(16 marks)

An electron gun is a very important component of many devices, including particle accelerators, electron microscopes and cathode-ray tubes. A schematic diagram of an electron gun is shown below.
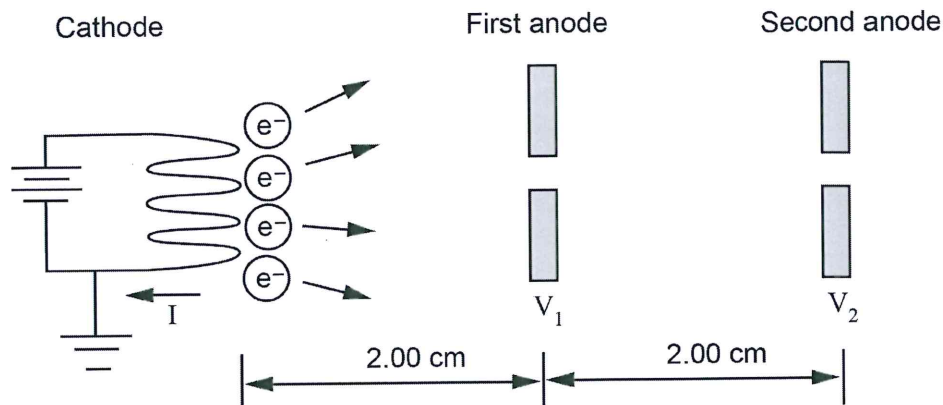
Assume the average initial velocity of a thermal electron is zero. The anode voltages are V_1 = 1500 V and V_2 = 4500 V and the distances between the cathode and anodes are as shown above.

(a) Calculate the velocity in m s^{-1} of the thermal electrons as they pass through the first anode.

(4 marks)

Description		Marks
$W = qV = \frac{1}{2} mv^2$	or $F/q = V/d$ and $F = ma$	1
$v = \sqrt{(2qV/m)}$	$a = Vq/md = 1.32 \times 10^{16}$ m s^{-2}	1
$= \sqrt{(2 \times 1.6 \times 10^{-19} \times 1500/9.11 \times 10^{-31})}$	$v = \sqrt{(2as)} = \sqrt{(2 \times 1.32 \times 10^{16} \times 0.02)}$	1
$= 2.30 \times 10^7$ m s^{-1}		1
	Total	**4**

(b) Calculate the average acceleration in m s^{-2} of an electron in the region between the cathode and the first anode.

(3 marks)

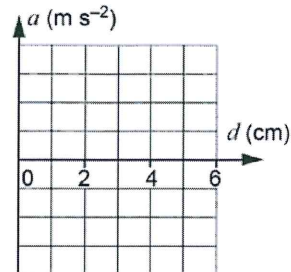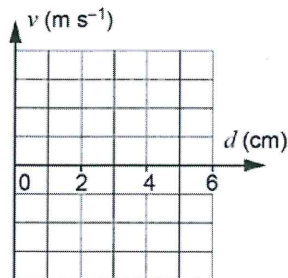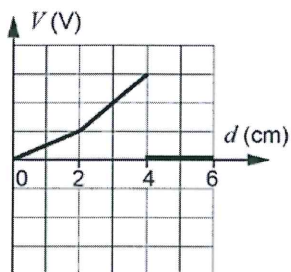| Description	Marks
$v^2 = u^2 + 2as$ $a = (v^2 - u^2)/2s$	1
$a = ((2.30 \times 10^7)^2 - 0^2)/(2 \times 0.02)$	1
$a = 1.32 \times 10^{16}$ m s^{-2} (may have been calculated in a)	1
Total	**3**

(c) Complete the sketches that qualitatively represent the situation on the axes below. The first graph, of distance versus potential difference, has been completed for you. (6 marks)

	Description	Marks
	Shows increasing velocity as √ function	1
	with second rise (Δv) smaller than first	1
	continuing velocity after 4 cm (accept slight decrease)	1
	Shows constant acceleration (positive or on the same side of x axis as above)	1
	with 1/3 and 2/3 step,	1
	0 acceleration (or slight negative) after 4 cm	1
	Total	6

(d) Calculate the electrical work done by the electric field in moving one electron from the first anode to the second anode. Include units with your answer. (3 marks)

Description	Marks
$W = qV = 1.6 \times 10^{-19} \times (4500\ V - 1500\ V)$ $= 4.8 \times 10^{-16}$	1–2
J	1
Total	3