1 **(a)** release of electrons due to heating/high temperature/heater B1

(b) X- and Y-plates labelled B1
anodes either order, labelled, either plates/cylinders with holes B1
closed tube of sensible shape
AND cathode AND anode(s) AND X- & Y- plates, all three features in correct order
labels not needed for last mark but if given must be correct B1

(c) change current in filament/cathode/heater IGNORE limit
OR change temperature/heat/power/energy of filament/cathode/heater
OR change cathode-anode p.d./voltage
OR change charge/voltage of grid B1

(d) (I=)Q/t in any form C1
0.0019 A OR 1.9×10^{3} A OR 1.9 mA A1

(ii) (E=) VIt OR VQ in any form, words, symbols, numbers (accept t=5s) C1
190 J OR candidate's I × 100 000 correctly evaluated A1 [9]

2 **(a** energy supplied / work done (per unit charge) to B1
drive charge round a (complete) circuit B1
OR
p.d. / voltage across battery / power sour B1

(b) **(i)** $P = IV$ OR (I =) P/V OR (I =) 60/240 C1
= 0.25 A OR ¼ A A1

(ii) $I = V/R$ OR other version OR (R =)V/I C1
OR (R =)240/0.25
OR $P=V^2/R$ or other version e.g. (R=) V^2/P
OR (R=) $240^2/60$
R= 960 Ω A1

(c) current in series circuit = 240 / 972 =0.247 A B1

current suits both bulbs, (so both light up so Y is correct) B1
OR
p.d. across bulb A = 240 × (960/972) = 237
p.d. across bulb B = 240 × 12/972 = 2.96 B1
p.d. suits both bulbs, (so both light up so Y correc B1 [8]

3 **(a) (i) 1.** resistance is constant / doesn't vary B1
2. resistance increases B1

(ii) 7 V B1

(b) resistance of resistor = 4/2.6 (= 1.54 Ω) C
resistance of lamp = 4/3.6 (= 1.11 Ω) C
$1/R = 1/R_1 + 1/R_2$ OR $(R =) R_1R_2/(R_1 + R_2)$ OR either eq. with numbers C1
0.645 or 0.65 Ω A1
OR
current through resistor = 2.6 A (C1
current through lamp = 3.6 A (C1
total current = 2.6 + 3.6 = 6.2 A (C1
0.645 Ω OR 0.65 Ω OR R = 4/sum of candidate's currents (A1) [7]
accept R value based on no. of sig. figs. for resistors used by candidate

4 **(a) (i)** 4 Ω B1

(ii) IVt OR I^2Rt OR V^2t/R in any form or words or numbers
Condone t = 9 if substituted possible ecf from **(i)** C1
540 (s) C1
437.4 J possible ecf if 4 Ω from **(i)** used A1

(b) $R = \rho L/A$ OR $R \propto L/A$ OR $R \propto L$ and $R \propto 1/A$ or $1/d^2$ or $1/r^2$ C1

$A_2 = ¼A_1$ OR $A_2 = 0.25A_1$ C1
$R_2 = (0.45/0.3) \times R_1$ OR $(3/2) \times R_1$ C1
⅜ OR 0.375 OR 37.5 % A1
OR
$R = \rho L/A$ OR $R \propto L/A$ OR $R \propto L$ and $R \propto 1/A$ or $1/d^2$ or $1/r^2$ C1

Resistance of thinner wire with same length as thicker wire = 4 × 4 = 16 Ω C1

Actual resistance of thinner wire = 1.8 /0.3 = 6.0 Ω C1

Ratio: L of thinner wire / L of thicker wire = 6.0 / 16 = 3/8 = 0.375 = 37.5 % A1 [8]

5 **(a** same/like/similar charges repel (ignore poles repel) B1
unlike/opposite/different charges attract (ignore poles attract) B1

(b) idea of car/person (being) charged (by friction) B1
idea of charge/electrons going to/from/through person B1

(c) **(i)** electrons / -ve charges move towards the rod / to R (ignore just "attracted")
ignore any mention of +ve charges moving
any mention of +ve electrons gets B0 B1

(ii) opposite charges attract OR electrons / -ve charges attracted to +ve / rod B1

attraction between opposite charges > repulsion between like charges
OR – ve charges (are) close(r) (to the rod) B1

(iii) electrons / -ve charges flow (up) from earth/wire no e.c.f. from **(i)**
ignore +ve charges moving, NOT +ve electrons B1
ball becomes –vely charged B1 [9]