Name: ______________________________ (   )   Class: 22 / ______

ANDERSON SERANGOON JUNIOR COLLEGE

2022 JC2 Preliminary Examination

PHYSICS Higher 2 9749/02

Paper 2 Structured Questions **Tuesday 13 September 2022**

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name, class index number and class in the spaces at the top of this page.
Write in dark blue or black pen on both sides of the paper.
You may use an HB pencil for any diagrams or graphs.

The use of an approved scientific calculator is expected, where appropriate.
Answer **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
Paper 2 (80 marks)	
1	/ 12
2	/ 8
3	/ 15
4	/ 10
5	/ 5
6	/ 10
7	/ 20
Deduct	
Total	

This document consists of **21** printed pages and **3** blank pages.

-

Data

speed of light in free space	c =	3.00×10^{8} m s^{-1}
permeability of free space	μ_0 =	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0 =	8.85×10^{-12} F m^{-1}
		$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e =	1.60×10^{-19} C
the Planck constant	h =	6.63×10^{-34} J s
unified atomic mass constant	u =	1.66×10^{-27} kg
rest mass of electron	m_e =	9.11×10^{-31} kg
rest mass of proton	m_p =	1.67×10^{-27} kg
molar gas constant	R =	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A =	6.02×10^{23} mol^{-1}
the Boltzmann constant	k =	1.38×10^{-23} J K^{-1}
gravitational constant	G =	6.67×10^{-11} N m^{2} kg^{-2}
acceleration of free fall	g =	9.81 m s^{-2}

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on/by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -\frac{Gm}{r}$
temperature	$T/\text{K} = T/^{\circ}\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V}\langle c^2 \rangle$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.	$v = v_0 \cos \omega t$ $= \pm \omega\sqrt{x_o{}^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage	$x = x_0 \sin \omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_o I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_o NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_o nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

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

1 **(a)** Use Newton's Laws to deduce the principle of conservation of momentum.

[3]

(b) Fig. 1.1 shows the variation with time of momentum for two colliding bodies P and Q.

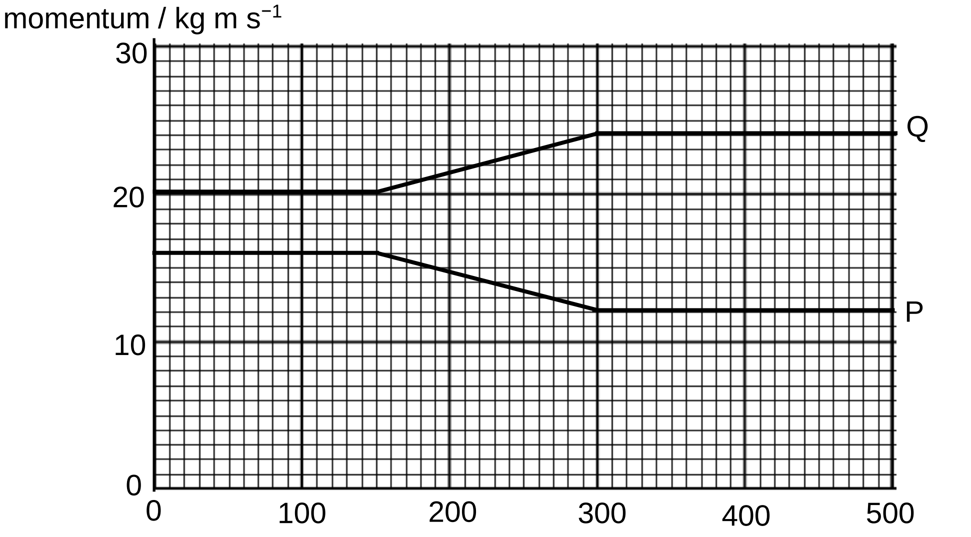

Fig. 1.1

The mass of bodies P and Q are 2.0 kg and 4.0 kg respectively.

(i) Explain why the gradients of the graphs during collision have opposite sign.

....

....

.... [1]

(ii) State the condition under which the momentum is conserved.

……………………………………………………………………………………………...................

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

(iii) Show that the momentum is conserved when the two bodies collide.

[1]

(iv) Calculate the magnitude of the force acting on body P during the collision.

force = …………………………….N [2]

(v) Calculate the magnitude of the impulse on body Q during the collision.

impulse = …………………………….N s [1]

(vi) By considering quantitively the relative speeds of approach and of separation of the two bodies, deduce whether the collision is elastic, inelastic or perfectly inelastic.

type of collision: ……………………………………[3]

[Total: 12]

2 A student sets out to investigate the oscillation of a mass suspended from the free end of a spring, as illustrated in Fig. 2.1.

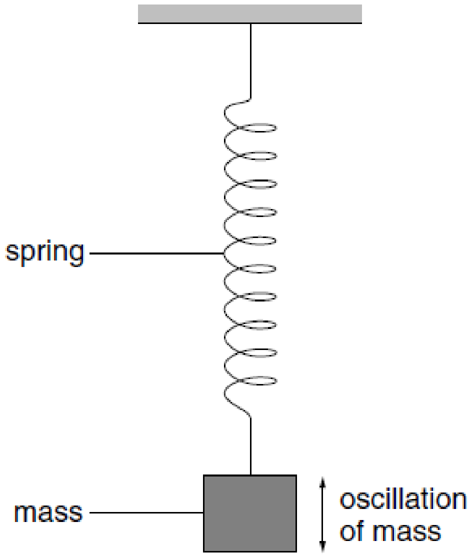

Fig. 2.1

The mass is pulled downwards and then released. The variation with time t of the displacement y of the mass is shown in Fig. 2.2.

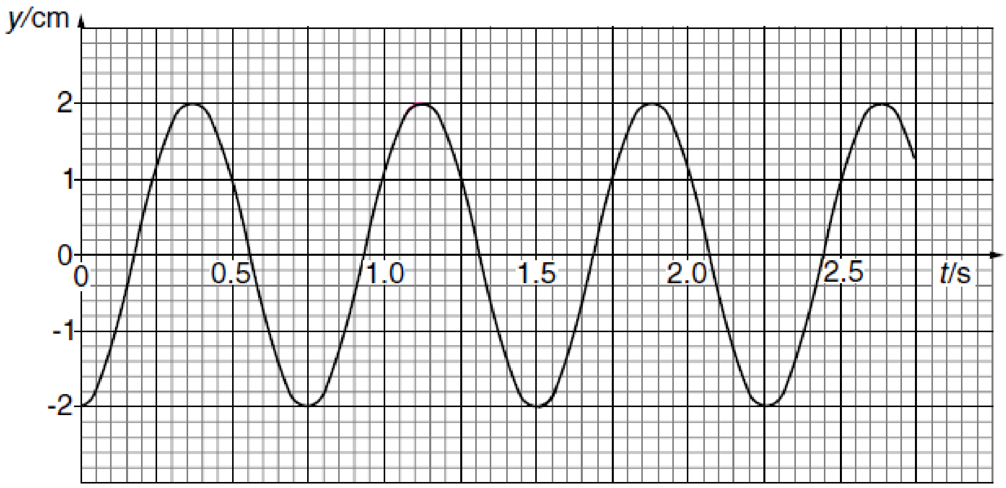

Fig. 2.2

(a) Use information from Fig. 2.2

(i) to explain why the graph suggests that the oscillations are undamped,

.... [1]

(ii) to calculate the angular frequency of the oscillations,

angular frequency = ……………………………….. rad s^{-1} [2]

(iii) to determine the maximum speed of the oscillating mass.

speed = ……………………………………….. m s^{-1} [2]

(b) **(i)** Determine the resonant frequency f_0 of the mass-spring system.

f_0 = …………………………… Hz [1]

(ii) The student finds that if short impulsive forces of frequency ½ f_0 are impressed on the mass-spring system, a large amplitude of oscillation is obtained. Explain this observation.

…………………………………………………………………………………………..……

…………………………………………………………………………………………..……

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

[Total: 8]

3 **(a)** A satellite passing the planet Neptune communicates with its controller on the Earth using a microwave transmitter with output power 25 W and wavelength 80 mm. Neptune is 4.4×10^{12} m from the Earth at the time when the communication takes place.

(i) State whether the microwaves are longitudinal or transverse.

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

(ii) Calculate the time taken for a signal to travel from the satellite to the Earth.

time taken = ……………………………. s [1]

(iii) Assuming the power transmitted by the satellite is radiated uniformly in all directions, calculate the power received on Earth by a dish aerial of effective area 280 m^2.

power = ……………………………. W [3]

(iv) The actual power received at the dish aerial is 1.2×10^{-15} W. Suggest why the actual power received is greater than that calculated in **(a)(iii)**.

……………………………………………………………………………………………..

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

(b) Circular water waves are produced by vibrating dippers at points P and Q, as shown in Fig. 3.1.

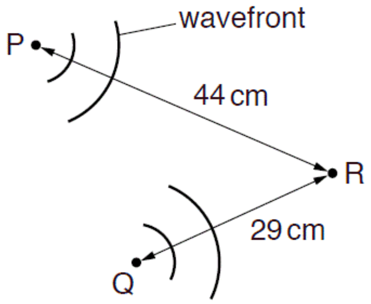

Fig. 3.1

The waves from P alone have the same amplitude at point R as the waves from Q alone. Distance PR is 44 cm and distance QR is 29 cm.

The dippers vibrate in phase with a period of 1.5 s to produce waves of speed 4.0 cm s^{-1}.

(i) Determine the wavelength of the waves.

wavelength = ……………………………. m [2]

(ii) By reference to the distances PR and QR, explain why the water particles are at rest at point R.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

……………………………………………………………………………………………………

…………………………………………………………………………………………… [3]

(c) A loudspeaker is held above a vertical tube of liquid, as shown in Fig. 3.2.

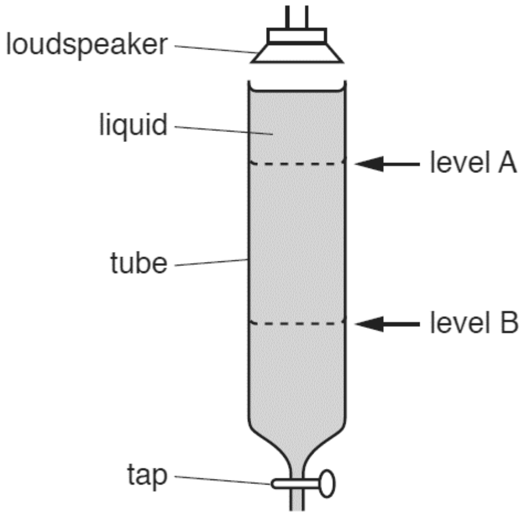

Fig. 3.2

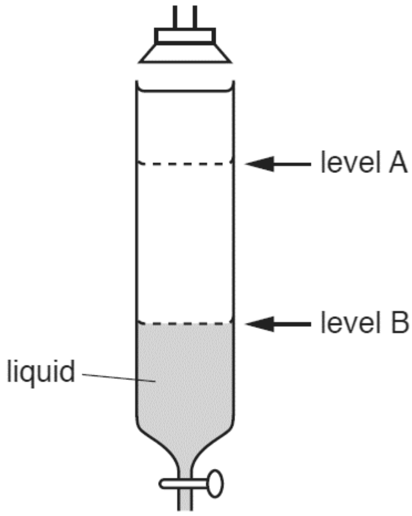

Fig. 3.3

A tap at the bottom of the tube is opened so that liquid drains out at a constant rate. The wavelength of the sound from the loudspeaker is 0.18 m.

A stationary wave is formed when the sound that is heard becomes much louder. This first occurs when the liquid surface reaches level A. The next time that the sound becomes much louder is when the liquid surface reaches level B, as shown in Fig. 3.3.

(i) Explain the formation of a stationary wave in the tube.

....

....

....

....

.... [2]

(ii) Calculate the vertical distance between level A and level B.

vertical distance = ... m [1]

(iii) **On Fig. 3.3**, label with the letter X the positions of maximum pressure variation that are formed in the air column when the liquid surface is at level B.

[1]

[Total: 15]

4 **(a)** For any point outside a spherical conductor, the charge on the sphere may be considered to act as a point charge at its centre. By reference to electric field lines, explain this.

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………

………………………………………………………………………………………………………[2]

(b) Two point charges A and B are separated by a distance of 12 cm in a vacuum, as shown in Fig. 4.1.

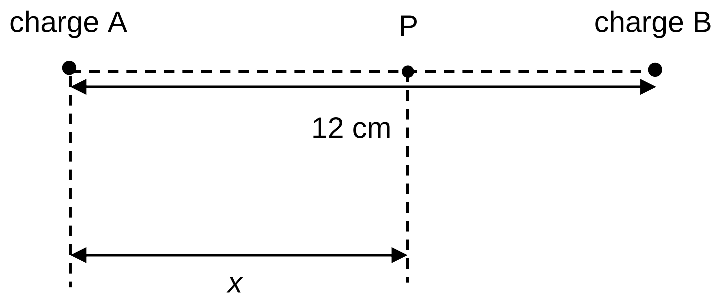

Fig. 4.1

The charge of A is +2.0 x 10^{-9} C.

A point P lies on the line joining charges A and B. Its distance from charge A is *x*.

The variation with *x* of the electric potential *V* at point P is shown in Fig 4.2.

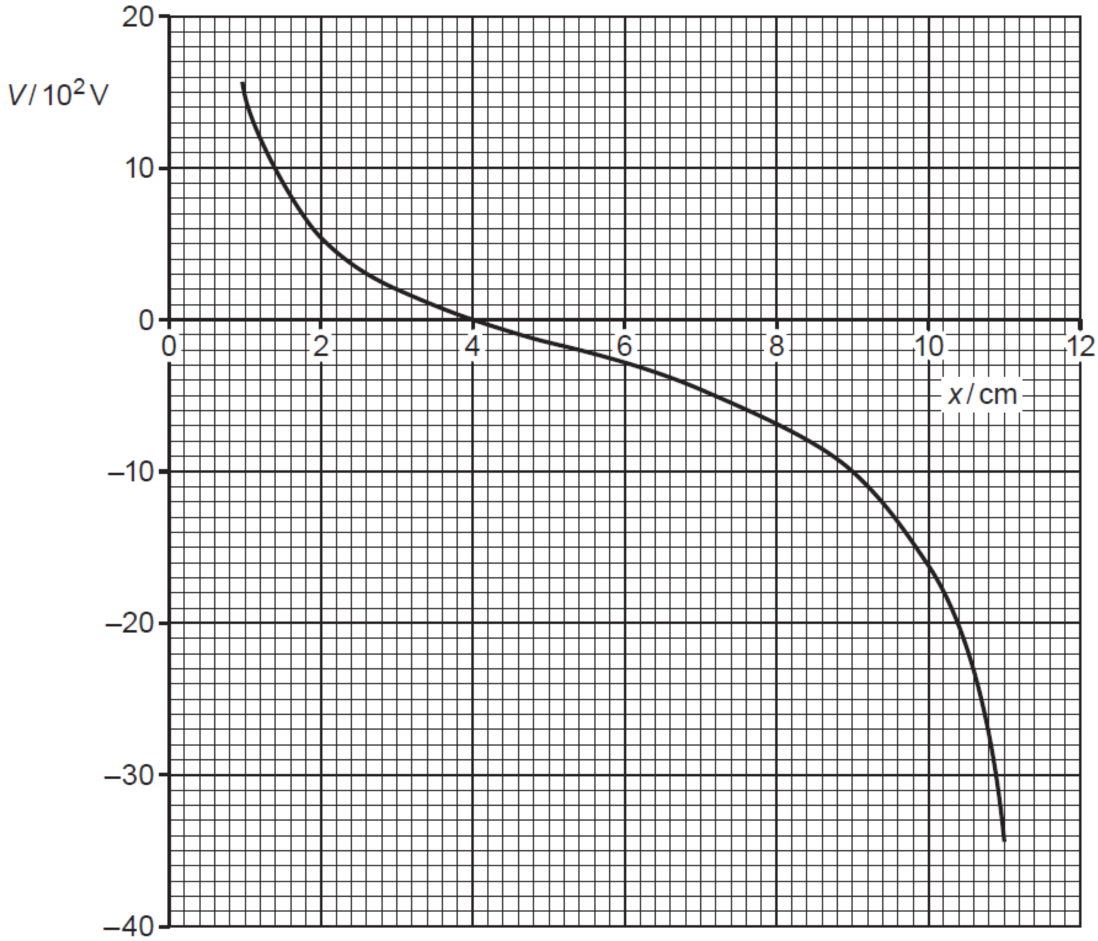

Fig 4.2

(i) Use Fig. 4.2 to determine:

1. the charge of B,

charge = ……………………………….C [2]

2. the change in electric potential when point P moves from the position where x = 9.0 cm to the position where x = 3.0 cm.

change = ……………………………….V [1]

(ii) An α-particle moves along the line joining the centres of the two spheres in Fig 4.1.

The α-particle moves from the position where x = 9.0 cm and just reaches the position where x = 3.0 cm.

Use your answer in **(b)(i)2** to calculate the speed of the α-particle at the position where x = 9.0 cm.

speed = ……………………………m s^{-1} [2]

(iii) Using Fig. 4.2, state the distance x at which the electric field strength is the least.

x = ……………………………cm [1]

(iv) Determine the magnitude of the electric field strength at the position in **(b)(iii).**

electric field strength = ……………………………V m^{-1} [2]

[Total: 10]

5 An X-ray tube uses molybdenum as the target element and another X-ray tube uses tungsten. An accelerating potential of 35 kV is applied to both tubes, resulting in continuous spectrums being formed. The atomic number of molybdenum is 42 while that of tungsten is 74.

Characteristic peaks K_α and K_β occur for molybdenum, but not for tungsten at an accelerating potential of 35 kV. To obtain the characteristic peaks for tungsten, the accelerating potential has to be increased beyond 35 kV.

(a) Explain

(i) why the intensity of the K_α X-ray is greater than that of K_β X-ray for molybdenum.

....

.... [1]

(ii) why the characteristic peaks for tungsten only appear when the accelerating potential is greater than that necessary to produce characteristic peaks for molybdenum.

....

....

....

....

.... [2]

(b) The X-ray spectrum of molybdenum has a particular characteristic spectral line of wavelength 6.6×10^{-11} m, produced by electrons making transitions between two energy levels of the molybdenum atom.

Calculate, in electron-volts, the energy of an X-ray photon of wavelength 6.6×10^{-11} m.

energy = ... eV [2]

[Total: 5]

6 **(a)** When an α−particle bombards a stationary nitrogen−14 nucleus, the following nuclear reaction may occur.

$$^{14}_{7}N + ^{4}_{2}He \rightarrow ^{17}_{8}O + ^{1}_{1}H$$

The rest masses of the nuclei are

$^{14}_{7}N$ 14.007525*u*

$^{4}_{2}He$ 4.003860*u*

$^{17}_{8}O$ 17.004507*u*

$^{1}_{1}H$ 1.008142*u*

(i) Deduce that the energy associated with the change in mass in this reaction is approximately 1.9 x 10^{-13} J.

[2]

(ii) By reference to energy, suggest how it is possible for this reaction to occur.

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

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

(iii) The oxygen−17 nucleus and the hydrogen nucleus move apart after the reaction.

1. Explain why the oxygen−17 nucleus and the hydrogen nucleus move after the reaction.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

2. Describe the effect of this movement on your answer in **(ii)**.

……………………………………………………………………………………………………

……………………………………………………………………………………………………

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

(b) Products of a radioactive decay can be radioactive as well and give rise to a series of radioactive decay products. Each decay product has its own half-life, but eventually a stable nuclide is reached.

One such nuclide is xenon−140 ($^{140}_{54}Xe$), which eventually decays into cerium−140 ($^{140}_{58}Ce$), which is stable.

The series of decay products is as follow:

$$^{140}_{54}Xe \rightarrow {}^{140}_{55}Cs \rightarrow {}^{140}_{56}Ba \rightarrow {}^{140}_{57}La \rightarrow {}^{140}_{58}Ce$$

The half-lives of the radioactive nuclides are given in Fig. 6.1.

Nuclide	Half-life
xenon–140 $^{140}_{54}Xe$	16 s
caesium–140 $^{140}_{55}Cs$	1.1 minute
barium–140 $^{140}_{56}Ba$	13 days
lanthanum–140 $^{140}_{57}La$	40 hours

Fig. 6.1

(i) Initially, the total mass of undecayed xenon−140 in a radioactive sample is 5.7×10^{-12} kg.

Calculate the activity of the undecayed xenon−140 in the sample after 60 s.

activity = ……………………………Bq [3]

(ii) The activity of the sample after 1 minute is higher than the value calculated in **(b)(i)**. Suggest a reason for the difference using the given data.

....

....

....[1]

[Total: 10]

7 Lithium solid-state batteries represents a new concept in battery technology. Solid-state means that the liquids and pastes present in ordinary battery systems such as lithium-ion batteries are replaced by a solid plastic film.

Solid-state batteries are broadly classified into two types: bulk solid-state batteries, and thin film solid-state batteries. The large capacity bulk solid-state batteries can store a lot of energy. While the capacity of thin film solid-state batteries is less than that of bulk solid-state batteries, they have advantages of long cycle life and the ease of manufacturing.

In a lithium solid-state battery, the plastic film separates a lithium metal anode (positive electrode) from a composite electrode (negative electrode) which is in contact with aluminium foil as shown in Fig. 7.1. The resultant cell can be constructed so that it has a large electrode area but is less than 0.2 mm thick. It is in many ways similar to a sheet of paper and can be cut and formed into almost any shape. Lithium solid-state cell is rechargeable.

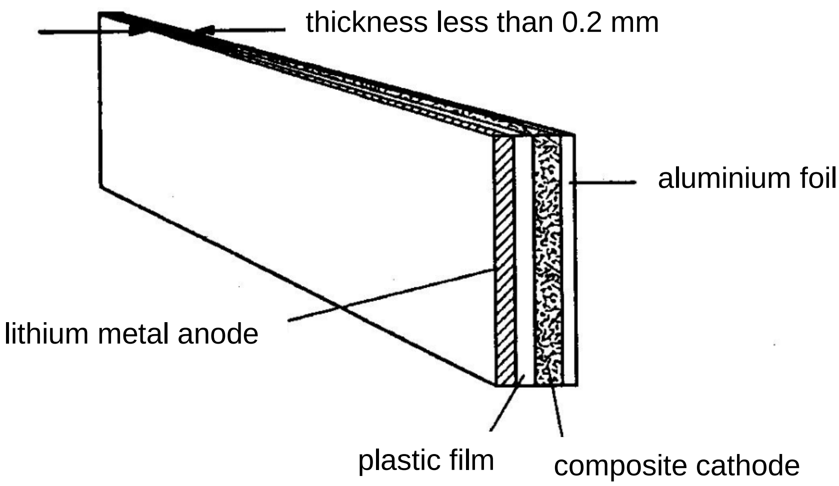

Fig. 7.1

The initial electromotive force (e.m.f). of the cell at full charge is 3.4 V but it rapidly falls to about 2.8 V on load and thereafter falls as shown in Fig. 7.2. The cell needs to be recharged when the e.m.f. reaches 2.0 V. In practice, its average e.m.f. is 2.5 V.

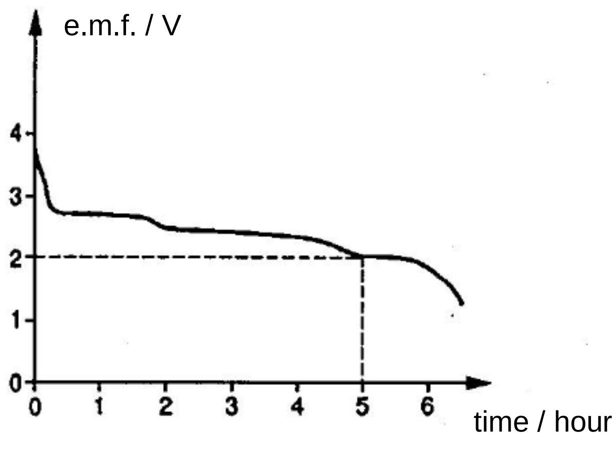

Fig. 7.2

The current density, energy density and charge capacity all have to be considered for a particular application.

The recommended maximum value of discharge current density is 0.15 milliampere per square centimetre of electrode area, the charge capacity is 3.6 coulombs per square centimetre of the electrode area, and the energy density is 120 watt-hours per kilogram of cell mass.

Charging one of these cells should be carried out with a constant applied voltage of 3.4 V and with a current density limited to 2.5 milliampere per square centimetre. A typical charging current against time graph is shown in Fig. 7.3 for a cell of electrode area 50 cm^2.

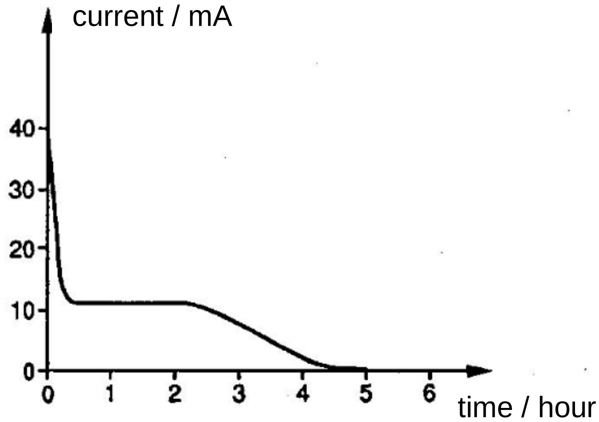

Fig. 7.3

(a) **(i)** Apart from having higher energy density, state one advantage of solid-state batteries over lithium-ion batteries.

.... [1]

(ii) Suggest one application of each of the following as a power source:

1. bulk solid-state battery,

....[1]

2. thin film solid-state battery.

....[1]

(iii) Other than the mass and volume, suggest one difference between bulk solid-state battery and thin film solid-state battery.

....

....[1]

(b) Deduce from the units, the meaning of the terms

(i) current density,

.... [1]

(ii) energy density.

.... [1]

(c) For the cell that has an electrode area of 50 cm^2, calculate

(i) the recommended charge-storage capacity of this cell,

charge-storage capacity = ……………………………C [1]

(ii) the recommended maximum value of the discharge current,

maximum current = ……………………………. mA [1]

(iii) the duration this cell can supply the maximum current in **(c)(ii)**,

duration = ……………………………. s [2]

(iv) the energy this cell can supply in this duration, assuming that the e.m.f. has a constant value of 2.5 V.

energy supply = ……………………………. J [2]

(d) **(i)** State the significance of the area under the graph in Fig. 7.3.

…………………………………………………………………………………....................

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

(ii) Estimate the average charging current over the 5-hour charging time.

average charging current = ……………………………. mA [1]

(e) The energy used in charging the cell is 550 J. Using your answer to **(c)(iv)**, deduce the electrical efficiency of the charge/discharge cycle.

efficiency = ……………………………. % [2]

(f) Suggest a reason for each of the safety considerations,

(i) the cells should not be used in environments with a temperature above 140 ^{o}C,

………………………………………………………………………………………..................

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

(ii) water or water vapour is kept away from lithium cells.

………………………………………………………………………………………..................

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

(g) Draw a diagram, using circuit symbols, to illustrate how you would connect a battery of cells which could produce a current of up to 300 mA at a voltage of approximately 10 V. In your answer, specify the electrode area of the individual cells.

electrode area = …………………………….cm^2 [2]

[Total: 20]

BLANK PAGE

BLANK PAGE

BLANK PAGE