Name of the Student:_____
Max. Marks : 20 Marks **Time : 20 Minutes**

Q1.

(a) Deuterium is an isotope of hydrogen. Its nucleus contains one proton and one neutron.

Calculate the specific charge of the deuterium nucleus.

specific charge = _____ C kg^{-1}

(2)

(b) The proton and neutron in the deuterium nucleus are held together by the strong nuclear force.

Which is an exchange particle of the strong nuclear force?
Tick (✔) **one** box.

moon ☐

photon ☐

pion ☐

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W^+ boson ☐

(1)

(c) The deuterium nucleus is stable.

Describe how the variation of the strong nuclear force with distance contributes to the stability of the deuterium nucleus.

(3)

(d) Tritium is an isotope of hydrogen. Its nucleus contains one proton and two neutrons. Tritium undergoes radioactive decay.

Three modes of radioactive decay are

- alpha decay
- beta minus (β^-) decay
- electron capture.

Deduce which of these modes could produce the nucleus of another element when the tritium nucleus decays.

(3)

(Total 9 marks)

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Q2.

This question is about two applications of photon energy and momentum: positron emission tomography (PET) and a solar sail.

$$\text{The momentum of a photon is } \frac{\text{photon energy}}{\text{speed of light in a vacuum}}$$

(a) In preparing for a PET scan of a patient's brain, a small sample of a substance containing unstable nuclei is injected into the patient.
A positron is emitted when one of the unstable nuclei undergoes β^+decay.

Explain how the change in quark character in β^+decay affects the number of neutrons and the number of protons in the unstable nucleus.

_____

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(2)

(b) The positron interacts with an electron, resulting in annihilation. As a result, gamma photons are produced.
The energy of each gamma photon is 0.52 MeV.

Calculate the momentum, in N s, of one of the gamma photons produced in this annihilation.

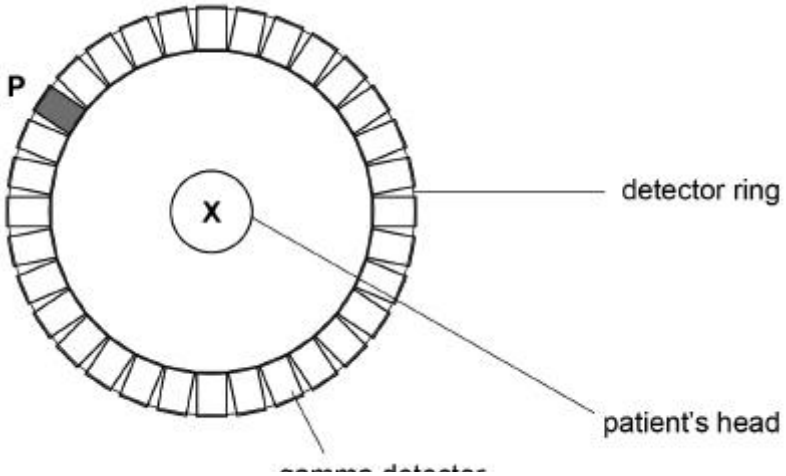
momentum = _____ N s

(2)

(c) **Figure 1** shows a cross-sectional view of the patient's head inside a ring of gamma detectors during the PET scan.

Figure 1

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A positron and an electron meet and annihilate at position **X** shown in **Figure 1**.
Assume they have negligible kinetic energy when they meet.

Gamma photons are produced in this annihilation and are detected. The arrival of one gamma photon at detector **P** triggers a signal. Detector **P** has been shaded in **Figure 1**.

Identify by shading any other detectors that will be triggered by this annihilation.

(1)

(d) Explain your answer to question **(c)**.

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(2)

(e) **Figure 2** shows a stream of photons of light, emitted from the Sun, incident on a solar sail. A solar sail is an experimental spacecraft that uses photons of light to accelerate it.

Figure 2

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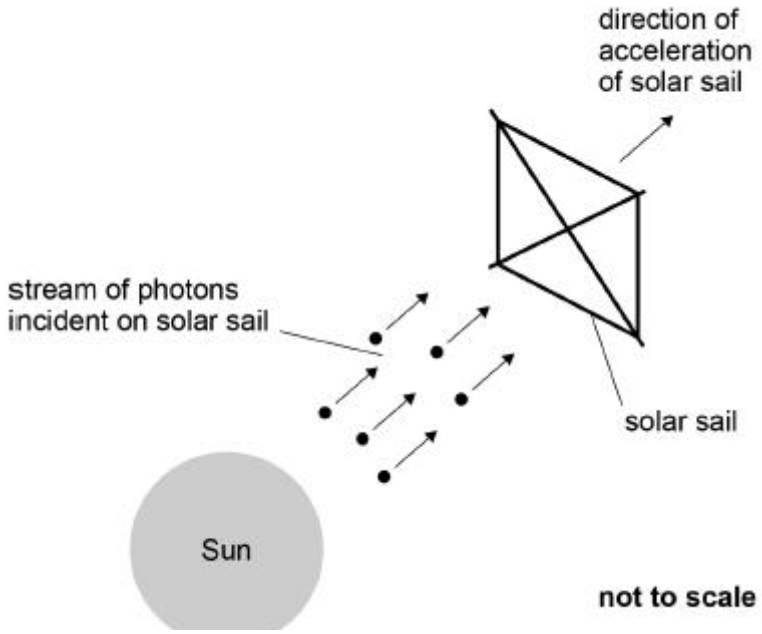
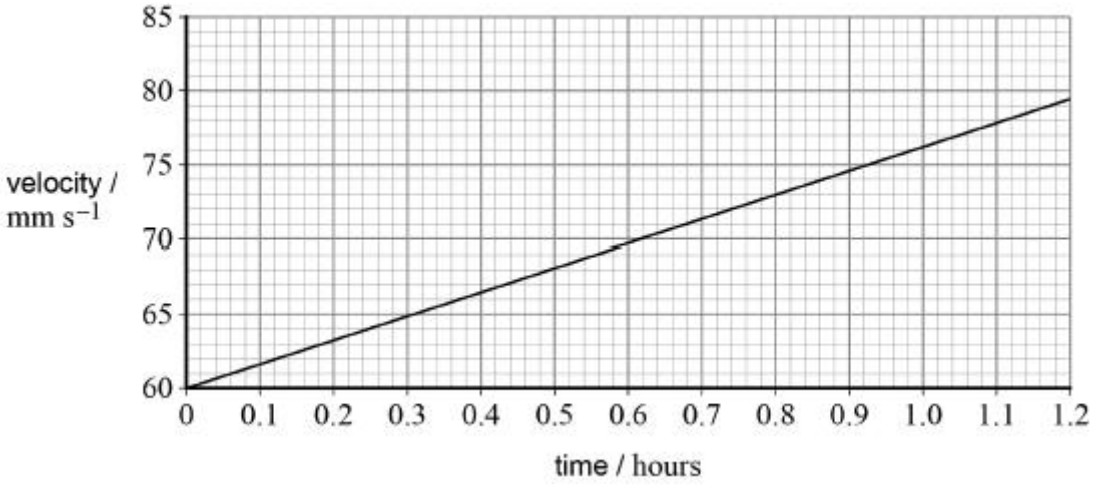


Figure 3 shows the velocity–time graph for the solar sail.

Figure 3



Calculate the acceleration, in m s^{-2}, of the solar sail.

acceleration = _____ m s^{-2}

(2)

(f) The reflectance of a surface is proportional to the percentage of incident photons that are reflected off the surface.

Explain the effect of increasing the reflectance of the solar sail on the acceleration. Assume gravity has negligible effect on the solar sail.

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(2)

(Total 11 marks)

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