Exercise walk-through

PET scanning ▪ 24.3

eXercise

You must be able to

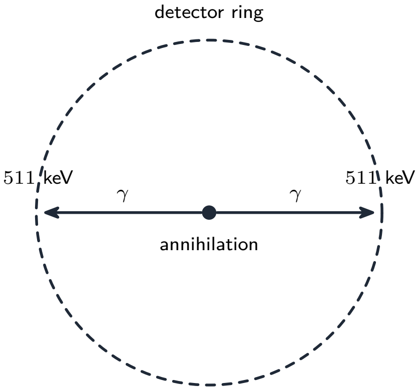
- explain the **tracer** and **annihilation**
- calculate the **annihilation photon energy**
- explain how the photons locate the event

Method — Tracer and annihilation

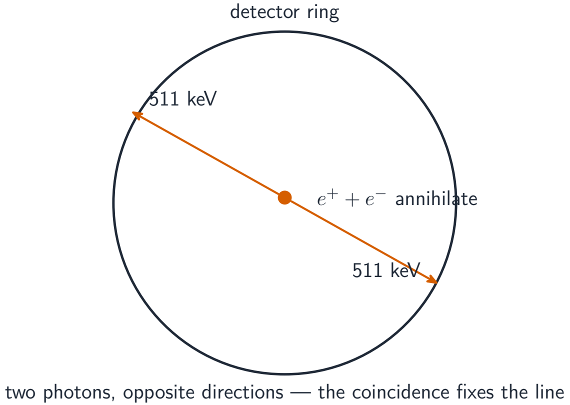
A **tracer** is a radioactive substance put into the body and taken up by the tissue studied. In **PET** it is a β^+ **(positron) emitter**. The positron meets an **electron** and they **annihilate**:

Mass-energy and **momentum** are conserved. Since the total momentum is ~zero, **two** γ photons go in **opposite directions**, each of energy $m_e c^2 = 511$ keV.

Detecting **both** photons (and their arrival times) lets the scanner work out the **line** they came from, building an image of tracer concentration.



Method — Tracer and annihilation



PET detects annihilation photons

Practice 2.1 ▪ 1 mark

State what a **tracer** is.

Solution 2.1

Worked steps

A substance containing **radioactive nuclei** introduced into the body and **taken up** by the tissue being studied **B1**.

Practice 2.2 ▪ 1 mark

State the type of **decay** a PET tracer undergoes.

Solution 2.2

Worked steps

β^+ **(positron)** decay **B1**.

Practice 2.3 ▪ 2 marks

Explain what **annihilation** is.

Solution 2.3

Worked steps

When a particle meets its **antiparticle**, they are destroyed and their **mass becomes energy** (electromagnetic radiation) B1 B1.

Practice 2.4 ▪ 1 mark

State the **energy** of each annihilation photon.

Solution 2.4

Method: Tracer and annihilation

Worked steps

511 keV $(= m_e c^2)$ **B1**.

Exam-style 3.1 ▪ 1 mark

In PET, the two γ photons from an annihilation travel:

A in the same direction

B in opposite directions

C at right angles

D in random directions

Solution 3.1

Method: Tracer and annihilation

A in the same direction

B in opposite directions ✓

C at right angles

D in random directions

Worked steps

B — in opposite directions.

Exam-style 3.2 ▪ 3 marks

Calculate the **energy** of each γ photon produced when an electron and positron annihilate. ($m_e = 9.11 \times 10^{-31}$ kg.)

Solution 3.2

Method: Tracer and annihilation

Worked steps

Total rest energy $= 2m_ec^2$, shared by two photons, so each $E = m_ec^2 = (9.11 \times 10^{-31})(3.0 \times 10^8)^2$ **M1** **M1** $= 8.2 \times 10^{-14}$ J $(= 511$ keV$)$ **A1**.

Exam-style 3.3 ▪ 2 marks

Explain why **two** photons are produced (not one), travelling in opposite directions.

Solution 3.3

Method: Tracer and annihilation

Worked steps

Momentum must be **conserved**; the pair's total momentum is ~zero, so the photons must go in **opposite directions** with equal momentum (a single photon could not conserve momentum) **B1** **B1**.

Exam-style 3.4 ▪ 2 marks

Explain how detecting the two photons helps locate the **annihilation** event.

Solution 3.4

Method: Tracer and annihilation

Worked steps

Both photons are detected (almost simultaneously) on **opposite sides** of the ring B1; the annihilation lies on the **straight line** joining the two detectors — combining many such lines builds the image B1.