Diploma Programme
Programme du diplôme
Programa del Diploma

**Physics
Higher level
Paper 2**

Friday 6 May 2016 (morning)

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.
- 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]**.

24 pages

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

1.   A company designs a spring system for loading ice blocks onto a truck. The ice block is placed in a holder H in front of the spring and an electric motor compresses the spring by pushing H to the left. When the spring is released the ice block is accelerated towards a ramp ABC. When the spring is fully decompressed, the ice block loses contact with the spring at A. The mass of the ice block is 55 kg.
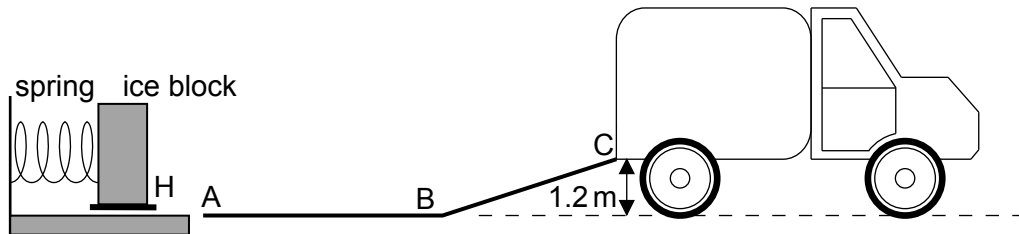
Assume that the surface of the ramp is frictionless and that the masses of the spring and the holder are negligible compared to the mass of the ice block.

(a)   (i)   The block arrives at C with a speed of $0.90\,\mathrm{m\,s^{-1}}$. Show that the elastic energy stored in the spring is 670 J.   [2]

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      (ii)   Calculate the speed of the block at A.   [2]

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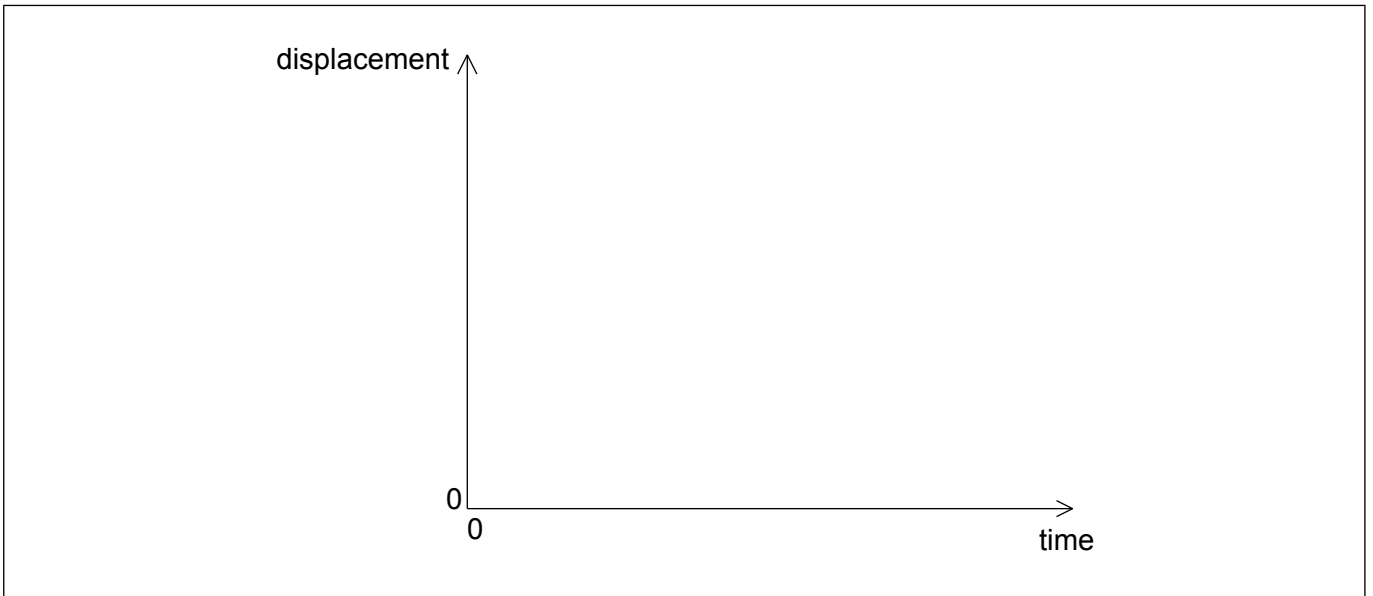**(Question 1 continued)**

(b)   Describe the motion of the block

(i)   from A to B with reference to Newton's first law.   [1]

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(ii)   from B to C with reference to Newton's second law.   [2]

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(c)   On the axes, sketch a graph to show how the displacement of the block varies with
time from A to C. (You do not have to put numbers on the axes.)   [2]

displacement

0

0   time

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(Question 1 continued)

(d)   The spring decompression takes 0.42 s. Determine the average force that the spring
      exerts on the block.   [2]

(e)   The electric motor is connected to a source of potential difference 120 V and draws a
      current of 6.8 A. The motor takes 1.5 s to compress the spring.

      Estimate the efficiency of the motor.   [2]

(f)   On a particular day, the ice blocks experience a frictional force because the section
      of the ramp from A to B is not cleaned properly. The coefficient of dynamic friction
      between the ice blocks and the ramp AB is 0.030. The length of AB is 2.0 m.

      Determine whether the ice blocks will be able to reach C.   [2]

2. The diagram shows a planet near two stars of equal mass M.

planet
●

○   ○
|←———— 6.8×10^{11} m ————→|
star   star
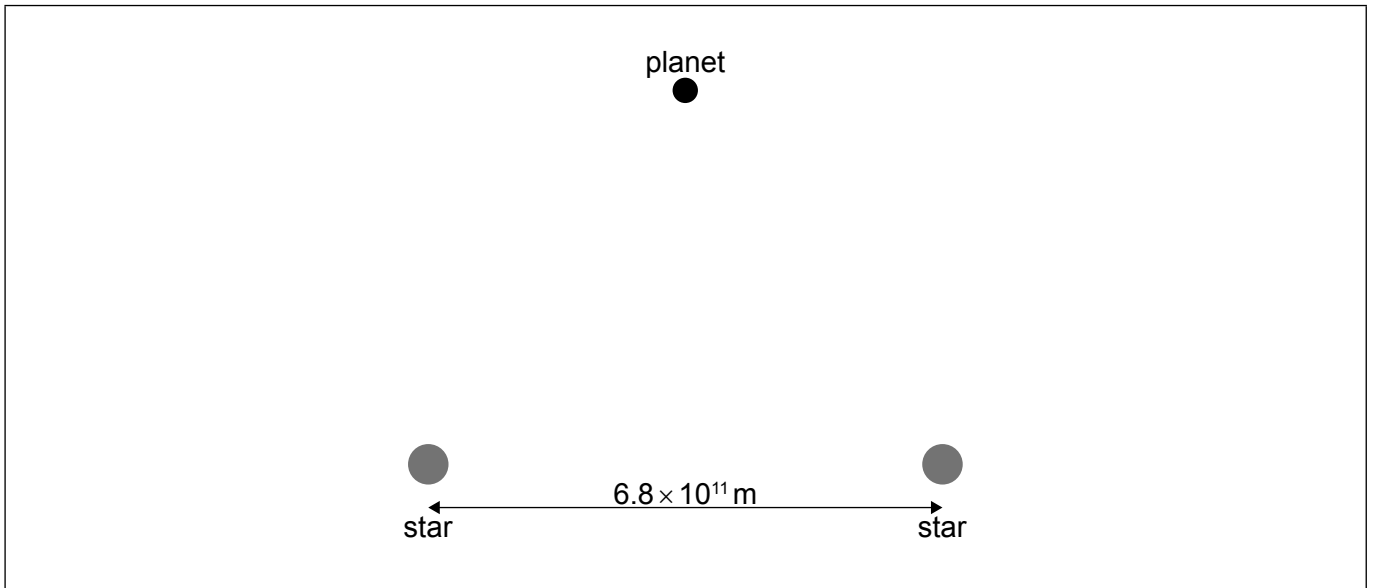
Each star has mass $M = 2.0 \times 10^{30}$ kg. Their centres are separated by a distance of 6.8×10^{11} m. The planet is at a distance of 6.0×10^{11} m from each star.

(a) On the diagram above, draw **two** arrows to show the gravitational field strength at the position of the planet due to each of the stars. [2]

(b) Calculate the magnitude and state the direction of the resultant gravitational field strength at the position of the planet. [3]

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3.   In an experiment to determine the specific latent heat of fusion of ice, an ice cube is dropped into water that is contained in a well-insulated calorimeter of negligible specific heat capacity. The following data are available.

Mass of ice cube	$= 25\,g$
Mass of water	$= 350\,g$
Initial temperature of ice cube	$= 0\,°C$
Initial temperature of water	$= 18\,°C$
Final temperature of water	$= 12\,°C$
Specific heat capacity of water	$= 4200\,J\,kg^{-1}K^{-1}$

(a)   Using the data, estimate the specific latent heat of fusion of ice.   [4]

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(b)   The experiment is repeated using the same mass of crushed ice.

Suggest the effect, if any, of crushing the ice on

(i)   the final temperature of the water.   [1]

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(ii)   the time it takes the water to reach its final temperature.   [1]

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

Answers written on this page
will not be marked.

4.   A longitudinal wave is travelling in a medium from left to right. The graph shows the variation with distance x of the displacement y of the particles in the medium. The solid line and the dotted line show the displacement at $t = 0$ and $t = 0.882$ ms, respectively.
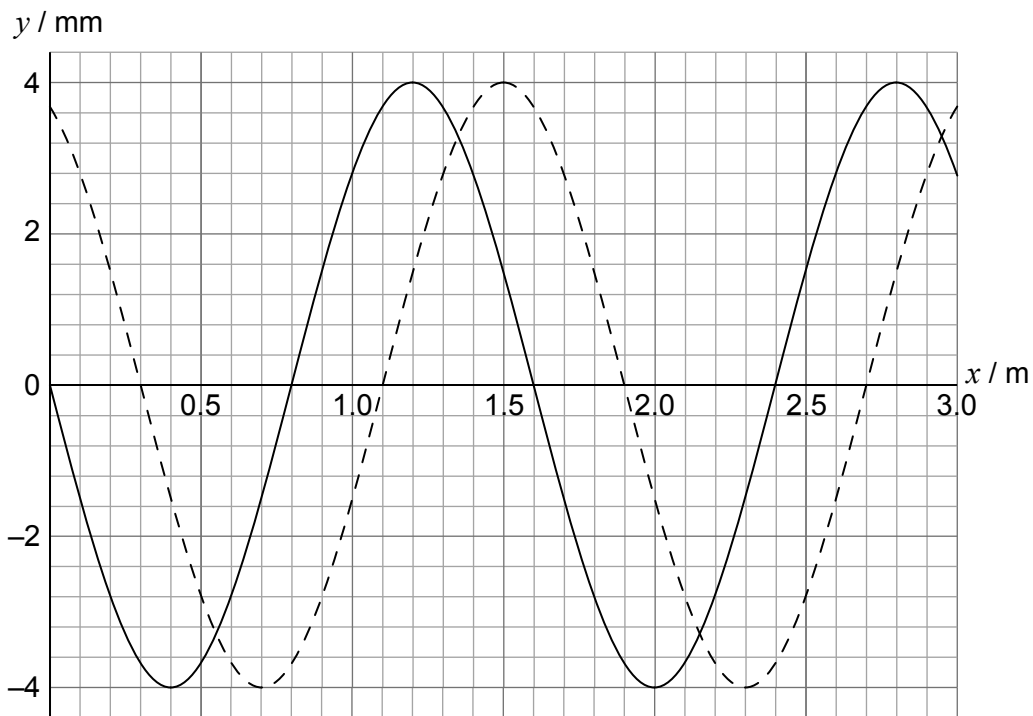
The period of the wave is greater than 0.882 ms. A displacement to the right of the equilibrium position is positive.

(a)   State what is meant by a longitudinal travelling wave.   [1]

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(b)   (i)   Calculate the speed of this wave.   [2]

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(This question continues on the following page)

(Question 4 continued)

    (ii)   Show that the angular frequency of oscillations of a particle in the medium is $\omega = 1.3 \times 10^3 \, \text{rad s}^{-1}$. [2]

    (c)   One particle in the medium has its equilibrium position at $x = 1.00 \, \text{m}$.

        (i)   State and explain the direction of motion for this particle at $t = 0$. [2]

        (ii)   Show that the speed of this particle at $t = 0.882 \, \text{ms}$ is $4.9 \, \text{m s}^{-1}$. [2]

(This question continues on the following page)

(Question 4 continued)

(d) The travelling wave in (b) is directed at the open end of a tube of length 1.20 m. The other end of the tube is closed.

(i) Describe how a standing wave is formed. [1]

(ii) Demonstrate, using a calculation, that a standing wave will be established in this tube. [2]

5. (a) Outline what is meant by escape speed. [1]

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(b) A probe is launched vertically upwards from the surface of a planet with a speed

$$v = \frac{3}{4}v_{esc}$$

where v_{esc} is the escape speed from the planet. The planet has no atmosphere.

Determine, in terms of the radius of the planet R, the maximum height from the surface of the planet reached by the probe. [3]

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(c) The total energy of a probe in orbit around a planet of mass M is $E = -\dfrac{GMm}{2r}$ where m is the mass of the probe and r is the orbit radius. A probe in low orbit experiences a small frictional force. Suggest the effect of this force on the speed of the probe. [3]

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6.   (a)   Two cells of negligible internal resistance are connected in a circuit.
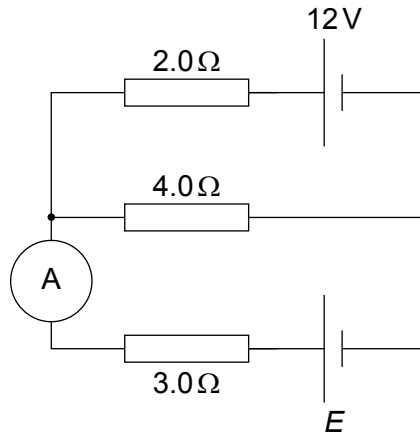
The top cell has electromotive force (emf) 12 V. The emf of the lower cell is unknown.
The ideal ammeter reads zero current.

Calculate the emf E of the lower cell.   [2]

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(Question 6 continued)

(b)   The diagram shows charge carriers moving with speed *v* in a metallic conductor of width *L*. The conductor is exposed to a uniform magnetic field *B* that is directed into the page.
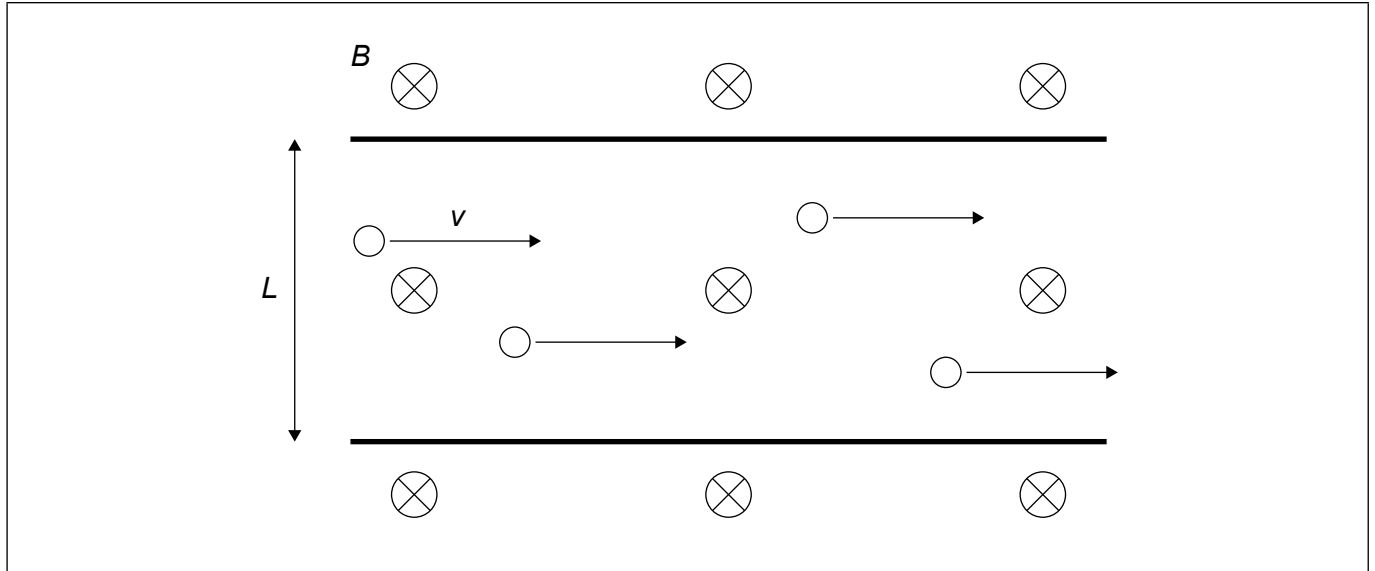
(i)   Show that the potential difference *V* that is established across the conductor is given by $V = vBL$.   [2]

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(ii)   On the diagram, label the part of the conductor where negative charge accumulates.   [1]

7. An uncharged capacitor in a vacuum is connected to a cell of emf 12 V and negligible internal resistance. A resistor of resistance R is also connected.
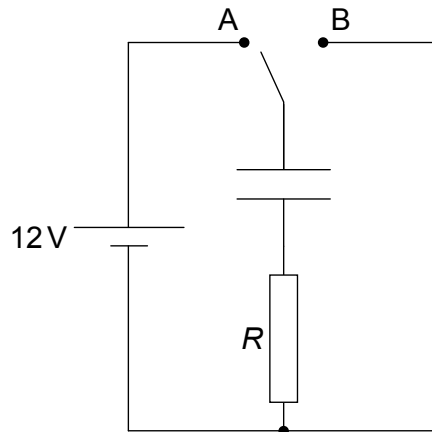
At $t = 0$ the switch is placed at position A. The graph shows the variation with time t of the voltage V across the capacitor. The capacitor has capacitance 4.5 μF in a vacuum.
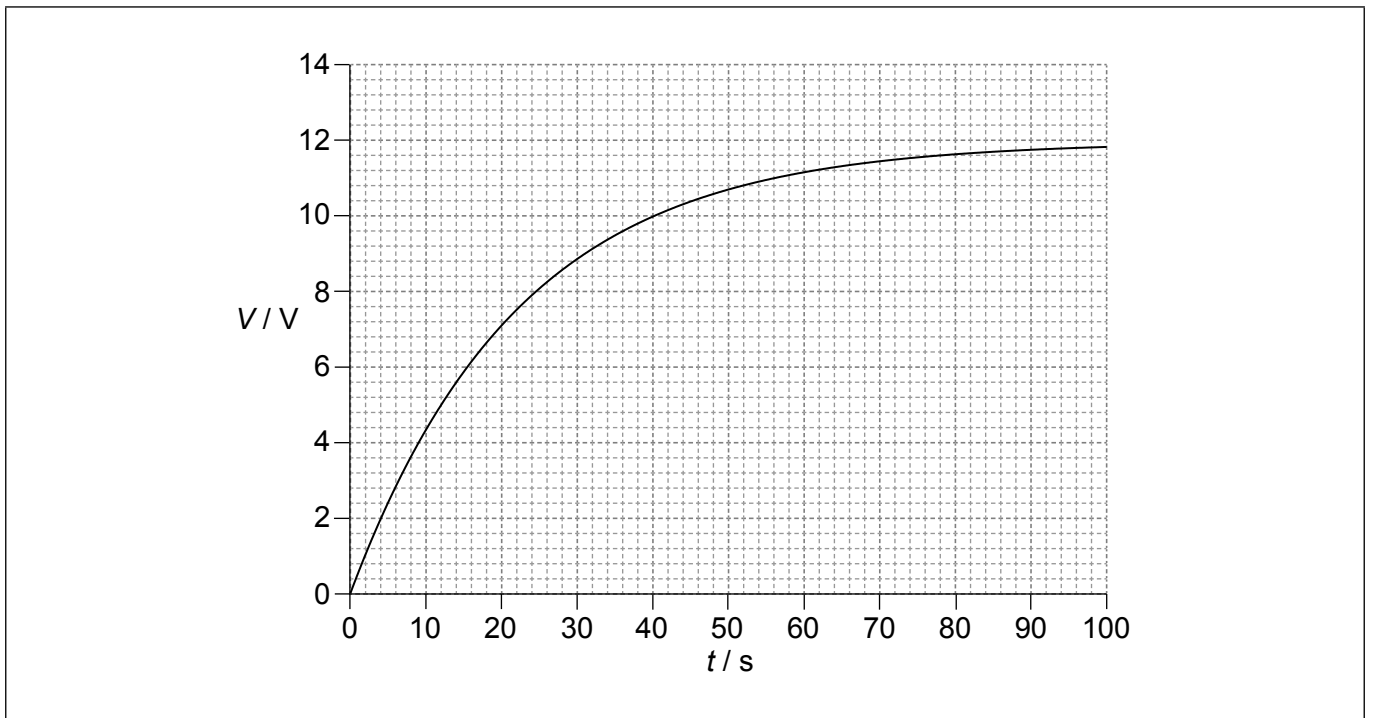
(a) On the axes, draw a graph to show the variation with time of the voltage across the resistor. [2]

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(Question 7 continued)

    (b)   (i)   The time constant of this circuit is $22\,\text{s}$. State what is meant by the time constant.   [1]

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          (ii)   Calculate the resistance R.   [1]

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    (c)   A dielectric material is now inserted between the plates of the fully charged capacitor. State the effect, if any, on

          (i)   the potential difference across the capacitor.   [1]

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          (ii)   the charge on one of the capacitor plates.   [1]

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(This question continues on the following page)

(Question 7 continued)

(d) (i) The permittivity of the dielectric material in (c) is twice that of a vacuum.
Calculate the energy stored in the capacitor when it is fully charged. [2]

(ii) The switch in the circuit is now moved to position B and the fully charged
capacitor discharges. Describe what happens to the energy in (d)(i). [1]

8.   In beta minus (β^-) decay a d quark decays into a u quark, an electron and an electron antineutrino.

(a)   Show that lepton number is conserved in this decay.   [1]

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(b)   A nucleus of phosphorus-32 $\left(^{32}_{15}P\right)$ decays by beta minus (β^-) decay into a nucleus of sulfur-32 $\left(^{32}_{16}S\right)$. The binding energy per nucleon of $^{32}_{15}P$ is 8.398 MeV and for $^{32}_{16}S$ it is 8.450 MeV.

(i)   State what is meant by the binding energy of a nucleus.   [1]

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(ii)   Determine the energy released in this decay.   [2]

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(c)   Quarks were hypothesized long before their existence was experimentally verified. Discuss the reasons why physicists developed a theory that involved quarks.   [3]

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9.   The Sun has a radius of 7.0×10^8 m and is a distance 1.5×10^{11} m from Earth. The surface temperature of the Sun is 5800 K.

(a)   Show that the intensity of the solar radiation incident on the upper atmosphere of the Earth is approximately 1400 W m^{-2}.   [2]

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(b)   The albedo of the atmosphere is 0.30. Deduce that the average intensity over the entire surface of the Earth is 245 W m^{-2}.   [2]

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(c)   Estimate the average surface temperature of the Earth.   [2]

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(This question continues on the following page)

(Question 9 continued)

(d)   The average surface temperature of the Earth is actually 288 K.

Suggest how the greenhouse effect helps explain the difference between the
temperature estimated in (c) and the actual temperature of the Earth.   [2]

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Turn over

10. Monochromatic light is incident normally on four thin, parallel, rectangular slits.

slits   distant screen   (not to scale)
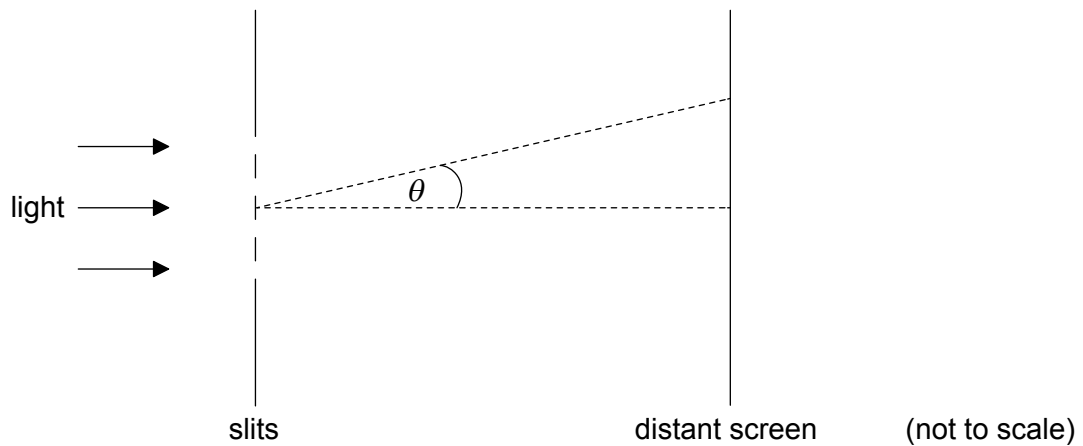
The graph shows the variation with diffraction angle θ of the intensity of light I at a distant screen.
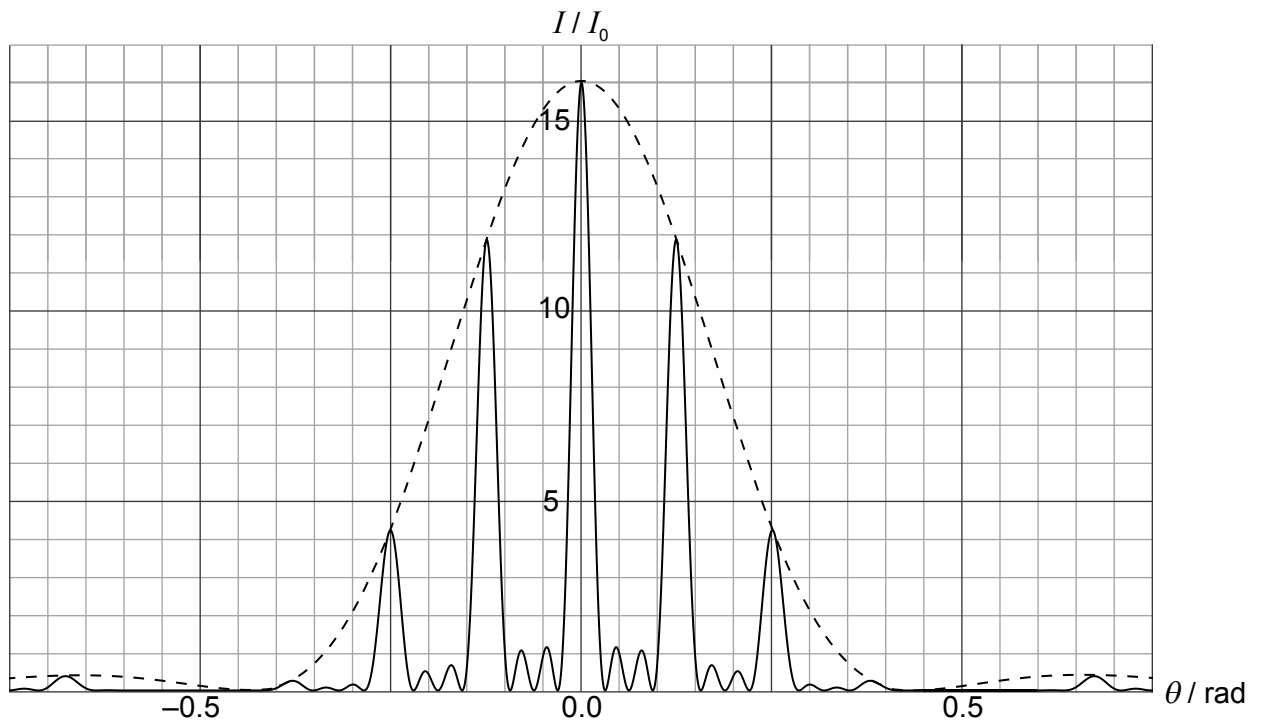
I_0 is the intensity of the light at the middle of the screen from **one** slit.

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(Question 10 continued)

(a)   Explain why the intensity of light at $\theta = 0$ is $16I_0$.   [3]

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(b)   The width of each slit is $1.0\,\mu m$.   Use the graph to

(i)   estimate the wavelength of light.   [2]

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(ii)   determine the separation of **two** consecutive slits.   [2]

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(Question 10 continued)

(c)   The arrangement is modified so that the number of slits becomes very large.
        Their separation and width stay the same.

   (i)   State **two** changes to the graph on page 20 as a result of these modifications.   [2]

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   (ii)   A diffraction grating is used to resolve two lines in the spectrum of sodium in the
           second order. The two lines have wavelengths 588.995 nm and 589.592 nm.

           Determine the minimum number of slits in the grating that will enable the two
           lines to be resolved.   [2]

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11. (a) An alpha particle with initial kinetic energy 32 MeV is directed head-on at a nucleus of gold-197 $\left(^{197}_{79}Au\right)$.

(i) Show that the distance of closest approach of the alpha particle from the centre of the nucleus is about 7×10^{-15} m. [2]

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(ii) Estimate the density of a nucleus of $^{197}_{79}Au$ using the answer to (a)(i) as an estimate of the nuclear radius. [3]

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(b) The nucleus of $^{197}_{79}Au$ is replaced by a nucleus of the isotope $^{195}_{79}Au$. Suggest the change, if any, to your answers to (a)(i) and (a)(ii). [2]

Distance of closest approach:

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Estimate of nuclear density:

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(This question continues on the following page)

(Question 11 continued)

(c)   An alpha particle is confined within a nucleus of gold. Using the uncertainty principle, estimate the kinetic energy, in MeV, of the alpha particle.   [3]

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