A-LEVEL PHYSICS • EXERCISE SHEET

24.2 Production and use of X-rays

Name: ____________ Class: ________ Date: __________ **Total: 12 marks**

Objective

Build the skills to answer exam questions on **X-rays** in medicine.

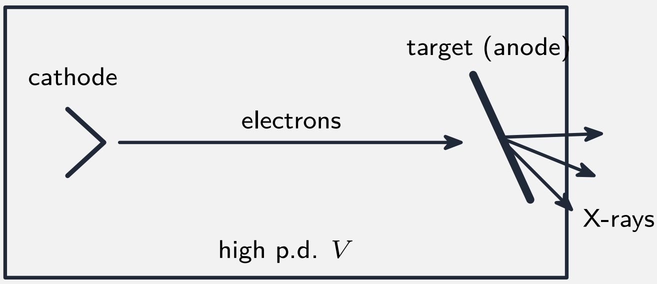
You must be able to:

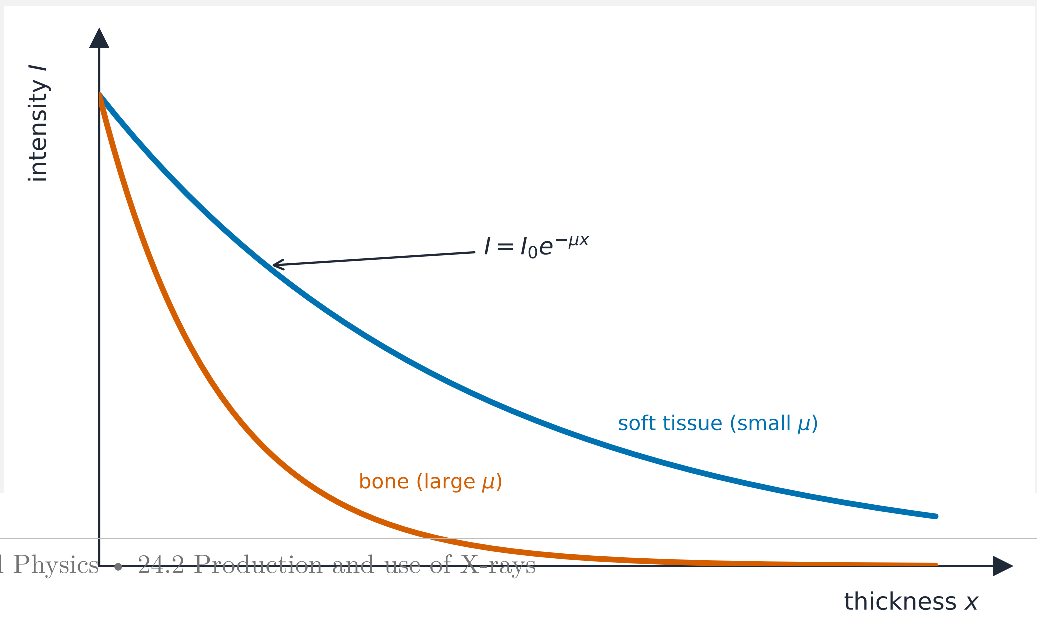
- explain X-ray production and find the **minimum wavelength**
- use the attenuation $I = I_0 e^{-\mu x}$ and **contrast**
- describe **CT scanning**

1 Worked examples

Study these first. Each one shows the method for a question type used later —follow the steps and you can do the Practice and Exam-style questions yourself.

■ Production





X-ray attenuation through tissue

Electrons from a heated **cathode** are accelerated by a high p.d. V onto a metal **target**. The most energetic photon has the full electron KE:

$$hf_{\max} = eV, \qquad \lambda_{\min} = \frac{hc}{eV}.$$

Imaging

X-rays are **attenuated** as $I = I_0 e^{-\mu x}$; bone (high μ) absorbs more than soft tissue, giving **contrast**. **CT scanning** combines many X-ray images from different angles into a 2D slice, then stacks slices into a **3D** image.

2 Practice

Now apply the methods above.

2.1 Describe how **X-rays** are produced in an X-ray tube. [2]

2.2 Write the equation for the **minimum wavelength** of X-rays. [1]

2.3 Write the equation for the **attenuation** of X-rays. [1]

2.4 State what is meant by **contrast** in an X-ray image. [1]

3 Exam-style questions

3.1 The **minimum wavelength** of the X-rays from a tube depends on: [1]

- **A** the target metal
- **B** the accelerating p.d.
- **C** the tube current
- **D** the tube length

3.2 An X-ray tube uses an accelerating p.d. of 50 kV. Calculate the **minimum wave-**

length of the X-rays. [3]

3.3 Describe how a **CT scan** produces a 3D image of the body. [3]

4 Go further

You are now ready for the real exam questions on this subtopic. Open the **24.2 Production and use of X-rays** past-paper sheet in the Library, or try this in **Practice mode**:

- 9702/42 J25 —Q6 (X-ray production and minimum wavelength)

X-ray attenuation ($I = I_0 e^{-\mu x}$) also appears in the **24.1 Production and use of ultrasound** sheet, so practise that too.

Solutions

2.1 A heated **cathode** emits electrons (thermionic emission); a high p.d. accelerates them onto a metal **target**, where they decelerate and emit X-rays.

2.2 $\lambda_{\text{min}} = \dfrac{hc}{eV}$.

2.3 $I = I_0 e^{-\mu x}$.

2.4 The **difference in brightness** between structures (e.g. bone vs soft tissue) caused by their different absorption of X-rays.

3.1 **B** —the accelerating p.d.

3.2 $\lambda_{\text{min}} = \dfrac{hc}{eV} = \dfrac{(6.63 \times 10^{-34})(3.0 \times 10^{8})}{(1.6 \times 10^{-19})(50\,000)} = 2.5 \times 10^{-11}$ m.

3.3 Take many X-ray images of one **slice** from **different angles** and combine them into a 2D image of that slice; repeat for many slices **along the body**; stack the slices to build a **3D** image.