

# Cambridge Pre-U

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**PHYSICS**

**9792/02**

Paper 2 Written Paper

**October/November 2020**

**2 hours**

You must answer on the question paper.

You will need: Insert (enclosed)

## INSTRUCTIONS

- Section 1: answer **all** questions.
- Section 2: answer **the** question. The question is based on the material in the insert, which is a copy of the pre-release material.
- Use a black or dark blue pen. You may use an HB pencil for any diagrams or graphs.
- Write your name, centre number and candidate number in the boxes at the top of the page.
- Write your answer to each question in the space provided.
- Do **not** use an erasable pen or correction fluid.
- Do **not** write on any bar codes.
- You may use a calculator.
- You should show all your working and use appropriate units.

## INFORMATION

- The total mark for this paper is 100.
- The number of marks for each question or part question is shown in brackets [ ].

This syllabus is regulated for use in England, Wales and Northern Ireland as a Cambridge International Level 3 Pre-U Certificate.

This document has **28** pages. Blank pages are indicated.

**Data**

gravitational field strength close to Earth's surface	$g = 9.81 \text{ N kg}^{-1}$
elementary charge	$e = 1.60 \times 10^{-19} \text{ C}$
speed of light in vacuum	$c = 3.00 \times 10^8 \text{ m s}^{-1}$
Planck constant	$h = 6.63 \times 10^{-34} \text{ J s}$
permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-12} \text{ F m}^{-1}$
gravitational constant	$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$
electron mass	$m_e = 9.11 \times 10^{-31} \text{ kg}$
proton mass	$m_p = 1.67 \times 10^{-27} \text{ kg}$
unified atomic mass constant	$u = 1.66 \times 10^{-27} \text{ kg}$
molar gas constant	$R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$
Avogadro constant	$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$
Boltzmann constant	$k = 1.38 \times 10^{-23} \text{ J K}^{-1}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8} \text{ W m}^{-2} \text{ K}^{-4}$

**Formulae**

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
	$s = \left( \frac{u+v}{2} \right)t$
heating	$\Delta E = mc\Delta\theta$

change of state	$\Delta E = mL$
-----------------	-----------------

refraction	$n = \frac{\sin \theta_1}{\sin \theta_2}$
	$n = \frac{v_1}{v_2}$

diffraction		electromagnetic induction	$E = -\frac{d(N\Phi)}{dt}$
single slit, minima	$n\lambda = b \sin \theta$	Hall effect	$V = Bvd$
grating, maxima	$n\lambda = d \sin \theta$	time dilation	$t' = \frac{t}{\sqrt{1 - \frac{v^2}{c^2}}}$
double slit interference	$\lambda = \frac{ax}{D}$	length contraction	$l' = l\sqrt{1 - \frac{v^2}{c^2}}$
Rayleigh criterion	$\theta \approx \frac{\lambda}{b}$	kinetic theory	$\frac{1}{2}m\langle c^2 \rangle = \frac{3}{2}kT$
photon energy	$E = hf$	work done on/by a gas	$W = p\Delta V$
de Broglie wavelength	$\lambda = \frac{h}{p}$	radioactive decay	$\frac{dN}{dt} = -\lambda N$
simple harmonic motion	$x = A \cos \omega t$		$N = N_0 e^{-\lambda t}$
	$v = -A\omega \sin \omega t$		$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$
	$a = -A\omega^2 \cos \omega t$	attenuation losses	$I = I_0 e^{-\mu x}$
	$F = -m\omega^2 x$	mass-energy equivalence	$\Delta E = c^2 \Delta m$
	$E = \frac{1}{2}mA^2\omega^2$	hydrogen energy levels	$E_n = \frac{-13.6 \text{ eV}}{n^2}$
energy stored in a capacitor	$W = \frac{1}{2}QV$	Heisenberg uncertainty principle	$\Delta p \Delta x \geq \frac{h}{2\pi}$
capacitor discharge	$Q = Q_0 e^{-\frac{t}{RC}}$	Wien's displacement law	$\lambda_{\max} \propto \frac{1}{T}$
electric force	$F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$	Stefan's law	$L = 4\pi\sigma r^2 T^4$
electrostatic potential energy	$W = \frac{Q_1 Q_2}{4\pi\epsilon_0 r}$	electromagnetic radiation from a moving source	$\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$
gravitational force	$F = -\frac{Gm_1 m_2}{r^2}$		
gravitational potential energy	$E = -\frac{Gm_1 m_2}{r}$		
magnetic force	$F = BIl \sin \theta$		
	$F = BQv \sin \theta$		

**Section 1**

You are advised to spend about 1 hour 30 minutes on this section.

1 (a) State what is meant by a *heat engine*.

.....  
.....  
..... [2]

(b) The efficiency of a power station that generates 2.25 GW of electricity is 37.5% (0.375).

(i) Calculate the total energy input to the power station in 12.0 hours. Give your answer in joules.

total energy input = ..... J [3]

(ii) The power station is kept cool by pumping water through the heated parts at a rate of  $38\,000\text{ kg s}^{-1}$ . The specific heat capacity of water is  $4180\text{ J kg}^{-1}\text{ K}^{-1}$ .

Calculate the temperature increase of the water.

temperature increase = ..... K [3]

[Total: 8]

2 Steel is a material that can be formed into a wire because steel is tough.

(a) State what is meant by *tough*.

.....  
..... [1]

(b) A 2.50 m length of steel wire of diameter 0.610 mm is suspended vertically from a support. A 60.0 N weight is attached to the lower end of the wire and, as it stretches, the extension of the wire remains within the Hooke's law region.

(i) State what is meant by *the Hooke's law region*.

.....  
..... [1]

(ii) The Young modulus of steel is  $1.85 \times 10^{11}$  Pa.

Calculate the extension of the wire.

extension = ..... m [3]

(c) Explain, in terms of the atoms, how plastic deformation differs from elastic deformation.

.....  
.....  
.....  
.....  
..... [3]

[Total: 8]

3 A pulley system is a device that consists of wheels (pulleys) and a rope which is used to lift loads.

Fig. 3.1 shows a system of two pulleys with one pulley fixed to the ceiling but free to rotate. The other pulley is attached to a load.

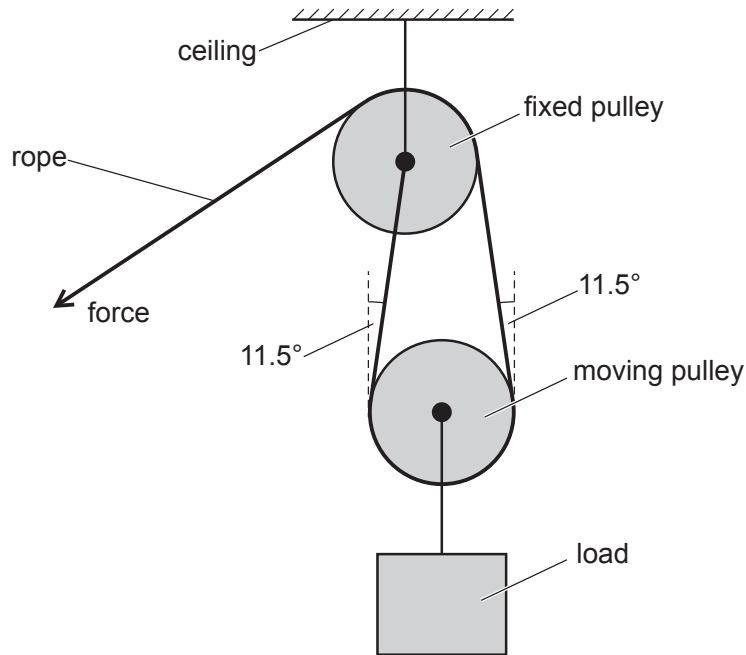


Fig. 3.1 (not to scale)

A force is used to pull the free end of the rope and this lifts the load at a constant speed. The air resistance and friction are negligible.

The moving pulley has a mass of 2.40 kg and the load is a box of weight 960 N.

(a) The tension  $T$  in the rope is constant along its length.

Calculate:

(i) the combined weight of the moving pulley and load

combined weight = ..... N [1]

(ii) tension  $T$ .

$T =$  ..... N [2]

(b) The load is lifted, at a constant speed, through a distance of 3.50 m.

(i) Calculate the gravitational potential energy gained by the load.

gravitational potential energy gained = ..... J [2]

(ii) As the load moves upwards, the tension in the rope changes.

Explain how the tension changes.

.....  
.....  
..... [2]

(iii) A graph of force applied against the distance moved by the force is plotted.

State how the work done by the force can be deduced from the graph.

.....  
..... [1]

(c) When the pulley system is used, the work done by the force pulling the rope is greater than the gravitational potential energy gained by the load.

(i) Suggest **one** reason for this.

.....  
..... [1]

(ii) Suggest **one** reason for using the pulley system.

.....  
..... [1]

[Total: 10]

4 Fig. 4.1 shows a laboratory trolley that contains a tank of water.

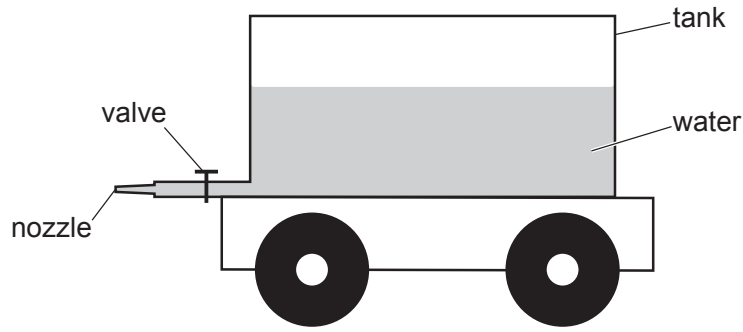


Fig. 4.1

The water in the tank is maintained at high pressure. At time  $t = 0$ , the valve is opened and water is expelled backwards through the circular nozzle at a constant rate. The jet of water leaves the nozzle horizontally and the trolley accelerates forwards in a straight line until there is no water left in the tank.

As the trolley moves forwards, it experiences a constant resistive force of  $0.050\text{ N}$ .

A sensor is used to measure the instantaneous speed of the trolley for the first  $7.0\text{ s}$  of its motion.

Fig. 4.2 is the speed–time graph for the trolley.

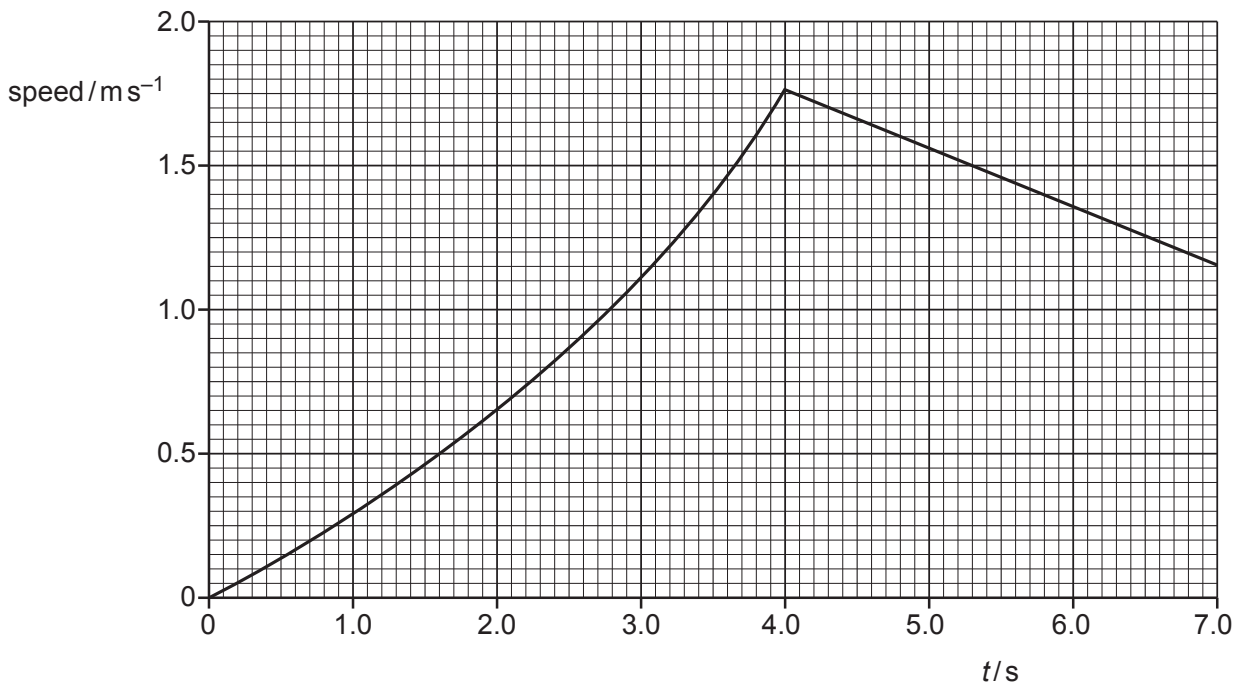


Fig. 4.2

The density of water is  $1000\text{ kg m}^{-3}$ .





5 A 12.0V battery, which has a negligible internal resistance, is used to power a 24.0W, 12.0V filament lamp.

(a) Calculate the resistance of the lamp when powered by the battery.

resistance = .....  $\Omega$  [1]

(b) (i) The 12.0V battery is the power source of a circuit that is used to obtain results for a voltage–current graph for the filament lamp. The circuit ensures all values of voltage from 0 to 12.0V inclusive can be supplied to the lamp.

Draw the circuit diagram and describe how the circuit is used.

.....  
 .....  
 .....  
 ..... [4]

(ii) The resistance of the filament lamp increases as its temperature increases.

On Fig. 5.1, sketch a voltage–current graph for the lamp. Include a value for  $I_O$ , the operating current.



Fig. 5.1

[2]

(c) The 12.0V battery is used to power the circuit shown in Fig. 5.2.

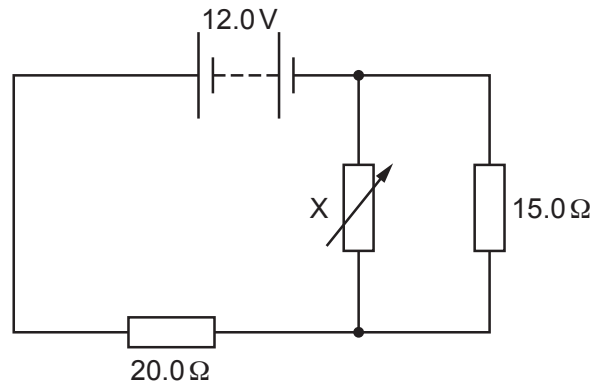


Fig. 5.2

The resistance of X is set at 30.0Ω.

(i) Calculate the current in the 15.0Ω resistor.

current = ..... A [3]

(ii) The resistance of X is gradually decreased.

Explain what happens to the current in the 15.0Ω resistor.

.....  
 .....  
 ..... [2]

[Total: 12]



6 A transmitter produces microwaves of wavelength 0.0310 m.

Fig. 6.1 shows the transmitter in front of a vertical aluminium sheet which reflects the microwaves incident on it.

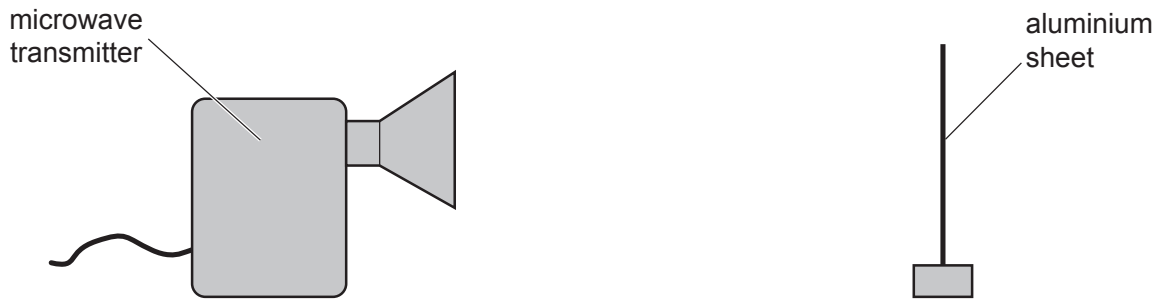


Fig. 6.1

(a) The microwaves produced by the transmitter create a standing wave in the region between the transmitter and the aluminium sheet.

(i) Describe what is meant by *standing wave*.

.....  
 .....  
 ..... [2]

(ii) State why a standing microwave is set up between the transmitter and the aluminium sheet.

.....  
 ..... [1]

(iii) Determine the distance between a node and an adjacent antinode in the standing wave.

distance = ..... m [1]

(b) The microwaves produced by the transmitter are plane-polarised.

(i) Explain why microwaves can be plane-polarised but sound waves cannot be.

.....  
 .....  
 ..... [2]

- (ii) The aluminium sheet in Fig. 6.1 is removed and replaced with the arrangement of thin, vertical conducting rods shown in Fig. 6.2.

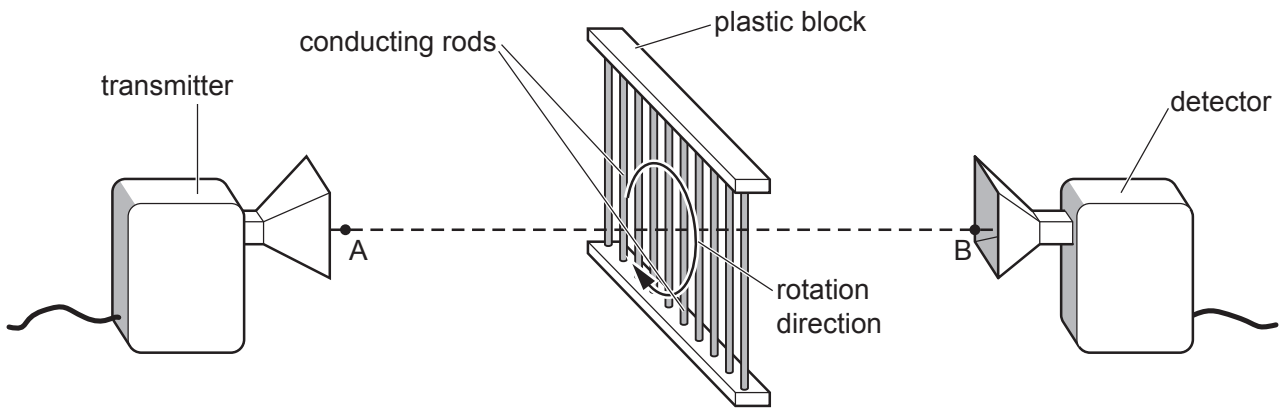


Fig. 6.2

The arrangement of rods is held in place by two plastic blocks. A microwave detector is placed behind the rods.

The arrangement acts as a polarising filter for the microwaves and with the rods vertical, no microwaves are detected.

The arrangement of rods is rotated by  $90^\circ$  about the axis AB to the position shown in Fig. 6.3.

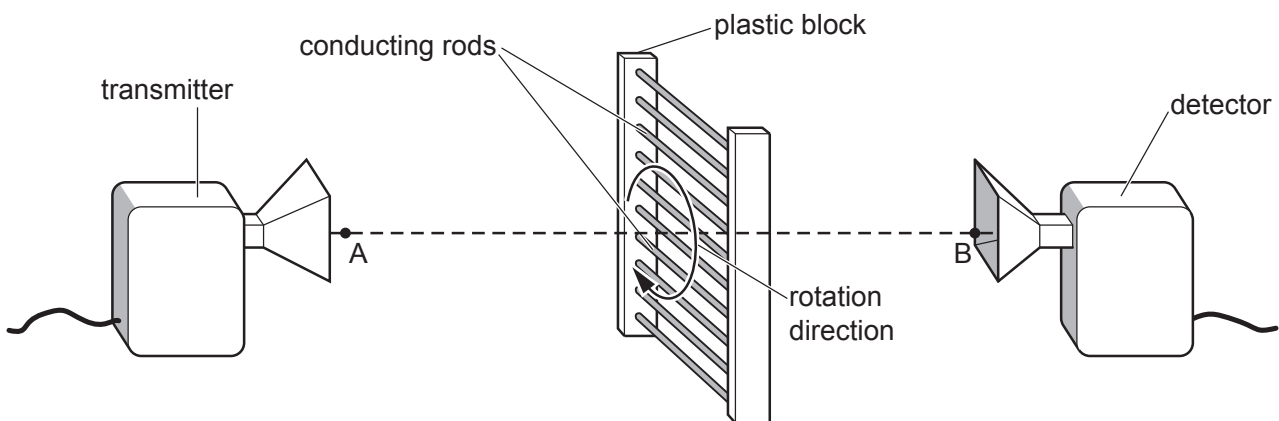


Fig. 6.3

On Fig. 6.4, sketch a graph to show how the amplitude of the waves detected changes as the arrangement of rods is rotated from 0 to 360° from the original, vertical position.

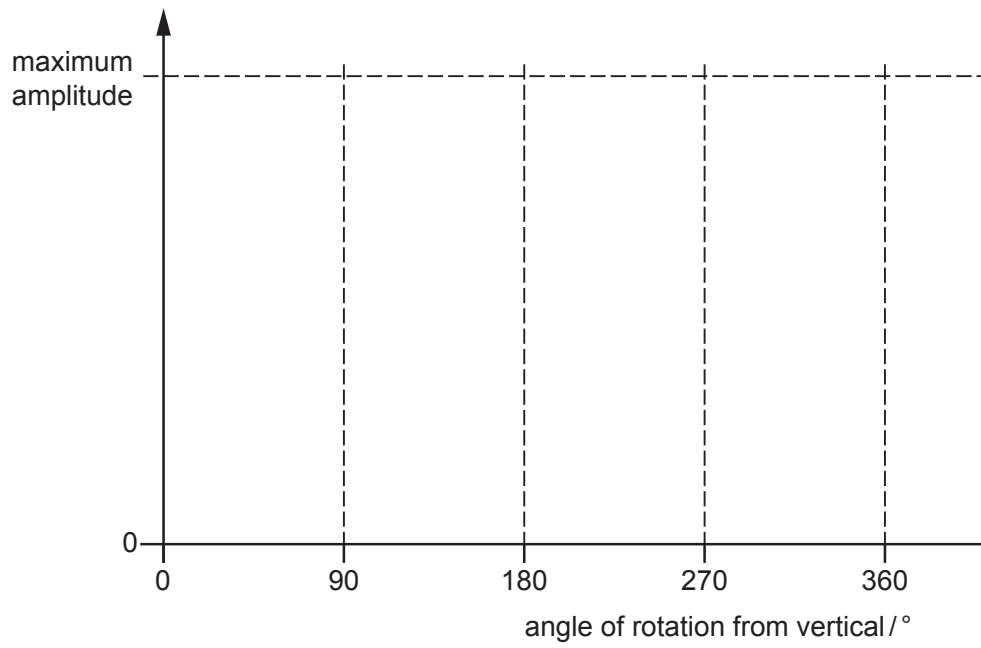


Fig. 6.4

[2]

[Total: 8]

7 Fig. 7.1 shows two aluminium spheres, X and Y, mounted on insulating stands.



**Fig. 7.1**

The surfaces of the two spheres are thoroughly cleaned. The positive terminal of a high-voltage power supply is connected to X and the negative terminal is connected to Y.

Sphere X gains a positive charge of  $6.24 \times 10^{-8}\text{C}$  and sphere Y gains a negative charge of the same magnitude. The charging takes a time of 0.325 ms.

(a) Calculate the average charging current in the connecting wires.

charging current = ..... A [2]

(b) The power supply is disconnected from both spheres and the spheres are moved a long way apart. Monochromatic ultraviolet radiation is directed onto both spheres.

(i) Explain why Y emits electrons from its surface and discharges but X does not discharge.

.....

.....

.....

..... [3]



- (ii) The kinetic energies of the electrons emitted by Y are measured and it is observed that their kinetic energies range from zero to a maximum value.

Explain why there is a maximum value of these kinetic energies.

.....  
.....  
..... [2]

- (iii) Explain why some electrons have kinetic energies less than the maximum value in (b)(ii).

.....  
..... [1]

- (iv) When the wavelength of the ultraviolet radiation used is  $2.56 \times 10^{-7}$  m, the maximum kinetic energy of the electrons emitted is  $1.24 \times 10^{-19}$  J.

Calculate the maximum kinetic energy of the electrons emitted when ultraviolet radiation of wavelength  $1.28 \times 10^{-7}$  m is directed onto an aluminium surface.

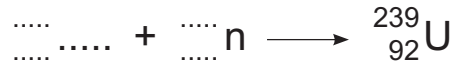
maximum kinetic energy = ..... J [3]

[Total: 11]

8 Plutonium-239 ( ${}^{239}_{94}\text{Pu}$ ) is produced in a nuclear reactor by exposing nuclei of a particular isotope to neutron radiation.

(a) A nucleus of the isotope absorbs a neutron. This produces a nucleus of uranium-239 ( ${}^{239}_{92}\text{U}$ ).

(i) Complete the nuclear equation that represents this first stage.



[2]

(ii) The uranium-239 nuclide is radioactive. It decays to produce an intermediate nuclide of neptunium (Np) which in turn decays to produce a nuclide of plutonium-239.

Deduce:

- the type of radioactive decay that produces the neptunium nuclide
- the type of radioactive decay by which the neptunium nuclide decays
- the proton number (atomic number) of neptunium.

neptunium nuclide produced by ..... decay

neptunium nuclide decays by ..... decay

proton number of neptunium = .....

[2]

(b) In a nuclear power station, plutonium-239 undergoes induced fission which leads to a chain reaction.

(i) Explain what is meant by *induced fission*.

.....  
 .....  
 ..... [2]

(ii) Explain what is meant by *chain reaction*.

.....  
 .....  
 ..... [2]

- (c) When plutonium-239 is used as fuel in a power station, it does not all undergo fission. The nuclear waste contains some plutonium-239. Its half-life is  $2.41 \times 10^4$  years.

Calculate the proportion of the original quantity of plutonium-239 that remains after  $9.64 \times 10^4$  years elapse.

proportion remaining = ..... [2]

[Total: 10]

## Section 2

You are advised to spend about 30 minutes on this section.

The questions in this section refer to the pre-release material provided as an insert to the question paper.

Your answers should, where possible, make use of any relevant physics.

- 9 (a) Table 9.1 shows the kinetic energies of two particles emitted during radioactive decay.

Table 9.1

parent nucleus	radiation emitted	particle kinetic energy /MeV
radon-222	alpha	5.48
carbon-14	beta	0.156

- (i) A moving alpha-particle has both charge and kinetic energy.

Calculate the charge of an alpha-particle.

charge = ..... C [1]

- (ii) A stationary alpha-particle is accelerated by a potential difference (p.d.) until its kinetic energy is equal to that of an alpha-particle emitted by radon-222.

Calculate the p.d. required.

p.d. = ..... V [1]

- (iii) Calculate the speed of a 5.48 MeV alpha-particle.

mass of alpha-particle  $m_{\alpha} = 6.64 \times 10^{-27}$  kg

speed = .....  $\text{ms}^{-1}$  [2]

(iv) Explain why beta-particles can penetrate much further through air than alpha-particles even though the beta-particles have far less energy.

.....

.....

.....

.....

..... [2]

(b) The linear accelerator (LINAC) in Fig. 9.1 is being used to accelerate protons.

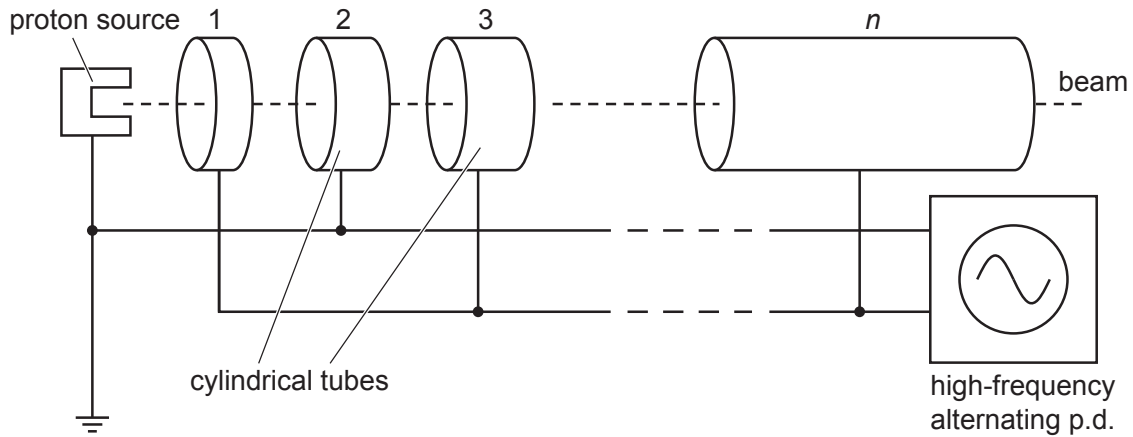


Fig. 9.1

The alternating p.d. shown in Fig. 9.2 is connected to the odd-numbered cylindrical tubes (tubes 1, 3, 5, etc.) in Fig. 9.1. The even-numbered tubes (tubes 2, 4, 6, etc.) are connected to the proton source which is at earth potential (0 V).

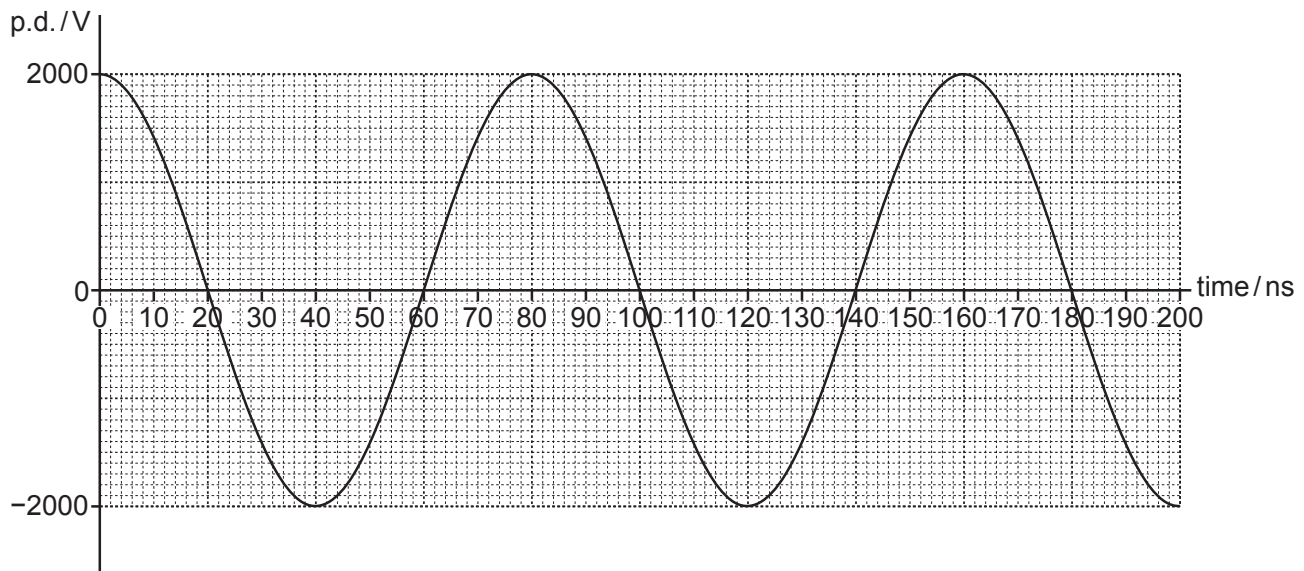


Fig. 9.2

- (i) On the graph of Fig. 9.2, mark with **X** a point where the p.d. causes a proton between tube 1 and tube 2 to accelerate away from the source. [1]

- (ii) Explain why the proton is only accelerated away from the source when it is between adjacent cylindrical tubes, even though the electric field changes direction regularly.

.....  
.....  
.....  
.....  
.....  
..... [3]

- (iii) At the time when LINACs were being developed, radio transmissions used electromagnetic waves with wavelengths in the range 10 m–2000 m.

Use data from Fig. 9.2 to justify whether the alternating p.d. source can be classified as *radiofrequency*.

.....  
.....  
..... [2]



- (c) Fig. 9.3 (a) and Fig. 9.3 (b) show a cyclotron, viewed along the direction of the magnetic field. It is being used to accelerate protons. The gap where the electric field  $E$  accelerates protons is much smaller than the radius of each *dee*.

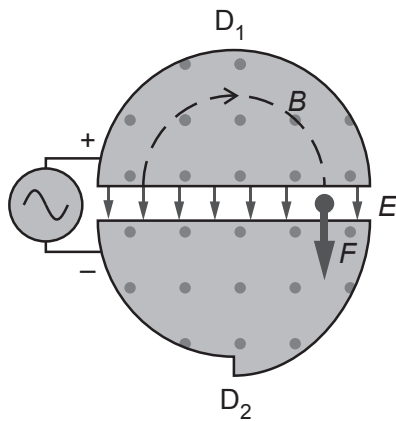


Fig. 9.3 (a)

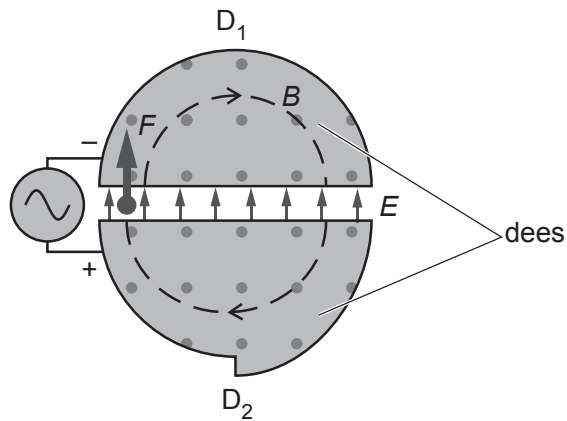


Fig. 9.3 (b)

- (i) The magnetic flux density  $B$  is constant over the area of the two dees and is perpendicular to, and out of, the plane of the diagram.

State why the protons within each dee follow a circular path. You can assume that the protons each have a constant speed within each dee.

.....

.....

..... [2]

- (ii) Show that the radius  $r$  of each semi-circular path is given by  $r = \frac{mv}{qB}$  where  $v$  is the speed of the proton,  $m$  is the mass of the proton and  $q$  is the charge of the proton.

[2]



- (iii) One of Lawrence's cyclotrons had a diameter of 0.28 m and a magnetic flux density of 1.1 T. It was reported that it could accelerate protons to energies greater than 1 MeV.

Use the equation in (c)(ii) to check this claim, justifying your choice of values used.

.....  
.....  
..... [3]

- (iv) The p.d. between the two dees in Lawrence's cyclotron described in (c)(iii) is 50 kV when the proton crosses the gap.

Calculate the number of complete rotations a proton must make to reach a kinetic energy of 1 MeV.

number of complete rotations = ..... [1]

- (v) Protons are injected into the cyclotron near the centre and emerge near the outside edge of one of the dees.

Estimate the total distance travelled by the 1 MeV proton while in the cyclotron.

.....  
.....  
..... [2]

(d) Maxwell showed that accelerating electric charges emit electromagnetic waves.

(i) Fig. 9.4 shows a radio transmitter antenna (aerial) consisting of two conductors AB and CD connected to an alternating source of p.d. as shown in Fig. 9.2. As a result, conductor AB becomes positively charged and CD becomes negatively charged. Some time later conductor AB becomes negatively charged and CD becomes positively charged. These two arrangements of charge then continue to alternate.

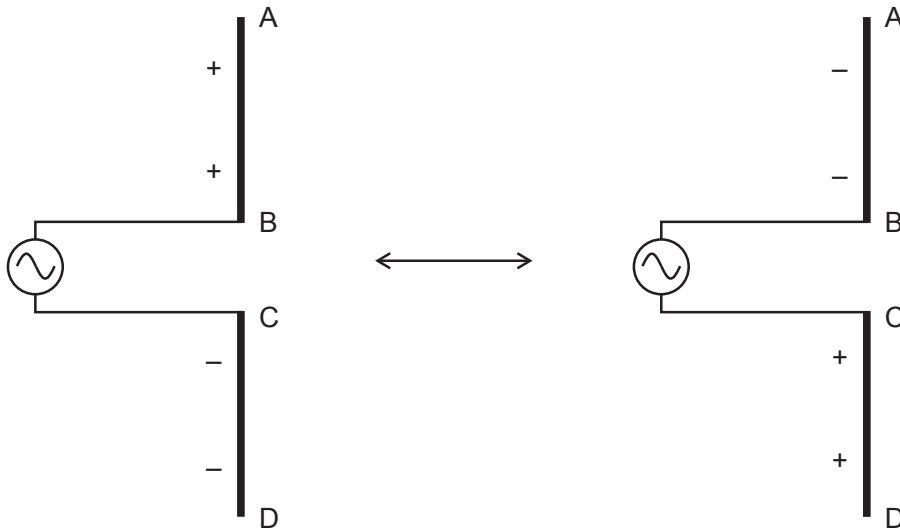


Fig. 9.4

Explain how this alternating p.d. results in the acceleration of charges in **AB**.

.....

.....

.....

..... [2]

(ii) Fig. 9.5 shows a proton travelling in a circular path at a constant speed in a synchrotron.

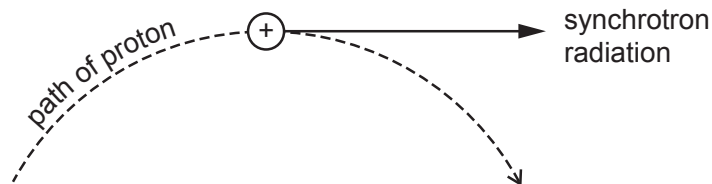


Fig. 9.5

State why the movement of the proton generates electromagnetic waves.

.....

..... [1]

[Total: 25]



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