Cambridge International Examinations

Cambridge International Advanced Subsidiary and Advanced Level

ALL THE BEST – CODE-9702

TEST - NO-3

Time : 02:00 Hrs ***Marks: 100 Marks***

Q.1 9702/41/M/J/15

6 **(a)** State the type of field, or fields, that may cause a force to be exerted on a particle that is

(i) uncharged and moving,

.... [1]

(ii) charged and stationary,

.... [1]

(iii) charged and moving at right-angles to the field.

.... [2]

(b) A particle X has mass 3.32×10^{-26} kg and charge $+1.60 \times 10^{-19}$ C.

The particle is travelling in a vacuum with speed 7.60×10^{4} m s^{-1}. It enters a region of uniform magnetic field that is normal to the direction of travel of the particle. The particle travels in a semicircle of diameter 12.2 cm, as shown in Fig. 6.1.

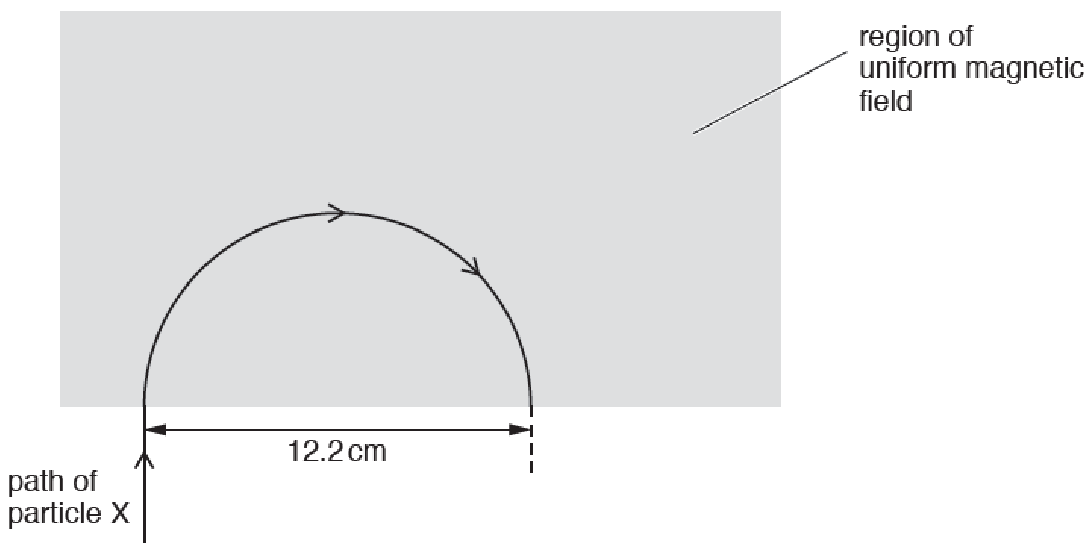

Fig. 6.1

For the uniform magnetic field,

(i) state its direction,

....

.... [1]

(ii) calculate the magnetic flux density.

magnetic flux density = ... T [3]

(c) A second particle Y has mass less than that of particle X in **(b)** and the same charge.

It enters the region of uniform magnetic field in **(b)** with the same speed and along the same initial path as particle X.

On Fig. 6.1, draw the path of particle Y in the region of the magnetic field. [1]

2. 9702/41/M/J/15

8 A photon of wavelength 6.50×10^{-12} m is incident on an isolated stationary electron, as illustrated in Fig. 8.1.

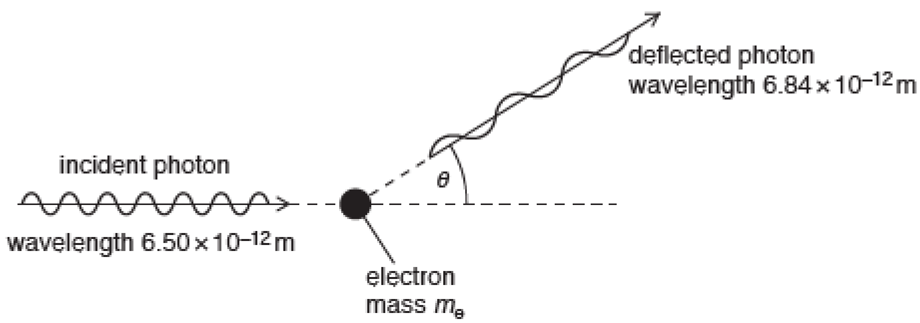

Fig. 8.1

The photon is deflected elastically by the electron of mass m_e. The wavelength of the deflected photon is 6.84×10^{-12} m.

(a) Calculate, for the incident photon,

(i) its momentum,

momentum = ... Ns [2]

(ii) its energy.

energy = ... J [2]

(b) The angle θ through which the photon is deflected is given by the expression

$$\Delta\lambda = \frac{h}{m_e c}(1 - \cos\theta)$$

where $\Delta\lambda$ is the change in wavelength of the photon, h is the Planck constant and c is the speed of light in free space.

(i) Calculate the angle θ.

θ = ... ° [2]

(ii) Use energy considerations to suggest why $\Delta\lambda$ must always be positive.

....

....

....

.... [3]

3. 9702/41/M/J/15

9 (a) An isotope of an element is radioactive. Explain what is meant by *radioactive decay*.

....

....

....

.... [3]

(b) At time t, a sample of a radioactive isotope contains N nuclei. In a short time Δt, the number of nuclei that decay is ΔN.

State expressions, in terms of the symbols t, Δt, N and ΔN for

(i) the number of undecayed nuclei at time $(t + \Delta t)$,

number = ... [1]

(ii) the mean activity of the sample during the time interval Δt,

mean activity = ... [1]

(iii) the probability of decay of a nucleus during the time interval Δt,

probability = ... [1]

(iv) the decay constant.

decay constant = ... [1]

(c) The variation with time t of the activity A of a sample of a radioactive isotope is shown in Fig. 9.1.

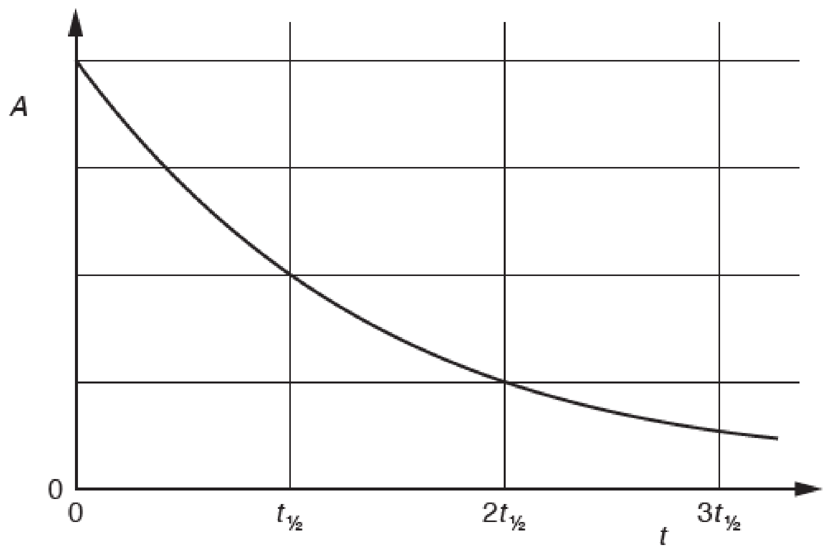

Fig. 9.1

The radioactive isotope decays to form a stable isotope S. At time $t = 0$, there are no nuclei of S in the sample.

On the axes of Fig. 9.2, sketch a graph to show the variation with time t of the number n of nuclei of S in the sample.

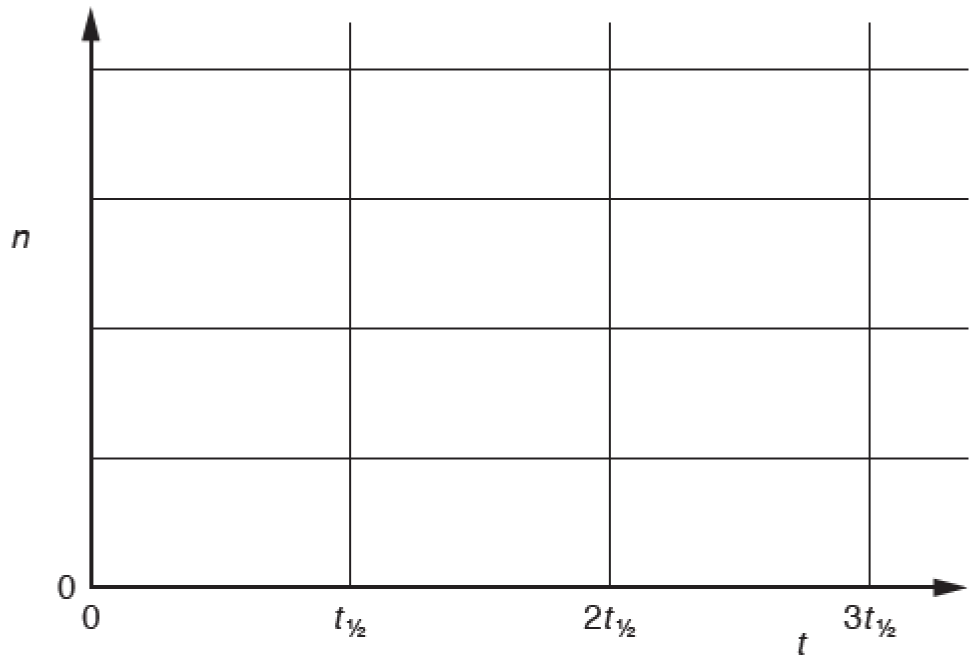

Fig. 9.2

4. 9702/41/M/J/15

10 An operational amplifier (op-amp) is used in the comparator circuit of Fig. 10.1.

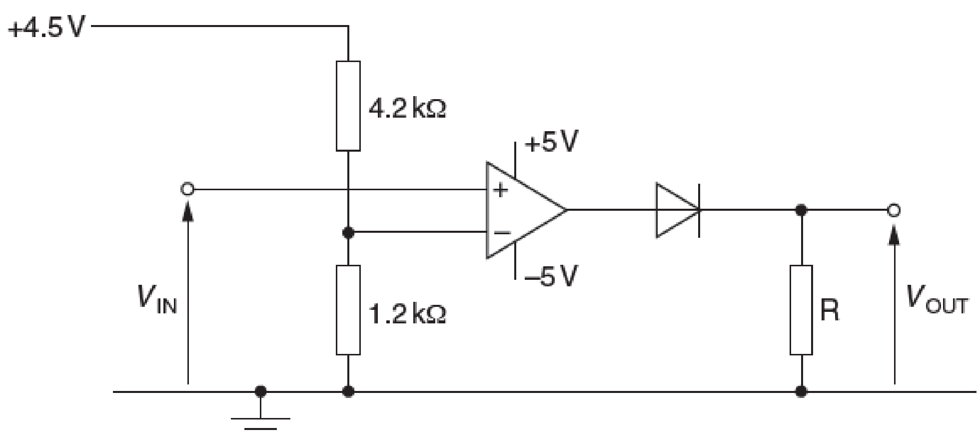

Fig. 10.1

(a) **(i)** Show that the potential at the inverting input of the op-amp is +1.0V.

[1]

(ii) Explain why the potential difference across resistor R is + 5 V when V_{IN} is greater than 1.0 V and is zero when V_{IN} is less than 1.0 V.

V_{IN} > 1.0 V: ....

....

....

V_{IN} < 1.0 V: ....

....

.... [4]

(b) The variation with time t of the input voltage V_{IN} is shown in Fig. 10.2.

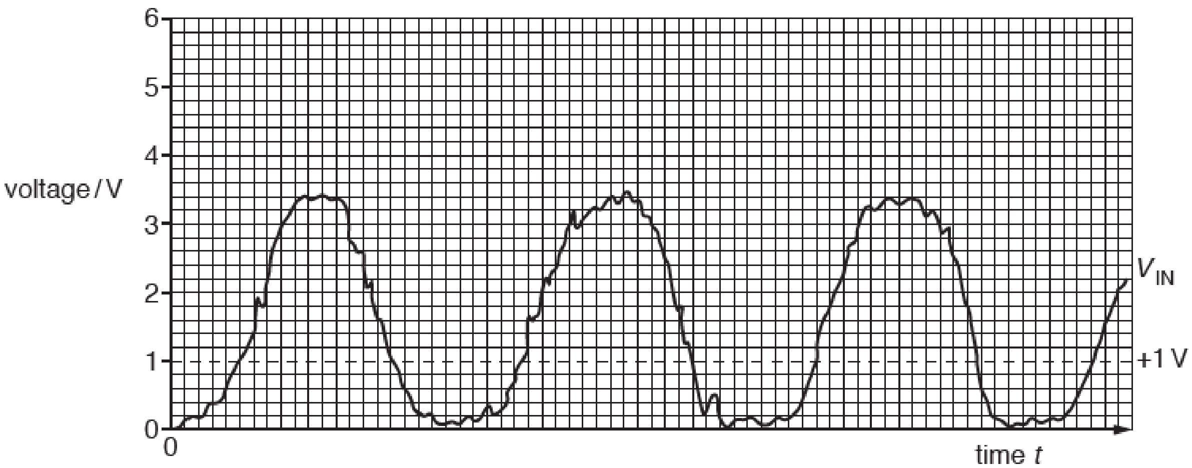

Fig. 10.2

(i) On the axes of Fig. 10.2, draw the variation with time t of the output potential V_{OUT}. [2]

(ii) Suggest a use for this type of circuit.

....

.... [1]

5. 9702/41/M/J/15

13 During magnetic resonance imaging to obtain information about internal body structures, a large constant magnetic field is used with a calibrated non-uniform magnetic field superimposed on it.

(a) State and explain the purpose of

(i) the large constant magnetic field,

....

....

.... [2]

(ii) the non-uniform magnetic field.

....

....

....

.... [3]

(b) The de-excitation energy E (measured in joule) of a proton in magnetic resonance imaging is given by the expression

$$E = 2.82 \times 10^{-26} B$$

where B is the magnetic flux density measured in tesla.
The energy E is emitted as a photon of electromagnetic radiation in the radio-frequency range.

Calculate the magnetic flux density required for the radio frequency to be 42 MHz.

magnetic flux density = ... T [2]

6. 9702/42/O/N/15

7 **(a)** By reference to the photoelectric effect, state what is meant by the *threshold frequency*.

....

....

....[2]

(b) Electrons are emitted from a metal surface when light of a particular wavelength is incident on the surface.
Explain why the emitted electrons have a range of values of kinetic energy below a maximum value.

....

....

....

....[2]

(c) The wavelength of the incident radiation is λ.
The variation with $1/\lambda$ of the maximum kinetic energy E_{MAX} of electrons emitted from a metal surface is shown in Fig. 7.1.

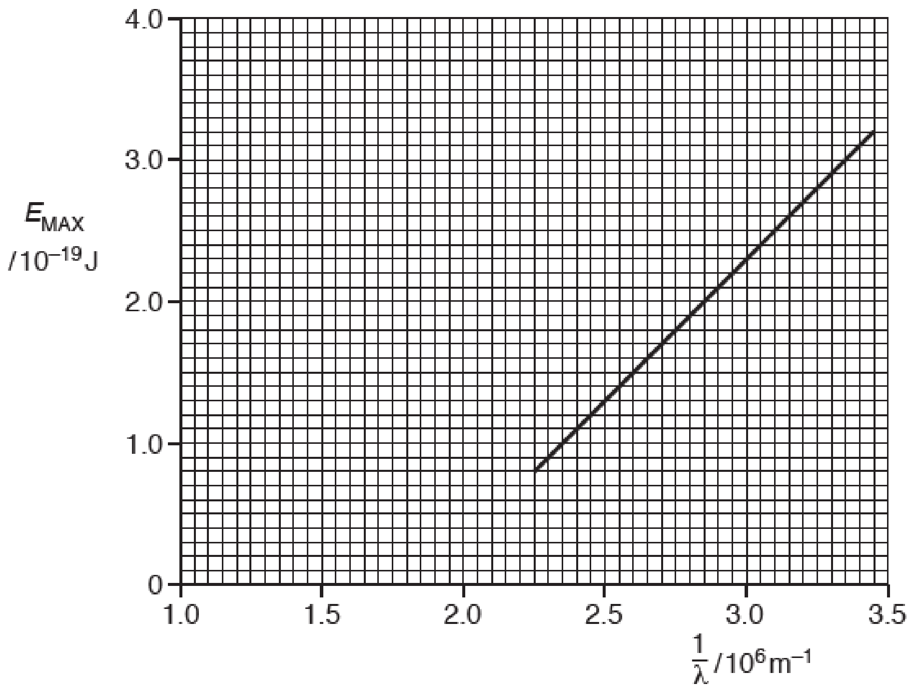

Fig. 7.1

(i) Use Fig. 7.1 to determine, without reference to the work function energy, the threshold frequency f_0.

f_0 = ... Hz [2]

(ii) Use your answer in (i) to calculate the work function energy Φ.

Φ = ... J [2]

(d) Caesium metal has a work function energy of 2.2×10^{-19} J.

On the axes of Fig. 7.1, sketch a graph to show the variation with $1/\lambda$ of E_{MAX} for caesium metal. [2]

7. 9702/42/O/N/15

8 **(a)** Distinguish, for an atom, between a nucleus and a nucleon.

nucleus: ....

....

nucleon: ....

....
[3]

(b) Radon gas is a naturally occurring radioactive gas with a half-life of 3.8 days.

The activity of radon gas in a room is found to be 97 Bq in each 1.0 m^3 of air.

(i) Calculate

1. the decay constant, in s^{-1}, of radon,

decay constant = ... s^{-1} [2]

2. the number of radon atoms giving rise to an activity of 97 Bq.

number = ... [2]

(ii) A volume of $2.5 \times 10^{-2}\,m^3$ of air in the room contains 1.0 mol of molecules.

Determine the ratio, for $1.0\,m^3$ of air,

$$\frac{\text{number of radon atoms}}{\text{number of air molecules}}.$$

ratio = ... [2]

8. 9702/42/O/N/15

9 A battery of e.m.f. 6.0 V and negligible internal resistance is connected to three resistors, each of resistance 2.0 kΩ, and a thermistor, as shown in Fig. 9.1.

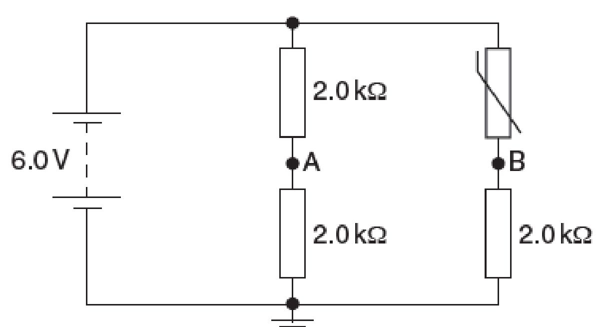

Fig. 9.1

The thermistor has resistance 2.8 kΩ at 10 °C and resistance 1.8 kΩ at 20 °C.

(a) Calculate the potential

(i) at point A,

potential = ... V [1]

(ii) at point B for the thermistor at 10 °C,

potential = ... V [2]

(iii) at point B for the thermistor at 20 °C.

potential = ... V [1]

(b) The points A and B in Fig. 9.1 are connected to the inputs of an ideal operational amplifier (op-amp), as shown in Fig. 9.2.

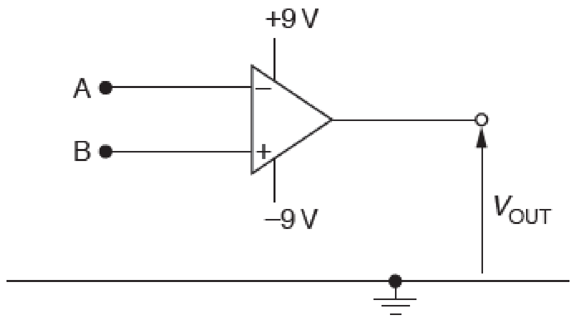

Fig. 9.2

The thermistor is warmed from 10 °C to 20 °C.

State and explain the change in the output potential V_{OUT} of the op-amp as the thermistor is warmed.

....

....

....

....

....

....[4]

9. 9702/42/O/N/15

10 **(a)** Explain what is meant by the *sharpness* and by the *contrast* of an X-ray image.

sharpness: ....

....

contrast: ....

....

[2]

(b) A parallel X-ray beam of intensity I is incident on a medium of thickness x, as illustrated in Fig. 10.1.

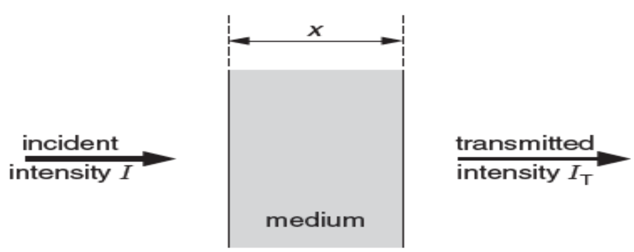

Fig. 10.1

The transmitted intensity is I_T.

Data for the linear absorption (attenuation) coefficient μ for 80 keV X-rays in bone and in muscle are given in Fig. 10.2.

	μ / cm^{-1}
bone	3.0
muscle	0.27

Fig. 10.2

(i) State, with reference to the production of X-rays, what is meant by *80 keV X-rays*.

....

....

....[2]

(ii) Calculate the ratio I_T / I for 80 keV X-rays passing through a thickness of 1.4 cm of bone.

ratio = ... [2]

(c) An X-ray image of the upper leg of a student is produced.
Part of the X-ray beam passes through a comparatively large thickness of muscle and part through some muscle and the leg bone.

Use data from Fig. 10.2 to suggest whether the image has good contrast.

....

....

....

....

....[3]

10. 9702/42/M/J/15

6 (a) Explain what is meant by a *photon*.

....

....

....[2]

(b) An X-ray photon of energy 3.06×10^{-14} J is incident on an isolated stationary electron, as illustrated in Fig. 6.1.

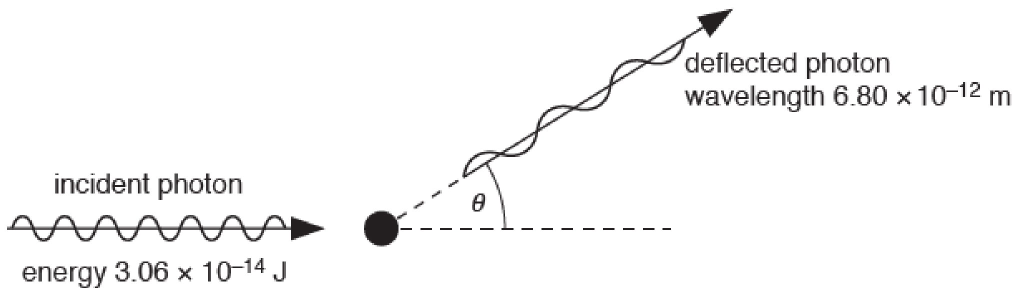

Fig. 6.1

The photon is deflected elastically by the electron through angle θ. The deflected photon has a wavelength of 6.80×10^{-12} m.

(i) On Fig. 6.1, draw an arrow to indicate a possible initial direction of motion of the electron after the photon has been deflected. [1]

(ii) Calculate

1. the energy of the deflected photon,

photon energy = ... J [2]

2. the speed of the electron after the photon has been deflected.

speed = ... $m\,s^{-1}$ [3]

(c) Explain why the magnitude of the final momentum of the electron is not equal to the change in magnitude of the momentum of the photon.

....

....

.... [2]

11. 9702/42/M/J/15

7 **(a)** A solenoid is connected in series with a resistor, as shown in Fig. 7.1.

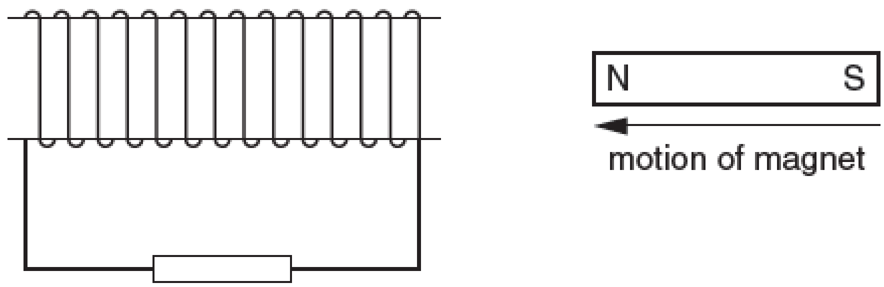

Fig. 7.1

As the magnet is being moved into the solenoid, thermal energy is transferred in the resistor. Use laws of electromagnetic induction to explain the origin of this thermal energy.

....

....

....

....

....

....

....[4]

(b) Explain why the alternating current in the primary coil of a transformer is not in phase with the alternating e.m.f. induced in the secondary coil.

....

....

....

....

....

....

....[4]

12.

8 The power for a space probe is to be supplied by the energy released when plutonium-236 decays by the emission of α-particles.

The α-particles, each of energy 5.75 MeV, are captured and their energy is converted into electrical energy with an efficiency of 24%.

(a) Calculate

(i) the energy, in joules, equal to 5.75 MeV,

energy = ... (2)

(ii) the number of α-particles per second required to generate 1.9 kW of electrical power.

number per second = ... s^{-1} [2]