1. A hospital uses the radioactive isotope technetium-99m as a tracer. Technetium-99m is produced using a Molybdenum-Technetium generator on site at the hospital.

(a) Explain why the value of the half-life of technetium-99m:

- makes it suitable for use as a tracer
- means that it must be produced in a generator on site.

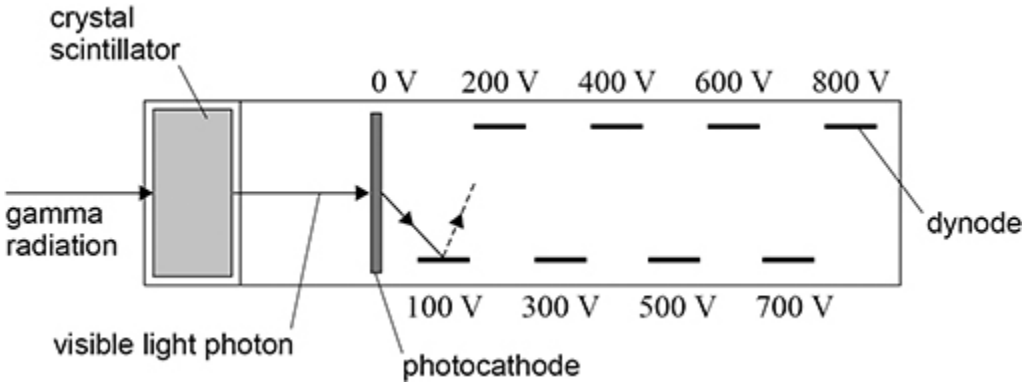
(4)

(b) Technetium-99m emits **only** gamma rays.

Explain why this makes technetium-99m suitable for use as a tracer.

(4)

(c) A gamma camera can be used to form images when using a tracer. The figure below shows a photomultiplier tube from a gamma camera.



At the crystal scintillator, each photon of gamma radiation leads to the emission of one visible light photon.

Describe how the current produced by the photocathode is amplified in the photomultiplier tube.

(3)

(d) Iodine-131 is a medical tracer that can be detected using a gamma camera.

Iodine-131 has a physical half-life of 8.0 days.

A patient is injected with iodine-131 that has an initial activity of 3.2 GBq. For this patient, the biological half-life is 66 days. For safety reasons, the patient cannot be discharged from hospital until the activity due to the iodine in the patient's body drops to 1.1 GBq.

Determine whether the patient can be safely released from hospital after 10 days.

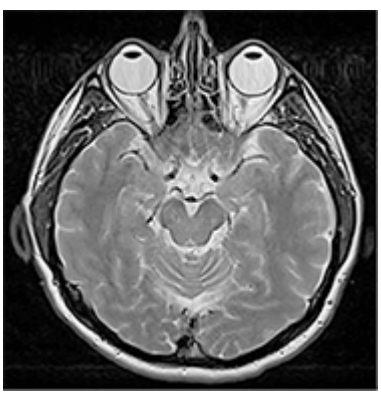
(4)

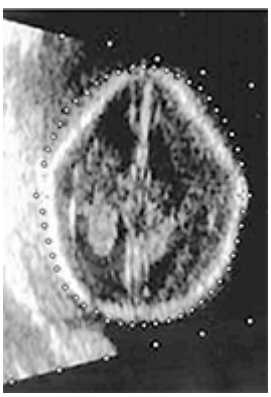
(Total 15 marks)

2. The figure below shows scanned images of three different human heads.
Each image used **one** of the following scanning techniques:

- magnetic resonance (MR)
- CT
- ultrasound
- PET.

A **B** **C**





Identify the scanning technique used for each image.
Go on to explain how the features of each image enabled you to identify the type of scan.

A: Scanning technique _____

Explanation _____

_____

_____

B: Scanning technique _____

Explanation _____

_____

_____

C: Scanning technique _____

Explanation _____

_____

_____

(Total 4 marks)

3. A patient is going to have a PET scan. A small amount of radioisotope is injected into the patient's bloodstream and the patient is left to relax. The patient then lies on a horizontal table and is moved into the PET scanner. The scanner has many detectors positioned in a vertical circular pattern around the patient.

(a) State what is meant by a radioisotope.

_____

_____

(1)

(b) The radionuclide used in the PET scan has a physical half-life of 110 minutes. The radionuclide is excreted from the body with a biological half-life of 185 minutes.

Show that the effective half-life of the radionuclide in the body is about 70 minutes.

(1)

(c) Discuss what might be a suitable length of time for the patient to relax between injecting the radionuclide and moving the patient into the PET scanner.

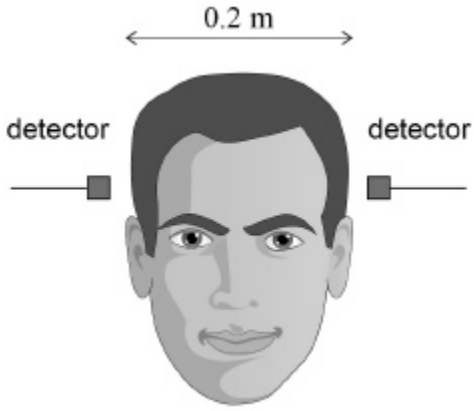
(3)

(d) The decay of the radionuclide results in the emission of a positron. Two of the detectors, directly opposite to each other, are triggered as they each receive a gamma photon.

Explain the process in which the gamma photons are created.

(2)

(e) The diagram shows the head of a patient that is 0.2 m across, placed centrally between two of the many detectors in a PET scanner.



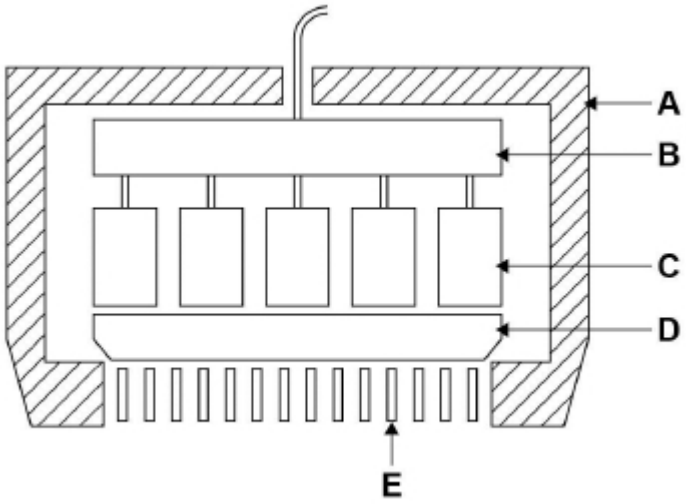
To determine the position where the gamma photons are produced between the detectors, the scanner measures the short interval of time Δt between the triggering of the first detector and the triggering of the second detector.

Discuss, for the detector positions shown in the diagram, the range of the values of Δt that the scanner must measure to perform a PET scan on the head.
Assume that the speed of the gamma photons in the head is 3×10^8 m s^{-1}.

(2)

(Total 9 marks)

4. (a) The diagram below shows the main components of a gamma camera.



Explain briefly the operation of the camera referring to the parts labelled A to E.

(4)

(b) Describe how the image obtained using the gamma camera differs from that obtained using diagnostic X−rays and why this difference can be an advantage in medical diagnosis.

(2)

(Total 6 marks)