



A-Level Physics

Electron Microscopes

Question Paper

Time available: 65 minutes

Marks available: 45 marks

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1.

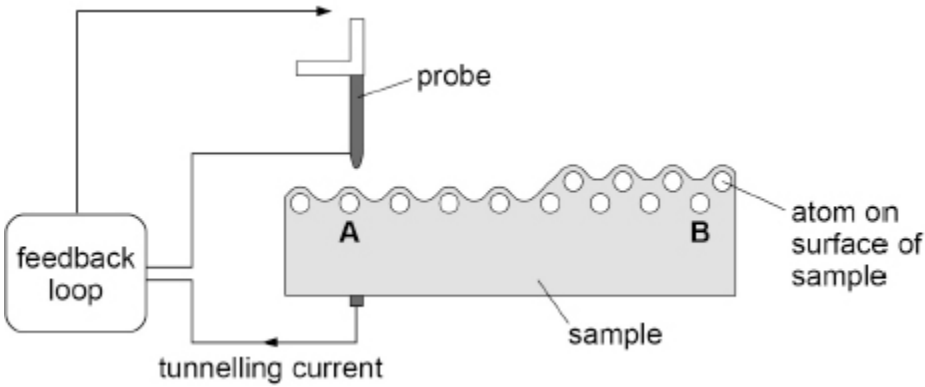
(a) The scanning tunnelling microscope (STM) uses a process called quantum tunnelling.

Explain what is meant by quantum tunnelling of an electron in an STM. You may include a diagram as part of your answer.

(2)

(b) An STM is used to map the positions of the atoms between points **A** and **B** on the surface of a sample.

The diagram shows some of the features of the operation of an STM.



The STM in the diagram above is in constant-current mode.

Describe how the STM creates a map of the positions of one row of atoms on the surface of the sample from **A** to **B**.

(3)

- (c) The smallest size of objects that the STM can resolve is similar to the de Broglie wavelength of the tunnelling electrons.

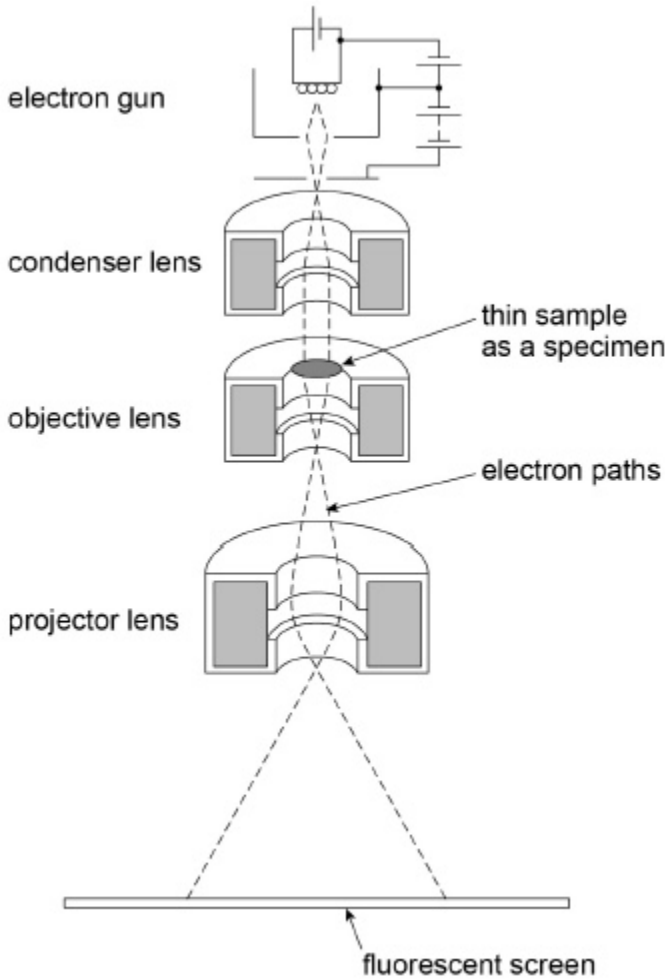
Deduce whether electrons with kinetic energies less than 1.5 eV are suitable to map the surface in the diagram above.

(3)

(Total 8 marks)

2.

The diagram shows the main parts of a transmission electron microscope (TEM).



(a) What is the process by which electrons are produced in an electron gun?
Tick (✓) the correct box.

- Beta particle emission
- Electron diffraction
- Photoelectric effect
- Thermionic emission

(1)

- (b) The electrons in a particular TEM have a kinetic energy of 4.1×10^{-16} J. Relativistic effects are negligible for this electron energy.

Suggest, with a calculation, whether the images of individual atoms can, in principle, be resolved in this TEM.

(3)

- (c) A typical TEM can accelerate electrons to very high speeds and form high resolution images.

Explain:

- the process of image formation, and
- the factors that affect the quality of, and the level of detail in, the image.

(6)

(Total 10 marks)

3.

In a transmission electron microscope (TEM) electrons are accelerated by a potential difference V between a cathode and anode. The de Broglie wavelength λ of the accelerated electrons depends on V .

(a) Identify which of the following represents the relationship between λ and V . Ignore relativistic effects.

Tick (✓) the correct answer in the right-hand column

	✓ if correct
$\lambda \propto \sqrt{V}$	
$\lambda \propto V$	
$\lambda \propto \frac{1}{V}$	
$\lambda \propto \frac{1}{\sqrt{V}}$	

(1)

(b) TEMs operate using wavelengths of about 0.1 nm.

Explain why operation at such wavelengths makes the instrument such an important research tool.

(2)

(c) State and explain **two** factors that limit the detail in the image produced by a TEM.

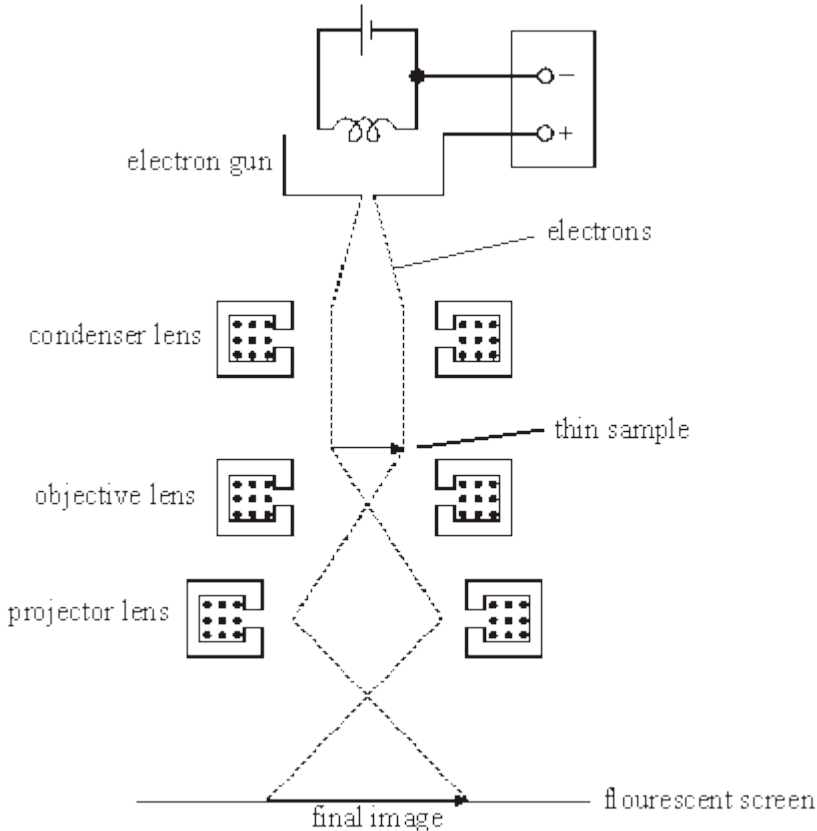
1. _____

2. _____

(4)
(Total 7 marks)

4.

In a transmission electron microscope, electrons from a heated filament are accelerated through a certain potential difference and then directed in a beam through a thin sample. The electrons scattered by the sample are focused by magnetic lenses onto a fluorescent screen where an image of the sample is formed, as shown in the figure below.



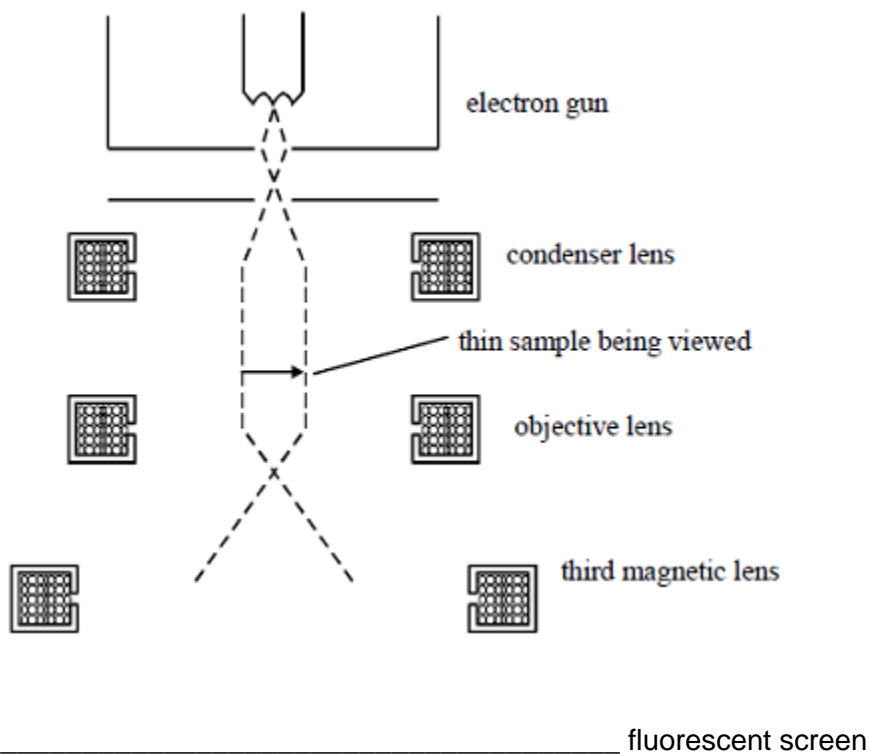
(a) State and explain **one** reason why it is important that the electrons in the beam have the same speed.

(2)

- (b) When the potential difference is increased, a more detailed image is seen. Explain why this change happens.

(3)
(Total 5 marks)

5. The diagram shows the lens arrangement of a transmission electron microscope (T.E.M.). The dashed lines show two of the many paths followed by electrons through the T.E.M.



- (a) Complete the two electron paths on the diagram and draw an arrow to represent the final image

(2)

- (b) What is the function of
- (i) the condenser lens,

(ii) the objective lens,

(iii) the third magnetic lens?

(3)

(c) (i) State and explain the effect on the resolving power of the T.E.M. if the anode voltage of the electron gun is increased.

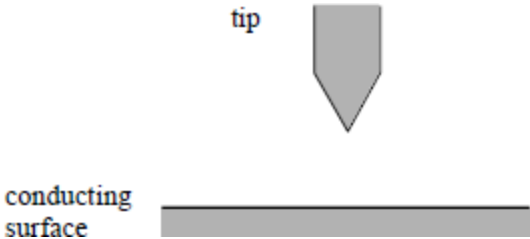
(ii) In practice, the resolving power of a T.E.M. is limited. State and explain **one** factor that limits the resolving power.

(4)

(Total 9 marks)

6.

The diagram shows the tip of a scanning tunnelling microscope (STM) above a conducting surface. The tip is at a potential of -1.0 V relative to the surface. If the tip is sufficiently close to the surface, electrons transfer from the tip to the surface.



(a) The tip is made to scan the surface along a horizontal line. Describe and explain the effect on the current between the tip and the surface if the tip moves across a pit in the surface.

(b) An STM image can resolve individual atoms of diameter 0.5 nm on the surface. Estimate the kinetic energy, in eV, of an electron which has a de Broglie wavelength of 0.5 nm .

(Total 6 marks)