Mark schemes

1 B

[1]

2 (a) (i) (use of $R = V/I$)

$R = 10/2.0 = 5.0\ \Omega$ ✓

1

(ii) $\frac{1}{R} = \frac{1}{3} + \frac{1}{3+3} = \frac{3}{6}$ ✓

$R = 2\ (\Omega)$ ✓

$R_{total} = 2 + 3$ ✓ (= 5 Ω)

3

(b) (i) voltage across Y = 10.0 – 2.0 × 3.0 = 4.0 V ✓

current in Y = 4.0/3.0 = 1.3 A ✓

2

(ii) current through W = 0.67 A ✓

voltage = 0.67 × 3 = 2.0 V ✓

(**or** 4.0/2 = 2.0 V ✓)

2

[8]

3 (a) (three parallel resistors) give $\frac{1}{40} + \frac{1}{20} + \frac{1}{40} = \frac{1}{R}$ **(1)**

R = 10 (Ω) **(1)**
10 Ω and 50 Ω in series gives 60 Ω **(1)**
(allow e.c.f. from value of R)

(3)

(b) ($V = IR$ gives) 12 = I × 60 and I = 0.2 A **(1)**
(allow e.c.f. from (a))

(1)

[4]

4 (a) (use of $1/R_{total} = 1/R_1 + 1/R_2$)

$1/R_{total} = 1/400 + 1/400 = 2/400$

$R_{total} = 200\ \Omega$ **(1)** (working does not need to be shown)

hence total resistance = 25 + 200 = 225Ω **(1)**

2

(b) (i) (use of $P = V^2/R$)

$1 = V^2/400$ **(1)**

$V^2 = 400$ (working does not need to be shown)

$V = 20$V **(1)**

(ii) (use of $I = V/R$)

$I = 20/400 = 0.05$A **(1)** (working does not need to be shown)

hence current = 2 × 0.05 = 0.10A **(1)**

(iii) (use of $V = IR$)

pd across 25Ω resistor = 25 × 0.10 = 2.5V **(1)**
(working does not need to be shown)

hence maximum applied pd = 20 + 2.5 = 22.5V **(1)**

6

[8]

5 (a) R = V/I

M1

with all **three** variables defined
accept voltage

A1

2

(b) *use of* $1/R = 1/R_1 + 1/R_2$

C1

effective resistance of parallel resistors = 2

C1

3

total resistance = 11 Ω

A1

(c) (i) ratio 2/3 seen/ V= 4.8 V used

/clear attempt to find pd across parallel resistors

C1

current = 1.6 A

c.a.o.

A1

4

(ii) *use of* $P= I^2R$ *(= 2.4^2 × 11)*

C1

total power = 63.4 W

allow e.c.f. from (b)

A1

[9]

6 (a) (i) 6.0 (Ω) **(1)**

1

(ii) 4.5 (V) **(1)**

1

(iii) (use of $I = V/R$)

I = 4.5/6.0 = 0.75 (A) **(1)**

current through cell A = 0.75/2 = 0.375 (A) **(1)**

2

(iv) charge = 0.375 × 300 = 112 **(1)** C **(1)**

2

(b) cells C and D will go flat first or A and B last longer **(1)**

current/charge passing through cells C and D (per second) is double/more than that passing through A or B **(1)**

energy given to charge passing through cells **per second** is double or more than in cells C and D **(1)** or in terms of power

3

[9]

7 (a) (for lamp and resistor) 18(Ω) + 12(Ω) = 30(Ω) **(1)**

(in parallel) $\frac{1}{30} + \frac{1}{15} = \frac{3}{30}$ **(1)** (gives $R = 10$(Ω))

(allow C.E.for wrong value in first step)

total resistance = $\frac{30}{3}$ + 10 **(1)**
(= 20 Ω)

3

(b) (i) (use of $V = IR$ gives) $I = \left(\frac{30}{20}\right)$ = 1.5 A **(1)**

(ii) pd_{AB} = 30 – (10 × 1.5) **(1)**
= 15V **(1)**
[or alternative method]
(allow C.E. for value of I from (i))

(iii) $I_{lamp} = \frac{6}{12}$ = 0.5 A **(1)**

[or alternative method] (allow C.E. for value of pd_{AB} from (ii))

4

(c) (i) (lamp power) (= I^2R) = $0.5^2 \times 12$ = 3.0 (W) **(1)**

(allow C.E. for value of I_{lamp} from (b) (iii))

(ii) power from battery = 30 × 1.5 = 45 (W) **(1)**

(allow C.E. for value of I from (b) (i))

$$\% = \frac{3 \times 100}{45} = 6.7(\%)$$ **(1)**

(allow C.E. for power in lamp and/or battery in (i))

3

[10]

8 (a) (i) (total) resistance = (20 + 60) (Ω) **(1)**

($V = IR$ gives) $I = \frac{6.0}{80}$ = 0 075 A **(1)**

(ii) with S closed, (effective) resistance = 20 (Ω) **(1)**

$I = \frac{6.0}{20}$ =0.3 A **(1)**

max 3

(b) use of same current as in part (i) **(1)**
voltmeter reading = 0.075 × 60 = 4.5 V **(1)**

[or use potentiometer equation $6 \times \frac{60}{80}$ = 4.5 V]
(allow C.E. for value of I from (a)(i)

2

[5]

9 (a) (i) three resistors in series **(1)**

(ii) R = 3.0 + 4.0 + 6.0 = 13 Ω **(1)**

(iii) three resistors in parallel **(1)**

(iv) $\frac{1}{R} = \frac{1}{3} + \frac{1}{4} + \frac{1}{6} = \frac{9}{12}$ **(1)**

R = 1.3 Ω **(1)**

5

(b) (i) two resistors in parallel give $\frac{1}{R'} = \frac{1}{3} + \frac{1}{6}$ and R' = 2.0 (Ω) **(1)**

total resistance = (2 + 4) = 6.0 Ω **(1)**

4

(ii) divide the emf in the ratio of 2 : 4 **(1)**
to give 4.0 V **(1)**
[or any suitable method]

[9]

10

(a) (i) for X: ($P = VI$ gives) 24 = 12I and I = 2 A **(1)**
for Y 18 = 6I and I = 3 A **(1)**

2

(b) (i) 12 V **(1)**

(ii) voltage across R_2 (= 12 – 6) = 6 (V) **(1)**
I = 3 (A) **(1)**
($V = IR$ gives) 6 = 3R_2 and R_2 = 2Ω **(1)**
(allow C.E. for I and V from (a) and (b)(i))

[or $V = I(R_y + R_2)$ **(1)** 12 = 3(2 + R_2) **(1)** R_2 = 2Ω **(1)**]

(iii) current = 2 (A) + 3 (A) = 5 A **(1)**
(allow C.E. for values of the currents)

(iv) 27 (V)– 12 (V) = 15 V across R_1 **(1)**

(v) for R_1, 15 = 5 R_1 and R_1 = 3Ω **(1)**
(allow C.E. for values of I and V from (iii) and (iv))

7

[9]

11

(a) (i) $I = \frac{12}{15}$ = 0.80 A **(1)**

(ii) P = $(0.80)^2 \times 5$ = 3.2 W **(1)** (allow e.c.f. from (a)(i))

(2)

(b) $I_{tot} = \frac{12}{7.5}$ **(1)** = 1.60 (A) **(1)**

$I = \frac{1.6}{2}$ = 0.80 (A) **(1)** (allow e.c.f. from I_{tot})

(3)

(c) same brightness **(1)**
because same current **(1)**
[or an answer consistent with their current values]

(2)

[7]

12

(a) between A and C: (each) series resistance = 100Ω **(1)**

(parallel resistors give) $\frac{1}{100} + \frac{1}{100} = \frac{1}{50}$ + = gives R_{AC} = 50Ω **(1)**

2

(allow C.E. for incorrect series resistance)

(b) between A and B: series resistance = 150Ω **(1)**

parallel = $\frac{1}{50} + \frac{1}{150}$ **(1)**

(allow C.E. for series resistance)

R_{AB} = 37.5Ω **(1)** (38Ω)

3

[5]

13

(a) first pair in parallel $\frac{1}{R'} = \frac{1}{30} + \frac{1}{60}$ **(1)**

= $\frac{3}{60}$ = gives R = 20 (Ω) **(1)**

second pair in parallel $\frac{1}{R''} = \frac{1}{40} + \frac{1}{120}$ gives R' = 30(Ω) **(1)**

resistance between A and B = 20 + 30 **(1)** (= 50 Ω)

(allow C.E. for values of R and R'')

4

(b) (i) total resistance = *50 + 50* = 100 Ω **(1)**
(*V* = *IR* gives) 24 = *I* 100 and *I* = 0.24 A **(1)**

(ii) current in 60 Ω = $\frac{1}{3}$ *I* **(1)**
= 0.080 (A) **(1)**
[or alternative method]
(allow C.E. for value of I from (b)(i))

4

[8]

14 (a) (i) *(use of V = IR)*

I = (12-8) / 60 ✓ = 0.067 Or 0.066(A) ✓

2

(ii) *(use of V = IR)*

R = 8/0.067 = 120 (Ω) ✓

1

(iii) *(use of Q = It)*

Q = *0.067 × 120* = 8.0 ✓ C ✓

2

(b) reading will increase ✓

resistance (of thermistor) decreases (as temperature increases) ✓

current in circuit increase (so pd across R_1 increases) OR correct potential divider argument ✓

3

[8]

15 (a) (i) 5 V **(1)**

(ii) R_T = 36 (Ω)
(use of *V* = *IR* gives) 15 = *I* × 36 and *I* = 0.42 A **(1)**

3

(b) (i) equivalent resistance of the two lamps $\frac{1}{R} = \frac{1}{12} \times \frac{1}{12} = \frac{1}{6}$ **(1)**

R_T = 6 + 12 = 18 (Ω) and 15 = *I* × 18 **(1)** (to give *I* = 0.83 A)

(ii) current divides equally between lamps (to give *I* = 0.42 A)
(or equivalent statement) **(1)**

3

(c) same brightness **(1)**
(because) same current **(1)**

2

[8]

16

(a) (i) $\frac{1}{R} = \frac{1}{40} + \frac{1}{40} + \frac{1}{40}$ **(1)**

$R = \frac{40}{3} = 13\ \Omega$ **(1)** (13.3)

(ii) two resistors in parallel give 20 (Ω) **(1)**
$R = 20 + 40 = 60$ (Ω) **(1)**

max 3

(b) (i) three resistors in parallel give $\frac{1}{6} + \frac{1}{6} + \frac{1}{6}$ (= 2 (Ω))

and total resistance = 4 (Ω) **(1)**

total current = $\frac{12}{4}$ = 3 (A) **(1)**

(allow C.E. for value of total resistance)

current in each element 1.0 A **(1)**

(allow C.E. for value of total current)

[or 6 V across each set
resistance of each set = 2 Ω, gives current through
each set = 3 (A)
current in each element = 1.0 A]
[or 6 V across each set/resistor,
resistance of one resistor = 6 Ω,
gives current in each element = 1.0 A]

(ii) six resistors in series gives $R = 36$ (Ω) and $I = \frac{12}{36}$ = 0.3 (A) **(1)**

heating effect (I^2R) much reduced [or less power] **(1)**

5

[8]

17 (a)

	total resistance in circuit
X open, Y closed	***R*** (given)
X closed, Y open	2/3 R
X open, Y open	2R
X closed, Y closed	$R/2$

(b) energy dissipation is V^2/R

or approach using both $I = V/R$ and $P = VI$

B1

highest resistance gives least energy

or X open, Y open or their highest tabulated resistance

B1

2

(c) electrons collide with ions

M1

transferring energy to them/giving them or increasing their vibrational/kinetic energy

A1

2

(d) voltage across load **lower** or load voltage = $\frac{R}{(R+r)}V$

B1

or load current reduced or load current = $\frac{V}{R+r}$

thermal energy output will decrease (in any stated circuit)

or identifies lowest resistance in table as being most affected

M1

since $P = \frac{V^2}{R}$ or since power = $I^2 R$

A1

3

(e) (i) resistance = $\frac{\rho L}{\pi r^2}$ or substitution *or* $A = 1.16 \times 10^{-7}$ (m^2)

C1

1.93×10^{-4} (m) 0.193mm

A1

(ii) **two** properties from

high resistance/resistivity (low electrical conductivity)

B1

high melting point

B1

low thermal capacity/specific heat capacity

B1

4

[14]

18 (a) (i) voltage = 0.01 × 540 = 5.4 V **(1)**

1

(ii) voltage = 15 – 5.4 = 9.6 V **(1)**

1

(iii) (use of resistance = voltage/current)

resistance = 9.6/0.01 **(1)** = 960 Ω **(1)**

or R_T = 15/0.01 = 1500 Ω **(1)**

R = 150 – 590 = 960 Ω **(1)**

or potential divider ratio **(1)(1)**

2

(iv) (use of $1/R = 1/R_1 + 1/R_2$)

$1/960 = 1/200 + 1/R_2$ **(1)**

$1/R_2 = 1/960 - 1/1200$

$R_2 = 4800\ \Omega$ **(1)**

2

(b) (voltage of supply constant)

(circuit resistance decreases)

(supply) current increases or potential divider argument **(1)**

hence pd across 540 Ω resistor increases **(1)**

hence pd across 1200 Ω decreases **(1)**

or resistance in parallel combination decreases **(1)**

pd across parallel resistors decreases **(1)**

pd across 1200 Ω decreases **(1)**

3

[9]

19 (a) so that each lamp is connected directly across the battery **(1)**

if one lamp blows others are still on **(1)**

2

(b) use of *power* = *VI* **(1)**

current through each headlight = 60/12 = 5.0 A

or current through each tail light = 8/12 = 0.67 A **(1)**

total current = 2 × 5.0 + 2 × 0.6667 = 11(.3) A **(1)**

3

(c) the lamp with the highest power rating has the least resistance **(1)**

the resistance is greater because the temperature of the filament is lower **(1)**

and resistance increases with temperature **(1)**

3

(d) (i) (use of energy = power × time)

energy dissipated = (8.5) × 2 × 12 × 3600 (any power ´ time) **(1)**

energy dissipated = 1.1(2) × 10^6 J **(1)**

2

(ii) stored energy in battery = 12 × 1.2 × 24 × 3600 = 1.24 × 10^6 **(1)**

energy to start = 12 × 100 × 1 = 1200 J **(1)**

energy left = (1.24 – 1.12) × 10^6 = 120 000 J **so** hence car will start **(1)**

(conclusion assuming all working correct)

3

[13]

20

(a) (i) no of bulbs = $\left(\frac{230}{5}\right)$ = 46 **(1)**

(ii) (use of $P = VI$ gives) $I = \left(\frac{0.4}{5}\right)$ = 0.080 A **(1)**

(iii) resistance of each bulb = $\frac{230}{0.080 \times 46}$ = 63 Ω (62.5 Ω)

(allow C.E. for number of bulbs and value of I)

[or $R\left(=\frac{V}{I}\right) = \frac{5}{0.08}$ = 62.5 Ω

or $\left(P = \frac{V^2}{R} \text{ gives}\right) R = \frac{25}{0.40}$ = 62.5 Ω]

5

(iv) energy consumed by the set = 0.4 × 46 × (2 × 60 × 60) **(1)**
= 132 kJ **(1)**
(allow C.E. for number of bulbs from (i))

(b) (i) no of bulbs = 56, gives total resistance = 62.5 × 56 (Ω) (= 3500) **(1)**

$I = \frac{230}{3500}$ = 0.066 A **(1)** (0.0657 A)

(use of 63 Ω gives 0.065 A)

(allow C.E. for no. of bulbs in (a) (i) and *R* in (a) (iii))

(ii) bulbs would shine less bright **(1)**

3

[8]

21 (a) (i) $P = V^2/R$ with substitution: 144/any resistance

C1

37.9 (W)

A1

2

(ii) use of 1/*R* formula with substitution of some data
even if not all five resistors

C1

correct calculation of 1/*R* (giving 0.897)

C1

1.11 (Ω)

A1

3

(iii) 144/their aii

C1

129 to 131 (W) **ecf**

A1

2

(b) lower resistance needed

B1

(to achieve) higher current (for I^2R to be the same)/
correct use of V^2/R

B1

2

[9]

22 (a) (i) *(use of P=VI)*

I = 36/12 + 6/12 ✓ = 3.5 (A) ✓

2

(ii) *(use of V=IR)*

R = 12/3 = 4 (Ω) ✓

1

(iii) *R* = 12/0.50 = 24✓ (Ω)

1

(b) terminal pd/voltage across lamp is now less OR current is less ✓

due to lost volts across internal resistance OR due to higher resistance ✓

lamps less bright ✓

3

(c) (i) current through lamps is reduced as resistance is increased **or**
pd across lamps is reduced as voltage is shared ✓

hence power is less OR lamps dimmer ✓

2

(ii) lamp Q is brighter ✓

lamp Q has the <u>higher resistance</u> hence <u>pd/voltage</u> across is greater ✓

current is the same for both ✓

hence power of Q greater ✓

3

[12]

23 (a) potential divider formula used or current found to be 0.25 A

C1

A1

allow 1 s.f.

2.0 V

1.0 V (with working) gains 1 mark

2

(b) main current =1.2 V / 4 Ω = 0.3 (A)

C1

R_{total} = 1.8 V / 0.3 A = 6 Ω or I_8 = 0.225 (A)

C1

R_V = 24 Ω

A1

3

[5]

24 (a) $I_3 = I_1 + I_2$ ✓

1

(b) 10 V ✓

1

(c) I_2 = (12 – 10) / 10 ✓

Allow ce for 10 V

1

= 0.2 A ✓

The first mark is for the pd

The second is for the final answer

1

(d) pd across R_2 increases

As R_1 increases, pd across R_1 increases as pd = $I_1 R_1$ ✓

First mark is for identifying that pd across R_1 increases (from zero).

1

pd across R_3 = 10 V – pd across R_1

Therefore pd across R_3 decreases ✓

Second mark is for identifying that pd across R_3 must decrease

1

pd across R_2 = 12 – pd across R_3

Therefore pd across R_2 increases ✓

Third mark is for identifying that this means pd across R2 must increase

1

[7]

25 (a) Correct substitution into P=VI
1.74 (A)

2

(b) (i) Correct substitution into R=V/I or V^2/P or P/I^2
264 (Ω)

Allow correct use of parallel resistor equation

2

(ii) Use of $1/R_T = 1/R_1 + 1/R_2$ or $R = V^2/P$
65 (66.1) (Ω)

2

(iii) $A = \pi(1.5 \times 10^{-4})^2/4$ or $\pi(7.5 \times 10^{-5})^2$ or 1.767×10^{-8} (m^2)
Substitution into $l=RA/\rho$ with their area
4.2 (4.18) (m)

2 marks for 17 (m), using of d instead of r

3

(c) Resistivity / resistance increases with increasing temperature
(Lattice) ions vibrate with greater amplitude
Rate of movement of charge carriers / electrons (along wire) reduced (for given pd)

ORA

Condone atoms for ions.

Accept "vibrate more".

Accept more frequent collisions occur between electrons and ions owtte

3

(d) $2.9 \times 10^{-3}/447$ or $2.9 \times 10^{-3}/174$ seen
$6.5\ (6.49) \times 10^{-6}$ (m)
Correct answer given to 2 sig fig

Condone use of 174 for T for C1 and B1 marks

Allow 3 sig fig answer if 2.90×10^{-3} used

3

[15]

Examiner reports

2 This question proved to be very discriminating with only the high performing candidates able to score high marks. The calculations involved in part (a) proved to be straightforward and the majority of candidates realised that this was 5.0 Ω. Part (a)(ii) caused more problems and there were many answers in which the calculation of the resistance of the parallel component was spoilt by poor setting out – equating ½ to 2 Ω was a common occurrence.

Part (b) required candidates to calculate currents in the parallel branches of the circuit. Many tried to do this by ratio and got the currents the wrong way round, ie quoting a value of 0.67 A instead of the correct 1.3 A. A more successful approach, used by more able candidates, involved the calculation the pd across the series resistor and hence the deduction of the pd across Y. Once this was known the current in Y could be correctly calculated. This approach also enabled candidates to give the correct pd across W because they realised it was half the value of the pd they had already calculated for Y.

3 Part (a) was, in general, very well done with the mathematical manipulation of three resistors in parallel posing a problem to only a handful of candidates. There were many attempts however where the candidates did not seem sure of the expression and had the four resistors in parallel, or, more frequently, considered the 50 Ω to be in series with 1 / R_t, where R_t was the sum of the three parallel resistors.

In contrast to part (a), part (b) gave very poor results with some 50% of the candidates failing to gain the allocated mark. The common error was giving the current as I = 12 / 50 i.e. ignoring the equivalent resistance of the three parallel resistors. This showed a very poor understanding of the dc circuit.

4 Part (a) was answered well, with many candidates obtaining full marks.

Part (b) caused more problems and the use of the power formula that involves potential difference and resistance was quite rare. In part (b) (ii) there was some confusion over potential difference and candidates frequently used their answer from part (b) (i). Part (b) (iii) was answered much better, with candidates frequently benefiting from consequential error.

5 (a) Fewer than half of the candidates were able to fully define electrical resistance.

(b) This was answered correctly by most. Those who did go wrong usually demonstrated a weakness in mathematics rather than in physics.

(c) This part was generally not answered well.

(i) Only the more able candidates were able to correctly answer this part.

(ii) Even with errors carried forward from part (i), only a few more candidates gained full marks for this question.

6 The majority of candidates seemed to approach this question with confidence and set out their working well. Many did not appreciate the effect of connecting the two identical cells in parallel and it was quite common to see them using the combination of parallel resistors formula to combine the emfs of the two cells. This was something that was not confined to the less able candidates but was seen across the full ability range. This was not a heavy penalty as subsequent answers received full credit whatever value candidates had deduced for the total emf.

Part (a) (iv) assessed the unit for charge and the majority of candidates had no problems with this.

The deduction required for part (b) proved quite discriminating and only the very best candidates obtained all three marks. The first mark for identifying cells C and D proved quite straightforward but the explanation less so. Many candidates appreciated that the greater current in the cells in series was significant but were unable to take this to the next step and link this with the rate of energy dissipation.

7 This question proved to be very accessible and full marks were gained frequently. It is worth, however, pointing out a few recurring errors. In part (a), because the answer was given, it was expected that candidates would show full working. Very often the final expression would contain 10Q*,* being added in series to the product of the parallel arrangement, the parallel resistance still being in the mathematical form $\frac{1}{R_1} + \frac{1}{R_2}$ etc.

Because it was so easy to deduce that the parallel section was equivalent to 10 Ω, examiners did expect to see the value being worked out from the basic expression, otherwise a mark would be deducted.

In part (b) the first two calculations were usually correct, but the third part often produced wrong answers, 1.25 A appearing quite frequently. Part (c) produced many correct answers, with candidates being quite familiar with calculations for power and being able to calculate the percentage.

8

The majority of candidates found this question straightforward and gained the maximum number of marks. Others, however, were not sure of the effect on the circuit of having the switch open or closed. A considerable number of candidates reversed the calculations for parts (a) (i) and (ii). Several candidates, in the situation when the switch was closed, i.e. effectively shorting out the 60Ω, resorted to adding up the two resistances using the expression for parallel resistors.

In part (b) the majority of candidates realized that a voltmeter of infinite resistance had the same effect on the circuit as an open switch and proceeded accordingly.

9

This is the first time in these series of examinations that candidates have been required to draw their own arrangement of resistors. The majority of candidates gave the correct answers in part (a), although some did try an arrangement of resistors similar to that in part (b). There were a few incorrect calculations in part (a) (ii) even though the three resistors were in series. The usual error in part (iv) was calculating correctly the value of \/*R* but then forgetting to invert to obtain *R.*

In part (b) the calculation for the total resistance was usually correct although there was some concern amongst the examiners to see the expression $R_T = \frac{1}{3} + \frac{1}{6} + 4$ occurring quite frequently.

Invariably this resulted in the wrong answer, because candidates would not invert the value for the parallel resistors. The occurrence of this ‘system’ of calculating resistance was brought to the attention of teachers in the last report, but it seems to be more common than before. Part (ii) was not answered well, with candidates just writing numbers down without any reasoning and in the end confusing themselves. Candidates who just gave an answer of 4 V with no working shown were not credited, because it was possible to obtain that answer by incorrect physics. Candidates should be trained to give some explanation of what they are attempting in such calculations. It was also sad to see candidates obtaining the (correct) answer of 4.0 V across the parallel resistors, but then shooting themselves in the foot by assuming that the voltage across the 6.0 Ω was different to that across the 3.0 Ω.

10 This question involved the analysis of a relatively difficult circuit, which included two lamps and two resistors. The question however, was so structured that the majority of candidates were able to work through and gain full marks. Others, unfortunately, although making a reasonable attempt, failed to gain many marks. In part (a), the majority of candidates calculated the correct value of the currents passing through each lamp.

In part (b), obtaining the correct answers to parts (i) and (ii) depended to a large extent on realising that the reading on the voltmeter equalled the voltage across lamp X. Many candidates missed this point, but were still able to gain some marks. In part (ii) the error that was committed regularly was determining the resistance of lamp Y instead of the resistance of resistor R_2. But at least, more candidates realised that the same current passed through lamp Y and R_2. Answers to parts (iii) and (iv) used the answer to part (a) as a starting point, but many candidates failed to realise that the current through R_1 was the sum of the current through the two lamps. Considerable guesswork took over at this stage and although most of it was wrong, candidates could still get a mark for part (v) by using the answers obtained to parts(iii) and (iv).

12 In this example of calculating equivalent resistance, the same resistor network was used twice, the equivalent resistance being calculated between different terminals. The majority of candidates had no difficulty with the calculations, but it was worrying to find many answers where the candidates had attempted a solution, not by calculation, but with phrases such as "electricity takes the path of least resistance and therefore the effective resistance (in part (b)) is 50 Ω."

It was surprising to find that a significant number of candidates obtained the correct result in part (b) but failed on part (a), since part (b) was deemed to be the most difficult of the two. Considerable arithmetical difficulty was encountered by many candidates with the reciprocal of the resistance when calculating the resistance of parallel resistors.

13 Part (a) was the calculation of the equivalent resistance of a network of resistors consisting of resistors connected in series and in parallel. The majority of candidates gained full marks on this section and were not troubled by the calculation. However, it is worth pointing out that since the final answer of 50 Ω was given in the question, then in order to gain full marks it was necessary to show that the two equivalent series resistors were being added together.

Part (b) did not prove to be as easy; the problem in (i) was that many candidates gave the total resistance as 50 Ω rather than 100 Ω. No consequential error for calculating the current was allowed and frequently no marks were awarded for this section. It was possible in part (b)(ii) to gain the two marks even if the answer to (i) was incorrect, but very few candidates managed to gain these marks. The usual error was giving the current in the circuit as 24/20, i.e. ignoring the second batch of parallel resistors. Again, many candidates, having calculated the total current correctly, assumed that 2/3 would pass through the 60 Ω resistor, not realising that the greater the resistor, the lower the current for a given voltage.

14 The majority of students were able to analyse the circuit correctly although surprisingly a significant minority had problems with (a)(i) because they did not appreciate that the pd across R_2 was 4.0 V. This did not affect their subsequent responses however, as the answer they gave was carried forward to subsequent calculations. The qualitative aspect of the question presented students with a greater challenge. Many incorrectly stated that the voltmeter reading would decrease as the thermistor resistance falls seemingly forgetting that the voltmeter was connected across R_1.

15 The question involved straightforward calculations on voltage, resistance and current. In part (a)(i) it was hoped that candidates would have spotted the correct voltage across each lamp by inspection. Surprisingly, even those who managed to get the wrong answer in part (i) nevertheless ignored their answer and proceeded from first principles to obtain the correct answer to part (ii).

Part (b) involved the same circuit components as in part (a) but connected differently. The majority of candidates showed that the current from the battery was the value given in the question. Using this value they then proceeded to argue or calculate the current in each lamp. Those candidates who merely halved the current value obtained in part (i) without any reasoning did not gain the mark.

Although the question told the candidates that the current through each lamp was the same in both circuits it was disappointing to find in part (c) how many candidates tried to argue that the brightness of the bulbs in the 2nd circuit would be different to that in the first, the main thrust of their argument being that the voltage across each bulb was different and therefore that the brightness would be different.

16 Candidates are by now well used to questions on resistors in series and in parallel and part (a) contained no hidden terrors. Invariably, correct answers were gained for both circuits. Examiners are concerned however at the trend of using an unusual nomenclature for a combination of resistors in series and in parallel, e.g. the combination of resistors in the second circuit would be given by candidates in some

centres as $R_T = \frac{1}{40} + \frac{1}{40} + 40$. The fact that they subsequently gave the correct

answer of 60 Ω showed that the candidates had worked out the parallel section first and then added the series section. Such a system is not to be encouraged since it serves to confuse and if a wrong answer is given, it does not help the examiner to find out where the error occurred and then perhaps award a consequential error mark. The other point concerning this section, was that answers to part (i) were given in many instances as $13^1/_3$ Ω or 13.3 Ω (i.e. recurring). These were treated as significant figure errors. Answers given as fractions are not accepted.

Part (b) was more difficult and many candidates failed to understand the physics of the circuit. Comparatively few candidates gained full marks. An error which cropped up continually in part (i) was correctly calculating the resistance of three resistors in parallel (2Ω) but then using 12 V to calculate the current, not realising that the effect of the other three resistors halved the pd. There were also many candidates who calculated the correct current from the supply, but split this equally between the six resistors and not three. In part (ii), although most candidates calculated the current as 0.33 A and thus correctly concluded that the current was less than that in the part (i), they failed to capitalise on this and merely said that ‘therefore the heater was less effective’. In order to gain the final mark it was necessary to mention the heat/power generated by the current.

17 Many were unable to identify which resistors were in the circuit for different switch settings and then calculate the total resistance in part (a). The 2*R* value was most easily identified but only about 20% of the candidates obtained credit for the other switch settings. Some could correctly write down the equations for calculating resistors in parallel but then got no further.

Part (b) was not done well. Few appreciated that they need to use $V2/R$ and not I^2R because potential difference was the common factor for each setting and not current.

Part (c) exposed many misconceptions about charge flow through conducting material. Many thought thermal energy to be produced by electrons bumping into each other or that they excite atoms which then release the energy as heat. Some thought the nuclei of atoms in the conducting material to be involved.

In part (d) a good proportion of the candidates appreciated that the thermal energy output would be decreased and, although there were some very good answers, many went on to give a partial explanation of why this would happen in terms of the reduced pd across the load or a reduced load current.

There were many correct answers to part (e) (i), but it was disappointing that a quarter of the candidates were unable to make any progress with the calculation.

A majority could give at least one sensible property in part (e) (ii), but many candidates had clearly confused the rod with the resistance wire so gave properties that were ‘opposite’ to those needed or irrelevant properties. Some gave contradictory properties such as ‘it must have a low resistivity and be a good conductor’.

18 This question proved to be very discriminating with only the more able candidates able to score high marks. The calculations involved in part (a) proved too challenging for many candidates. Part (a) (i) and (ii) generated the most correct responses, but the remainder of the analysis was only accessible to the more able candidates.

Part (b) required analysis without calculation and the majority of explanations seen were confused and not self consistent. Many candidates stated that more current goes through the thermistor and therefore the pd across it falls, resulting in the pd across the parallel 1200 Ω resistor increasing. Another common misunderstanding was the effect that the decreasing thermistor resistance had on the current through the battery. Many thought that the current remained constant and, although this still led them to deduce that the pd fell, their arguments frequently contained contradictions.

20 All candidates were able to gain a reasonable number of marks for this question, and many were awarded full marks. The answer to part (a) (i) was usually correct, but there were some problems with part (a) (ii). The most common error was obtaining the correct value of the current in the circuit, as required, but then dividing this value by the number of lamps. The resistance of each lamp, in part (iii), was usually calculated correctly, although some candidates made heavy weather of the calculation when using the expression *VIR* for power. Several recurring errors in part (iv) resulted in this part not being answered as well as the others. These errors would be calculating the energy used by one lamp instead of by the set, or omitting the factor of 2 (hours) when calculating the number of seconds, or omitting the conversion from minutes into seconds.

Incorrect answers in part (a) were allowed to be carried forward into part (b), which resulted in part (b) performing quite well. The usual error in part (i) was carrying out the calculations for 10 lamps, instead of 56. Answers to part (ii) were usually correct, candidates realising that the greater the current, the greater the brightness.

21 Almost all of the candidates correctly calculated the power of a headlight lamp. A very few extracted an incorrect value of resistance from the table. In part (a)(ii), candidates made the usual errors of using the resistors in series formula instead of resistors in parallel. Others omitted to invert their answer once they had calculated the sum of the reciprocals of the five resistors. In part (a)(iii), some candidates revisited their part (a)(i) type calculations to find the powers of all of the lamps, rather than using the overall resistance value that they had just calculated.

In part (b), most candidates realised that, in this circumstance, lamps of lower resistance ought to be used. Candidates' justifications were not always convincing. The best answers referred to the equation relating power to voltage and resistance. Some argued that lower resistances should be used so that the current would increase, this was acceptable. What was not acceptable was the argument that it was necessary to restore the current to its previous value.

22 The quantitative parts of this question were well answered but as is often case, students found the qualitative aspect the much more challenging. The calculations of current and resistance caused few problems and the majority of students were able to explain the effect of an appreciable internal resistance. Part (c) caused far more problems and a significant proportion could not convincingly explain why the lamps were not at normal brightness when connected in series. They seemed not to appreciate that the voltage of the 12 V battery was divided between the lamps or that the circuit resistance is higher when the lamps are in series. They also found it very difficult to explain which lamp was brighter – many incorrectly assuming that it was lamp P as it had a higher power rating.

23 The majority of candidates correctly calculated the voltage in (a). Many used the same current as in (a) to do the calculation in (b); dividing the difference in the voltage across the resistor [between (a) and (b) = 0.2 V] by the current in (a) to give 0.8 Ω was a very common incorrect answer. Only a few candidates were able to perform the complete calculation to obtain a resistance of 24 Ω.

25

(a) Most students obtained the total current but failed to appreciate the need to halve this value.

(b) A variety of routes were possible for part (i) but clear evidence of the method was expected to be seen. The 'parallel resistor' equation was often invoked but rarely written explicitly. Parts (ii) and (iii) were answered well.

(c) This was poorly answered. Explanations often lacked the required precision. Many students clearly thought that nichrome is a semi-conductor.

(d) Most students recognised the need to use Wien's Law and to convert the temperature to kelvin.