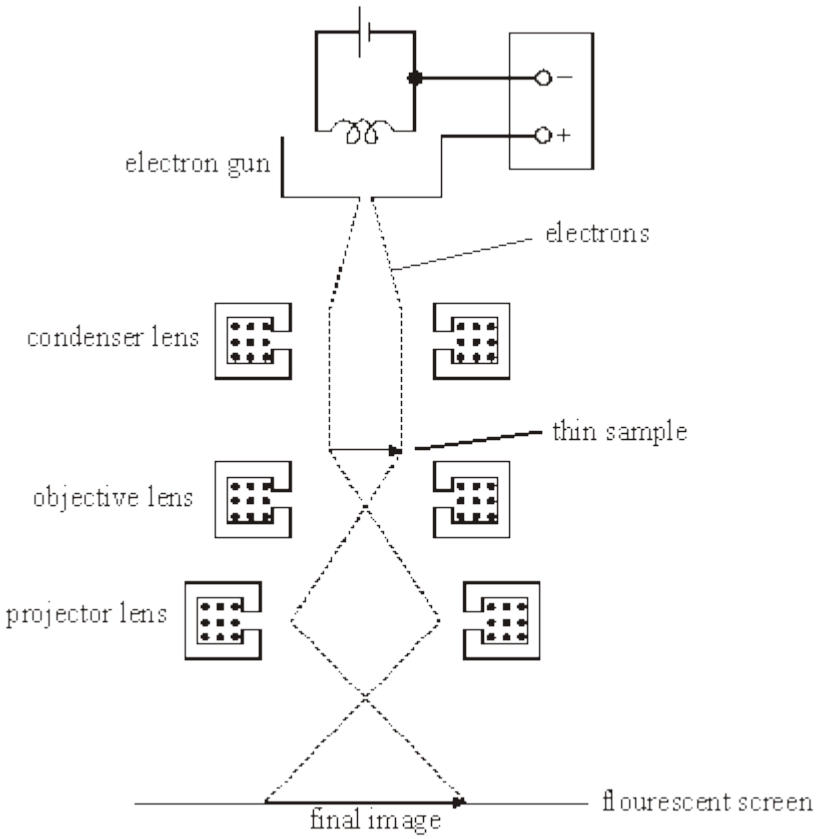
1 In a transmission electron microscope, electrons from a heated filament are accelerated through a certain potential difference and then directed in a beam through a thin sample. The electrons scattered by the sample are focused by magnetic lenses onto a fluorescent screen where an image of the sample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

_____

_____

_____

_____

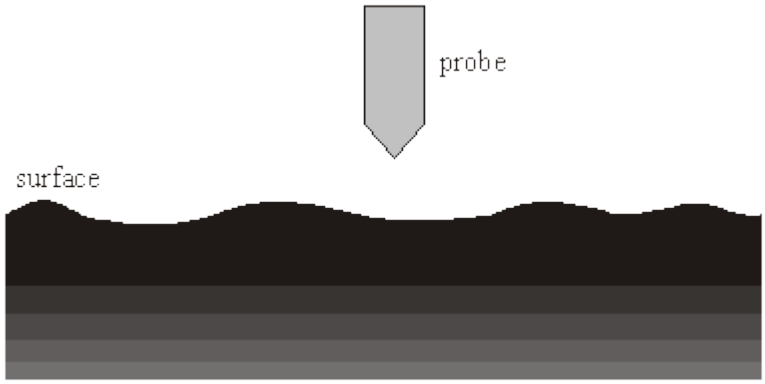
(2)

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

(3)

(Total 5 marks)

2 In a scanning tunnelling microscope (STM), a metal probe with a sharp tip is scanned across a surface, as shown in the figure below.



(a) Explain why electrons transfer between the tip of the probe and the surface when the gap between the tip and the surface is very narrow and a pd is applied across it.

(3)

(b) Describe how an STM is used to obtain an image of a surface.

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_____

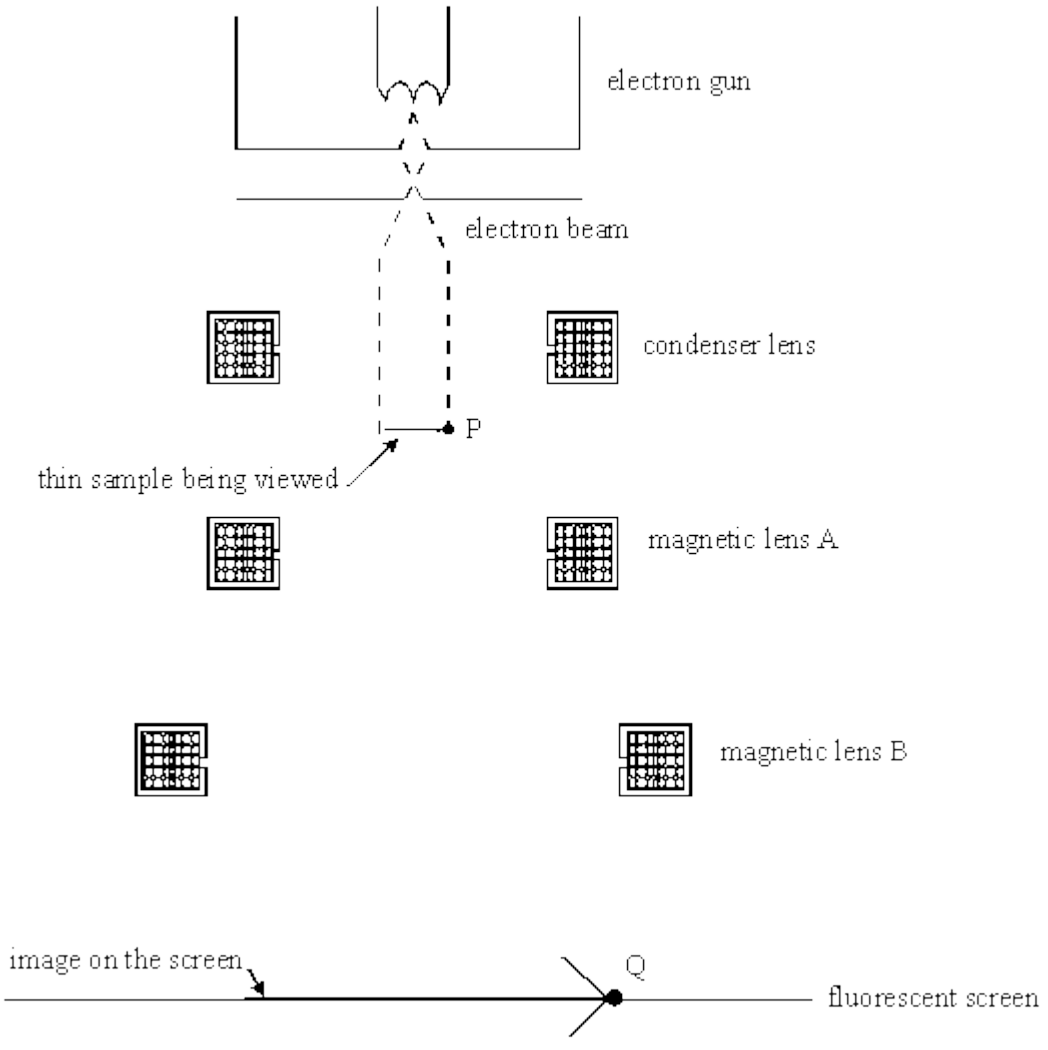
_____

_____

(3)

(Total 6 marks)

3 The diagram below shows a Transmission Electron Microscope. Electrons from the electron gun pass through a thin sample and then through two magnetic lenses A and B on to a fluorescent screen. An enlarged image of the sample is formed on the screen.



(a) (i) Sketch the path of an electron that reaches point Q on the screen after passing through the sample at point P and through the two magnetic lenses A and B.

(ii) State the function of magnetic lens A and the function of magnetic lens B.

magnetic lens A _____

_____

_____

magnetic lens B _____

_____

_____

(4)

(b) Explain why greater image detail is seen when the anode voltage is increased.

_____

_____

_____

_____

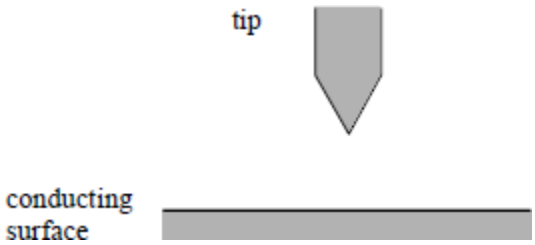
_____

_____

(3)

(Total 7 marks)

4 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.

_____

_____

_____

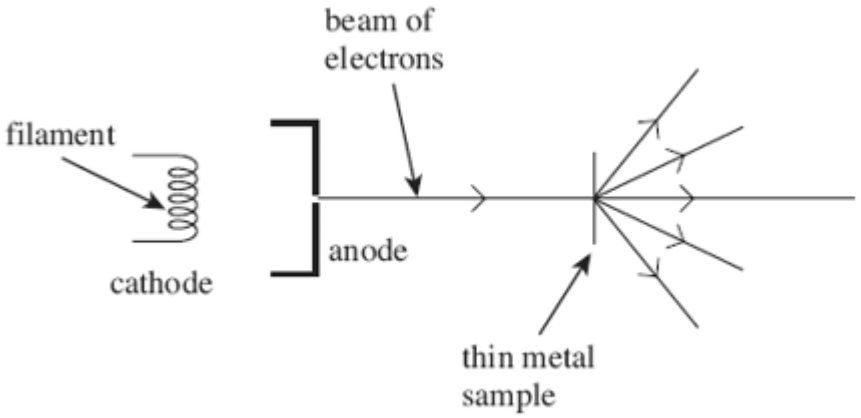
_____

_____

(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)

5 In the figure below, a beam of monoenergetic electrons is produced by thermionic emission from a wire filament in an evacuated tube. The beam is directed at a thin metal sample at normal incidence and it emerges from the sample in certain directions only, including its initial direction.



(a) (i) Name the physical process occurring at the thin metal sample in the figure above which shows the electrons behaving as waves.

(1)

(ii) Explain why the electrons need to be monoenergetic in order for them to emerge in certain directions only.

_____

_____

_____

_____

(2)

(b) A transmission electron microscope (TEM) operating at an anode potential of 25kV is used to observe an image of a thin sample.

(i) Calculate the momentum of the electrons emerging from the anode, stating an appropriate unit.

answer = _____

(4)

(ii) Describe and explain how the resolution of the image would change if the anode potential were increased.

_____

_____

_____

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(3)

(Total 10 marks)

6 (a) In the Scanning Tunnelling Microscope (STM), electrons cross a gap between a sharp metal tip and a conducting surface when the gap is small and a potential difference exists across it.

(i) Explain, in terms of wave particle duality, why an electron can cross this small gap.

_____

_____

_____

_____

_____

(ii) Explain, why it is necessary for a potential difference to exist across the gap?

_____

_____

_____

_____

(4)

(b) Calculate the speed of an electron which has a de Broglie wavelength of 1 nm.

_____

_____

_____

_____

(2)

(Total 6 marks)

7 (a) The anode voltage of a certain transmission electron microscope is 20 kV.

Calculate

(i) the speed of the accelerated electrons,

_____

_____

_____

_____

(ii) the de Broglie wavelength of these electrons.

_____

_____

_____

_____

(4)

(b) State and explain how the image of an object observed using this transmission electron microscope in part (a) would change when the anode voltage was increased.

_____

_____

_____

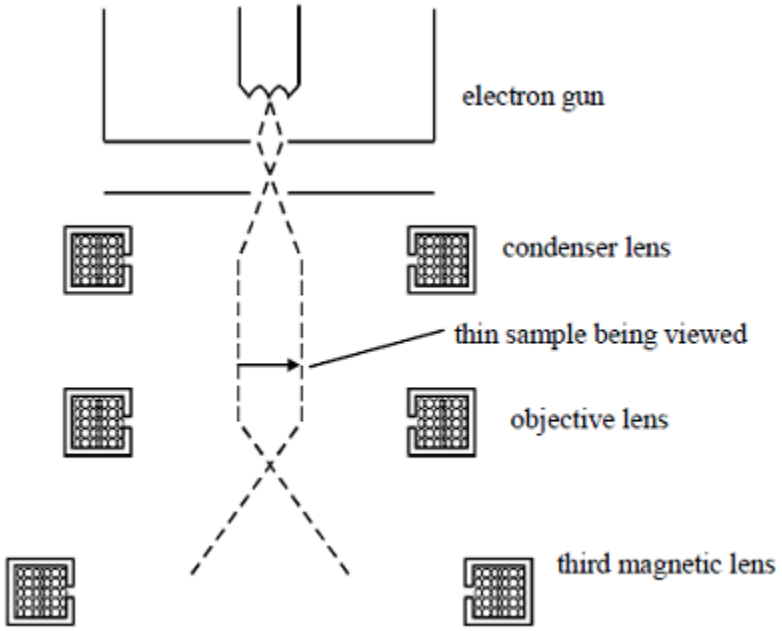
_____

_____

(2)

(Total 6 marks)

8 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.



_____ fluorescent screen

(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.

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(4)

(Total 9 marks)