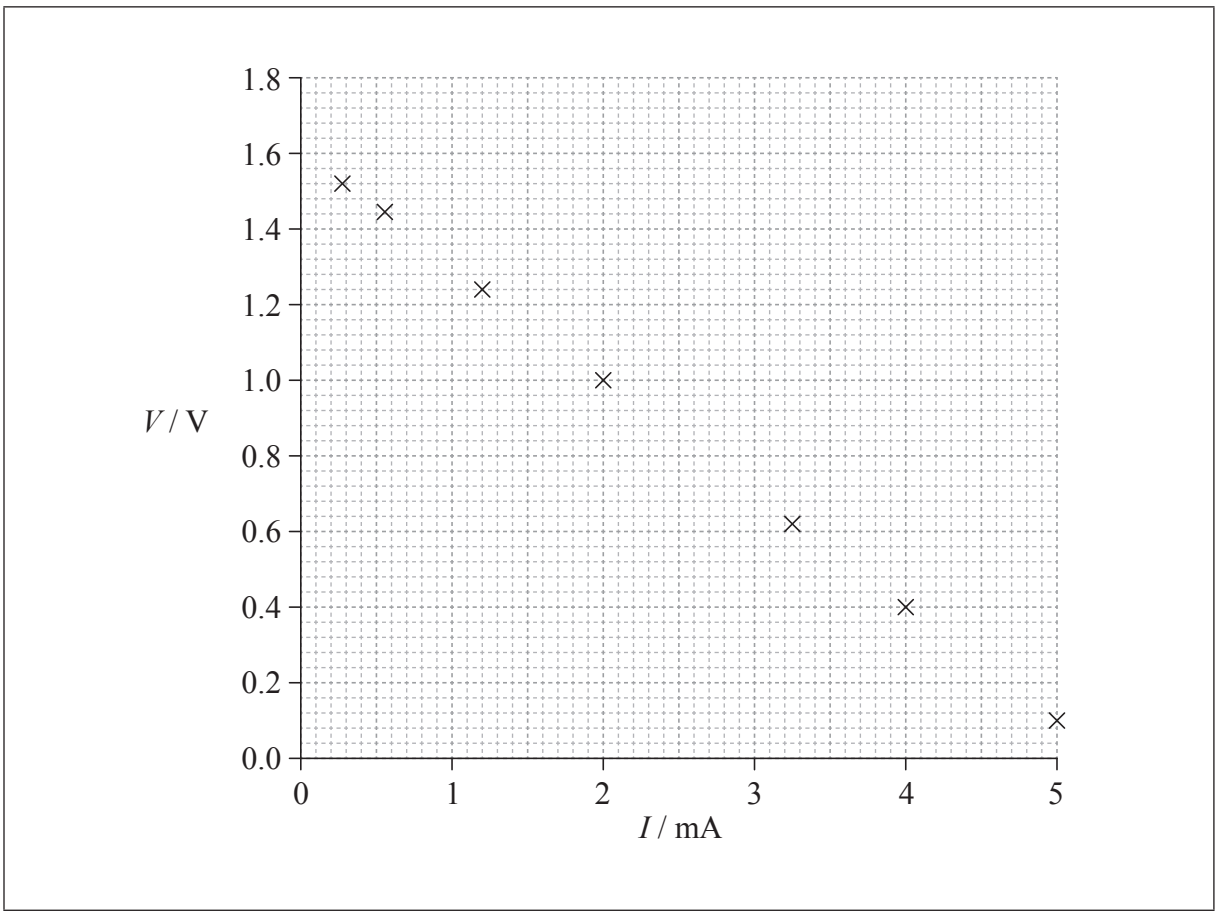
(Question 8, part 1 continued)

(iii) The graph shows how V varies with I.



Using the graph, estimate the emf of the lemon cell. *[2]*

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(Question 8, part 1 continued)

(iv) Determine the internal resistance of the lemon cell. *[3]*

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(v) The lemon cell is used to supply energy to a digital clock that requires a current of 6.0 μA. The clock runs for 16 hours. Calculate the charge that flows through the clock in this time. *[1]*

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(vi) Calculate the energy transferred by the lemon cell in 16 hours. *[1]*

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(Question 8 continued)

Part 2 Atoms

(c) State what is meant by the photoelectric effect. *[1]*

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(d) Photoelectric emission occurs when ultraviolet radiation is incident on the surface of mercury but not when visible light is incident on the metal. Photoelectric emission occurs when visible light of all wavelengths is incident on caesium.

(i) Suggest why the work function for caesium is smaller than that of mercury. *[1]*

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(ii) Ultraviolet radiation of wavelength 210 nm is incident on the surface of mercury. The work function for mercury is 4.5 eV. Determine the maximum kinetic energy of the photoelectrons emitted. *[3]*

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(Question 8, part 2 continued)

(e) Explain how discrete energy levels arise in the "electron in a box" model of the atom. *[2]*

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(f) An exact determination of the location of the electron in a hydrogen atom is not possible. Outline how this statement is consistent with the Schrödinger model of the hydrogen atom. *[3]*

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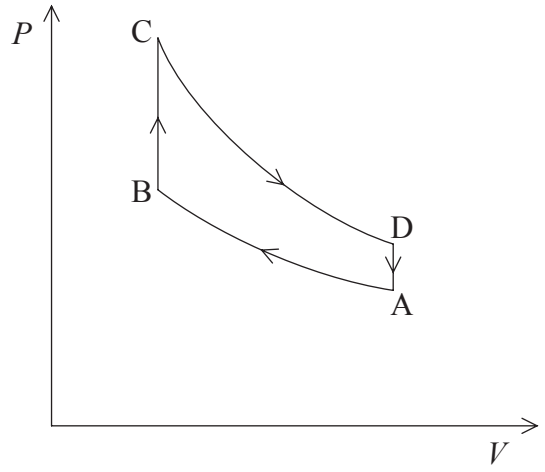
9. This question is about the thermodynamics of a car engine and the dynamics of the car.

A car engine consists of four cylinders. In each of the cylinders, a fuel-air mixture explodes to supply power at the appropriate moment in the cycle.

The diagram models the variation of pressure P with volume V for one cycle of the gas, ABCDA, in one of the cylinders of the engine. The gas in the cylinder has a fixed mass and can be assumed to be ideal.



(a) At point A in the cycle, the fuel-air mixture is at 18 °C. During process AB, the gas is compressed to 0.046 of its original volume and the pressure increases by a factor of 40. Calculate the temperature of the gas at point B. *[1]*

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(b) State the nature of the change in the gas that takes place during process BC in the cycle. *[1]*

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(This question continues on the following page)

(Question 9 continued)

(c) Process CD is an adiabatic change. Discuss, with reference to the first law of thermodynamics, the change in temperature of the gas in the cylinder during process CD. *[3]*

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(d) Explain how the diagram can be used to calculate the net work done during one cycle. *[2]*

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(Question 9 continued)

(e) The car is travelling at its maximum speed of $56\,m\,s^{-1}$. At this speed, the energy provided by the fuel injected into one cylinder in each cycle is 9200 J. One litre of fuel provides 56 MJ of energy.

(i) Calculate the volume of fuel injected into one cylinder during one cycle. *[1]*

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(ii) Each of the four cylinders completes a cycle 18 times every second. Calculate the distance the car can travel on one litre of fuel at a speed of $56\,m\,s^{-1}$. *[2]*

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(f) The car accelerates uniformly along a straight horizontal road from an initial speed of $12\,m\,s^{-1}$ to a final speed of $28\,m\,s^{-1}$ in a distance of 250 m. The mass of the car is 1200 kg. Determine the rate at which the engine is supplying kinetic energy to the car as it accelerates. *[4]*

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(Question 9 continued)

(g) Later, the car is travelling along the straight horizontal road at its maximum speed of $56\,m\,s^{-1}$. The power output required at the wheels is 0.13 MW.

(i) Calculate the total resistive force acting on the car when it is travelling at a constant speed of $56\,m\,s^{-1}$. *[2]*

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(ii) The mass of the car is 1200 kg. The resistive force F is related to the speed v by $F \propto v^2$. Using your answer to (g)(i), determine the maximum theoretical acceleration of the car at a speed of $28\,m\,s^{-1}$. *[3]*

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(Question 9 continued)

(h) A driver moves the car in a horizontal circular path of radius 200 m. Each of the four tyres will not grip the road if the frictional force between a tyre and the road becomes less than 1500 N.

(i) Calculate the maximum speed of the car at which it can continue to move in the circular path. Assume that the radius of the path is the same for each tyre. *[3]*

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(ii) While the car is travelling around the circle, the people in the car have the sensation that they are being thrown outwards. Outline how Newton's first law of motion accounts for this sensation. *[3]*

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