Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Monday 15 May 2017 (afternoon)

2 hours 15 minutes

Candidate session number

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 **[95 marks]**.

28EP01

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

1.   A glider is an aircraft with no engine. To be launched, a glider is uniformly accelerated from rest by a cable pulled by a motor that exerts a horizontal force on the glider throughout the launch.
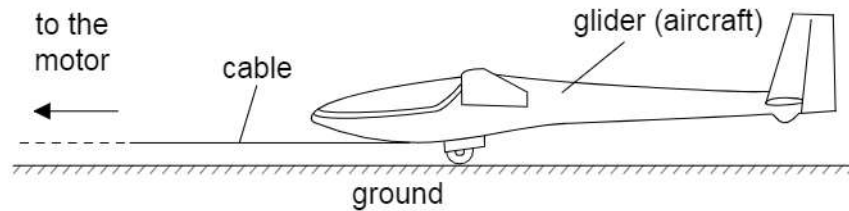
(a)   The glider reaches its launch speed of $27.0\,m\,s^{-1}$ after accelerating for $11.0\,s$. Assume that the glider moves horizontally until it leaves the ground. Calculate the total distance travelled by the glider before it leaves the ground.   [2]

(b)   The glider and pilot have a total mass of $492\,kg$. During the acceleration the glider is subject to an average resistive force of $160\,N$. Determine the average tension in the cable as the glider accelerates.   [3]

(This question continues on the following page)

(Question 1 continued)

    (c)   The cable is pulled by an electric motor. The motor has an overall efficiency of 23 %.
             Determine the average power input to the motor.   [3]

    (d)   After takeoff the cable is released and the unpowered glider moves horizontally at
             constant speed. The wings of the glider provide a lift force. The diagram shows the
             lift force acting on the glider and the direction of motion of the glider.

vertical

direction of
motion

lift force
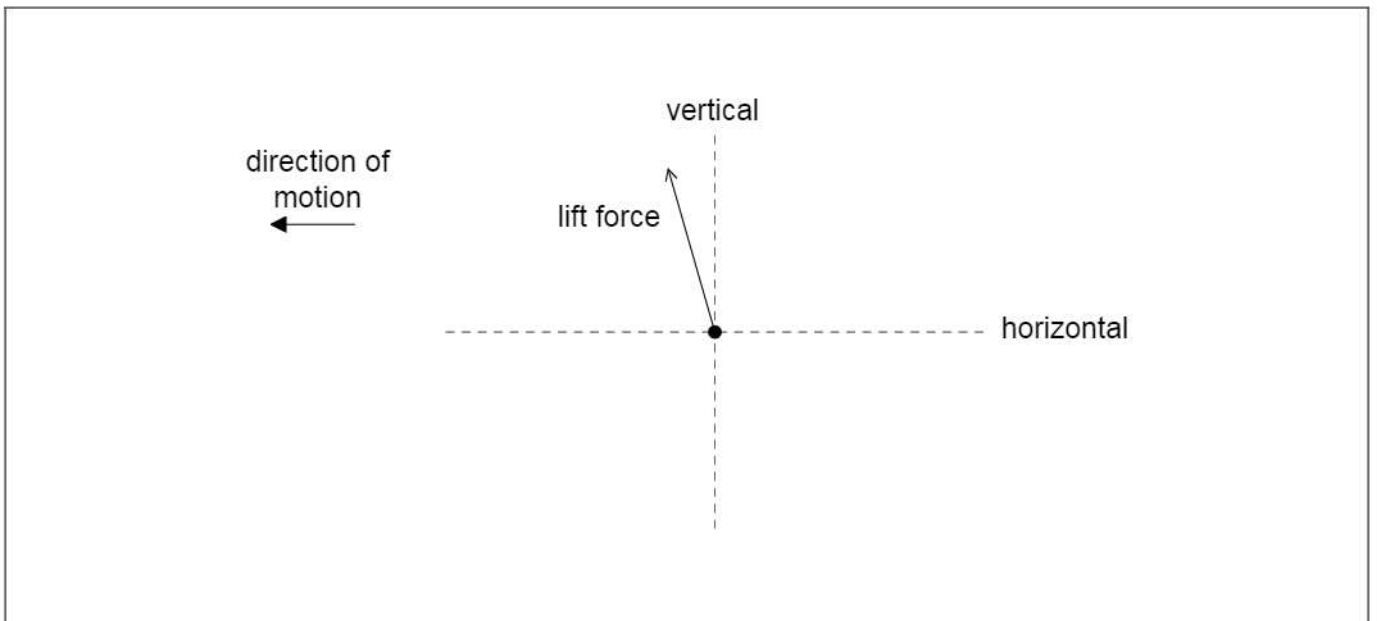
horizontal

             Draw the forces acting on the glider to complete the free-body diagram. The dotted lines
             show the horizontal and vertical directions.   [2]

Turn over

2.   (a)   Outline the conditions necessary for simple harmonic motion (SHM) to occur.   [2]

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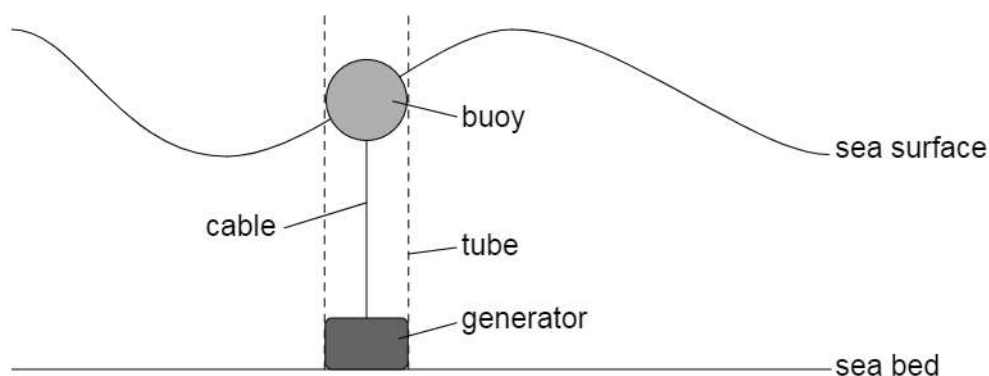..

(b)   A buoy, floating in a vertical tube, generates energy from the movement of water waves
on the surface of the sea. When the buoy moves up, a cable turns a generator on the
sea bed producing power. When the buoy moves down, the cable is wound in by a
mechanism in the generator and no power is produced.

The motion of the buoy can be assumed to be simple harmonic.

(i)   A wave of amplitude 4.3 m and wavelength 35 m, moves with a speed of
3.4 m s^{-1}. Calculate the maximum vertical speed of the buoy.   [3]

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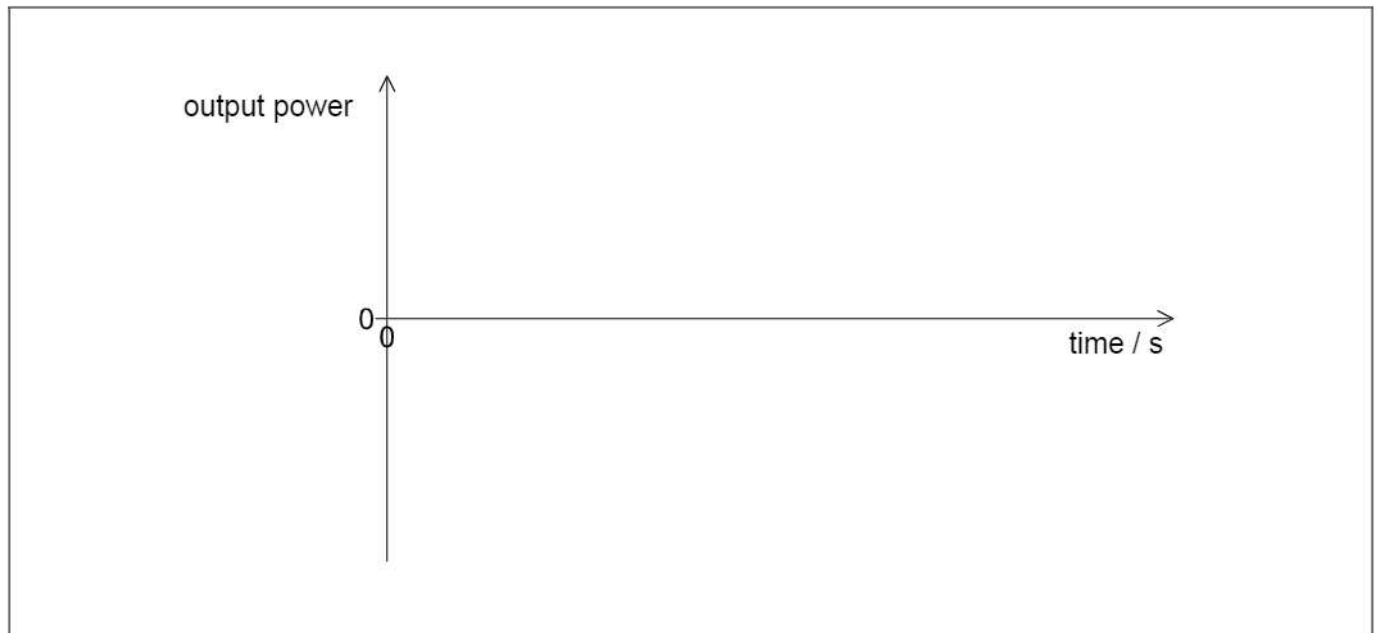
(This question continues on the following page)

(Question 2 continued)

   (ii)   Sketch a graph to show the variation with time of the generator output power.
          Label the time axis with a suitable scale.   [2]

output power

0

0   time / s

(This question continues on the following page)

Turn over

(Question 2 continued)

(c)   Water can be used in other ways to generate energy.

(i)   Outline, with reference to energy changes, the operation of a pumped storage hydroelectric system. [2]

(ii)   The water in a particular pumped storage hydroelectric system falls a vertical distance of 270 m to the turbines. Calculate the speed at which water arrives at the turbines. Assume that there is no energy loss in the system. [2]

(iii)   The hydroelectric system has four 250 MW generators. Determine the maximum time for which the hydroelectric system can maintain full output from the stored energy when a mass of 1.5×10^{10} kg of water passes through the turbines. [2]

(This question continues on the following page)
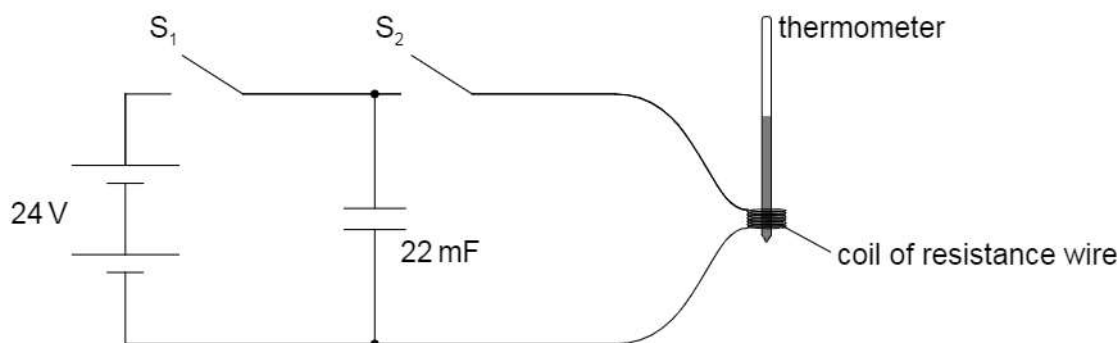
(Question 2 continued)

      (iv)   Not all the stored energy can be retrieved because of energy losses in the system. Explain **two** such losses. [2]

1. . . . .

2. . . . .

Turn over

3. The electrical circuit shown is used to investigate the temperature change in a wire that is wrapped around a mercury-in-glass thermometer.

A power supply of emf (electromotive force) 24 V and of negligible internal resistance is connected to a capacitor and to a coil of resistance wire using an arrangement of two switches. Switch S_1 is closed and, a few seconds later, opened. Then switch S_2 is closed.

(a) The capacitance of the capacitor is 22 mF. Calculate the energy stored in the capacitor when it is fully charged. [1]

(b) The resistance of the wire is 8.0 Ω. Determine the time taken for the capacitor to discharge through the resistance wire. Assume that the capacitor is completely discharged when the potential difference across it has fallen to 0.24 V. [3]

(This question continues on the following page)

(Question 3 continued)

(c)   (i)   The mass of the resistance wire is 0.61 g and its observed temperature rise is 28 K. Estimate the specific heat capacity of the wire. Include an appropriate unit for your answer.   [2]

(ii)   Suggest **one** other energy loss in the experiment and the effect it will have on the value for the specific heat capacity of the wire.   [2]

4.   A student investigates how light can be used to measure the speed of a toy train.

direction of travel

double slit

laser light →   1.5 mm

toy train

light sensor

5.0 m

(not to scale)
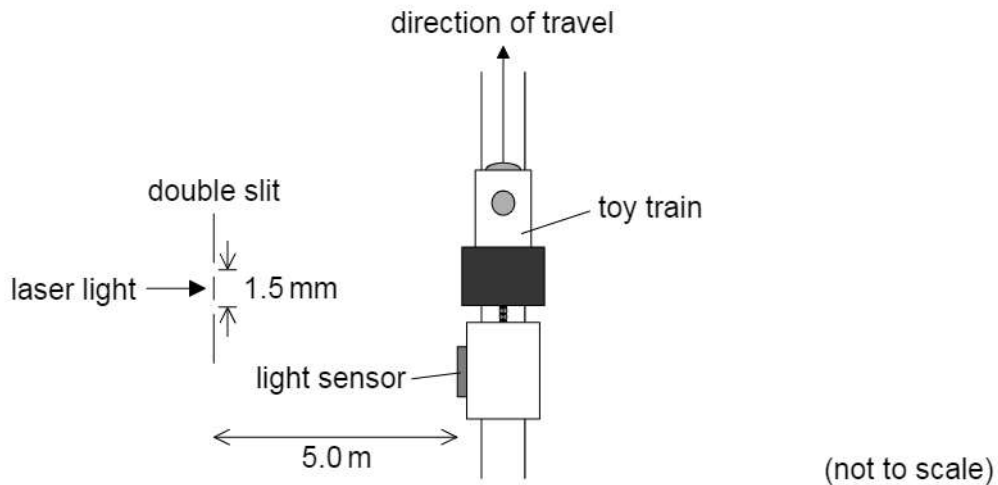
Light from a laser is incident on a double slit. The light from the slits is detected by a light sensor attached to the train.

The graph shows the variation with time of the output voltage from the light sensor as the train moves parallel to the slits. The output voltage is proportional to the intensity of light incident on the sensor.

output voltage

0
    0   25   50   75   100

time / ms
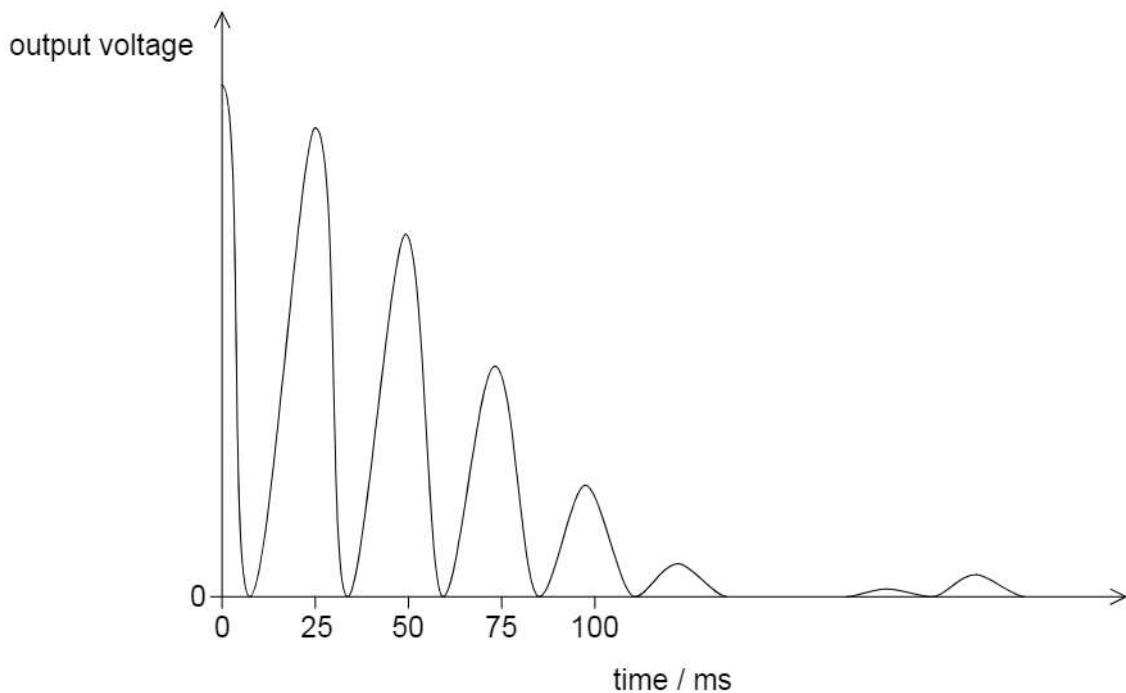
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(Question 4 continued)

    (a)　Explain, with reference to the light passing through the slits, why a series of voltage peaks occurs.　　　[3]

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    (b)　(i)　The slits are separated by 1.5 mm and the laser light has a wavelength of 6.3×10^{-7} m. The slits are 5.0 m from the train track. Calculate the separation between two adjacent positions of the train when the output voltage is at a maximum.　　　[1]

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        (ii)　Estimate the speed of the train.　　　[2]

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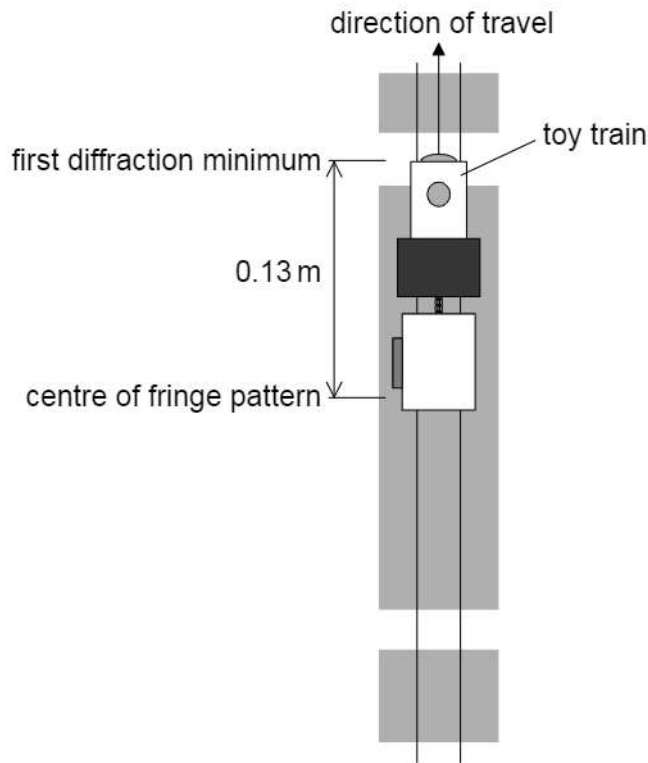...

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(Question 4 continued)

(c)   As the train continues to move, the first diffraction minimum is observed when the light sensor is at a distance of 0.13 m from the centre of the fringe pattern.

(not to scale)

(i)   Determine the width of one of the slits.   [2]

(ii)   Suggest the variation in the output voltage from the light sensor that will be observed as the train moves beyond the first diffraction minimum.   [2]
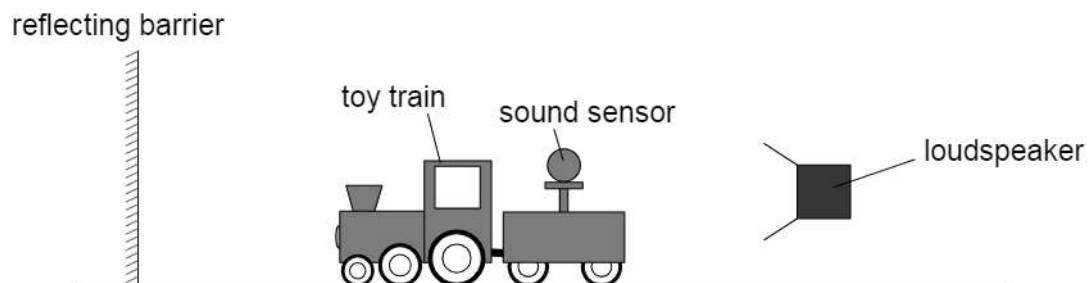
**(This question continues on the following page)**

(Question 4 continued)

(d)   In another experiment the student replaces the light sensor with a sound sensor. The train travels away from a loudspeaker that is emitting sound waves of constant amplitude and frequency towards a reflecting barrier.

The graph shows the variation with time of the output voltage from the sounds sensor.
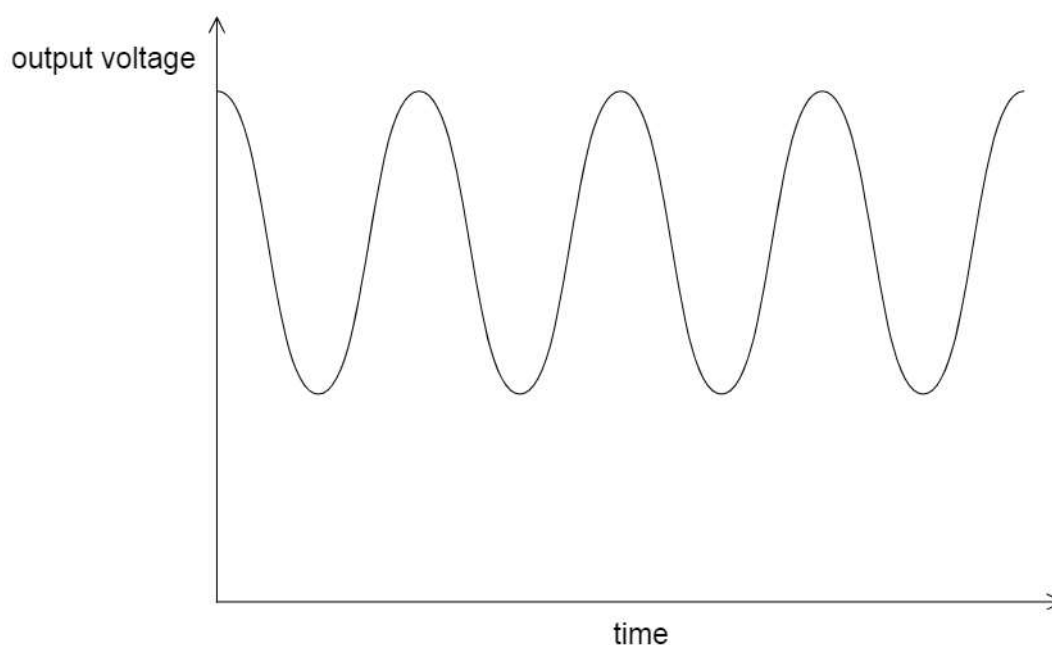
Explain how this effect arises.   [2]

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Turn over

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be marked.

5.   The first scientists to identify alpha particles by a direct method were Rutherford and Royds. They knew that radium-226 ($^{226}_{88}$Ra) decays by alpha emission to form a nuclide known as radon (Rn).
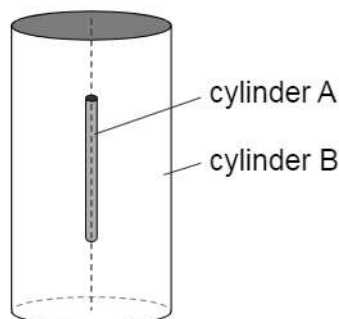
(a)   Write down the nuclear equation for this decay.   [2]

(This question continues on the following page)

Turn over

(Question 5 continued)

(b)　At the start of the experiment, Rutherford and Royds put 6.2×10^{-4} mol of pure radium-226 in a small closed cylinder A. Cylinder A is fixed in the centre of a larger closed cylinder B.

cylinder A

cylinder B

The experiment lasted for 6 days. The decay constant of radium-226 is $1.4 \times 10^{-11}\,\text{s}^{-1}$.

(i)　Deduce that the activity of the radium-226 is almost constant during the experiment.　[2]

(ii)　Show that about 3×10^{15} alpha particles are emitted by the radium-226 in 6 days.　[3]

(This question continues on the following page)

(Question 5 continued)

    (c)   At the start of the experiment, all the air was removed from cylinder B. The alpha particles combined with electrons as they moved through the wall of cylinder A to form helium gas in cylinder B.

        (i)   The wall of cylinder A is made from glass. Outline why this glass wall had to be very thin. [1]

        (ii)   The experiment was carried out at a temperature of $18\,°C$. The volume of cylinder B was $1.3 \times 10^{-5}\,m^3$ and the volume of cylinder A was negligible. Calculate the pressure of the helium gas that was collected in cylinder B over the 6 day period. Helium is a monatomic gas. [3]

(This question continues on the following page)

(Question 5 continued)

(d)   Rutherford and Royds identified the helium gas in cylinder B by observing its
emission spectrum. Outline, with reference to atomic energy levels, how an
emission spectrum is formed.   [3]

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(e)   The work was first reported in a peer-reviewed scientific journal. Outline why
Rutherford and Royds chose to publish their work in this way.   [1]

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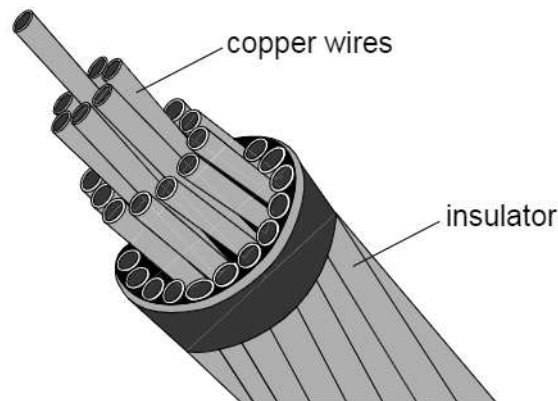
6.   A cable consisting of many copper wires is used to transfer electrical energy from an
      alternating current (ac) generator to an electrical load. The copper wires are protected by
      an insulator.

      (a)   The copper wires and insulator are both exposed to an electric field. Discuss,
             with reference to charge carriers, why there is a significant electric current only in
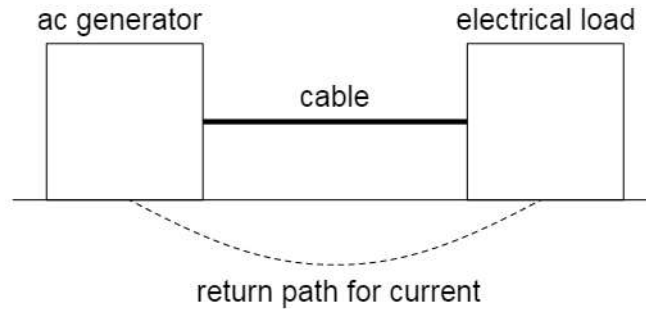   the copper wires.   [3]

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(This question continues on the following page)

(Question 6 continued)

(b) The cable consists of 32 copper wires each of length 35 km. Each wire has a resistance of 64 Ω. The cable is connected to the ac generator which has an output power of 110 MW when the peak potential difference is 150 kV. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega\,m$.

output power = 110 MW

ac generator   electrical load

cable

return path for current

(i) Calculate the radius of each **wire**. [2]

(ii) Calculate the peak current in the **cable**. [1]

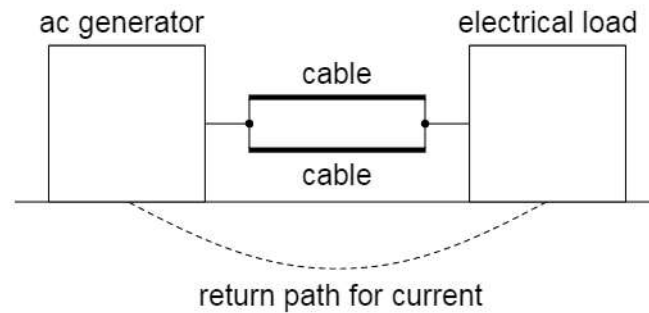(iii) Determine the power dissipated in the cable per unit length. [3]

(This question continues on the following page)

(Question 6 continued)

(c)   To ensure that the power supply cannot be interrupted, two identical cables are connected in parallel.

Calculate the root mean square (rms) current in each cable.   [1]

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(d)   The two cables in part (c) are suspended a constant distance apart. Explain how the magnetic forces acting between the cables vary during the course of one cycle of the alternating current (ac).   [2]

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(Question 6 continued from page 21)

(e)   The energy output of the ac generator is at a much lower voltage than the 150 kV used for transmission. A step-up transformer is used between the generator and the cables.

(i)   Suggest the advantage of using a step-up transformer in this way.   [2]

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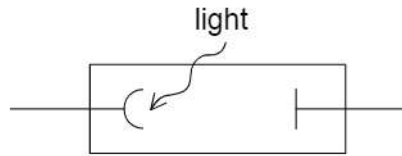
(ii)   The use of alternating current (ac) in a transformer gives rise to energy losses. State how eddy current loss is minimized in the transformer.   [1]

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7. **(a)** Yellow light of photon energy 3.5×10^{-19} J is incident on the surface of a particular photocell.

    (i) Calculate the wavelength of the light. [1]

    (ii) Electrons emitted from the surface of the photocell have almost no kinetic energy. Explain why this does **not** contradict the law of conservation of energy. [2]

(b) Radiation of photon energy 5.2×10^{-19} J is now incident on the photocell. Calculate the maximum velocity of the emitted electrons. [2]
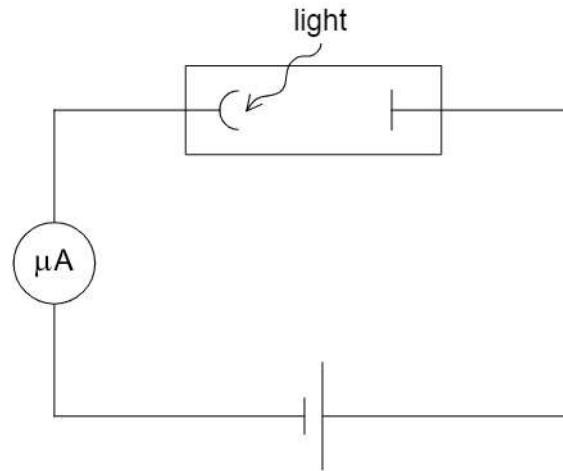
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28EP24

(Question 7 continued)

(c)   The photocell is connected to a cell as shown. The photoelectric current is at its maximum value (the saturation current).

Radiation with a greater photon energy than that in (b) is now incident on the photocell. The intensity of this radiation is the same as that in (b).

(i)   Describe the change in the number of photons per second incident on the surface of the photocell.   [1]

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(ii)   State and explain the effect on the maximum photoelectric current as a result of increasing the photon energy in this way.   [3]

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Turn over

8. The gravitational potential due to the Sun at its surface is -1.9×10^{11} J kg^{-1}. The following data are available.

$$
\begin{aligned}
\text{Mass of Earth} &= 6.0 \times 10^{24} \text{ kg} \\
\text{Distance from Earth to Sun} &= 1.5 \times 10^{11} \text{ m} \\
\text{Radius of Sun} &= 7.0 \times 10^{8} \text{ m}
\end{aligned}
$$

(a)   Outline why the gravitational potential is negative.   [2]

(b)   (i)   The gravitational potential due to the Sun at a distance r from its centre is V_S. Show that

$$rV_S = \text{constant}.$$ [1]

(ii)   Calculate the gravitational potential energy of the Earth in its orbit around the Sun. Give your answer to an appropriate number of significant figures.   [2]

(This question continues on the following page)

(Question 8 continued)

(iii)   Calculate the total energy of the Earth in its orbit.   [2]

(iv)   An asteroid strikes the Earth and causes the orbital speed of the Earth to suddenly decrease. Suggest the ways in which the orbit of the Earth will change.   [2]

(c)   Outline, in terms of the force acting on it, why the Earth remains in a circular orbit around the Sun.   [2]

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Answers written on this page
will not be marked.