Mark schemes

1 A

[1]

2 A

[1]

3 D

[1]

4 D

[1]

5 D

[1]

6 (a) the (total) energy transferred/work done when one unit/coulomb of charge

B1

is moved around a circuit/provided by the supply

B1

2

(b) work is done inside the battery/there is resistance inside the battery

B1

so less energy is available for the external circuit/someoltage is lost between the terminal/mention of lost volts

B1

2

(c) (i) 9.00 V

c.a.o.

B1

(ii) lost voltage = E - V or E = I(R + r)

C1

0.82r = 0.59

C1

5

internal resistance = 0.720 Ω

A1

(iii) because the battery has to provide more energy/power

B1

[9]

7 (a) $V = -Ir + \epsilon$ **(1)**

1

(b) straight line (within 1st quadrant) **(1)**
negative gradient **(1)**

2

(c) ϵ : intercept on voltage axis **(1)**
r: gradient **(1)**

2

[5]

8 (a) work done per unit charge

Allow V=W/Q if W and Q defined

1

(b) Voltmeter reading / terminal pd drops
Battery has internal resistance
pd occurs within battery / 'lost volts' within battery / emf is shared between internal and external resistances

3

[4]

9

(a) 12 * 15/25

C1

= 7.2 V

A1

2

(b) total *R* now 32.5

C1

12 * 7.5/32.5 = 2.7[7] V **or** calculates *I* = 0.369 A

C1

terminal p.d. 12 - 2.8 = 9.2 V **or** V = 0.369 × (10 + 15) = 9.2 V

A1

3

[5]

10

(a) (i) work done (by the battery) per unit charge **(1)**
or (electrical) energy per unit charge
or pd/voltage when open circuit/no current

(ii) the resistance of the materials within the battery **(1)**
or hindrance to flow of charge **in** battery
or loss of pd/voltage per unit current

2

(b) (i) (use of $E = V + Ir$)

12 = V + 800 × 0.005 **(1)** (working/equation needs to be shown)

V = 12 – 4 = 8.0V **(1)**

(ii) (use of $P = I^2r$)

$P = 800^2 \times 0.005$ **(1)** (working/equation needs to be shown)

P = 3200 **(1)** W **(1)** **or** J s^{-1}

5

(c) car will probably **not** start **(1)**

battery will not be able to provide enough current **(1)**
or less current
or lower terminal pd/voltage

2

[9]

11 (a) time base is (switched) off ✓
TO for y-input switched off

not affected by x plates because these plates are not switched on

1

(b) (i) emf (of battery) ✓

not just terminal pd

TO applied for non-emf statements

Allow explanation of emf

1

(ii) (emf = 3 × 2.0 =) 6.0 V ✓

penalise 1 sf

1

(c) Because the pd across the y plates has decreased ✓

there is a current (in the battery) ✓

there is a pd / voltage across the internal resistance **or** there are (now) lost volts ✓

terminal pd decreases **or** terminal pd now less than emf **or** $IR = \varepsilon - Ir$ ✓

3

(d) *V*= 2.5 × 2.0 = 5 V
or (use of V=IR) by I = their incorrect voltage ÷18 ✓

Must see I as subject or their working leading to answer line for use of

I=0.28(A) ✓ cao

2

(e) (use of $\varepsilon = IR + Ir$)
6.0 = 2.5 × 2.0 + 0.28× r

$$r = \frac{\varepsilon - IR}{I}$$

or correct rearrangement to make r subject
or sets $R_{(T)} = \frac{\varepsilon}{0.28}$ = 21.2 or 21.4 (ohms) with subject seen
or $\frac{1}{0.28}$ ✓
r = 3.4 to 3.6 Ω ✓

Ecf for I and V ecf ans = $\frac{6 - \text{their V}}{\text{their I}}$

2
[10]

12 (a) (i) work (done)/energy (supplied) per unit charge (by battery) **(1)**

(or pd across terminals when no current passing through cell or open circuit)

1

(ii) when switch is closed a **current flows** (through the battery) **(1)**

hence a pd/lost volts develops across the internal resistance **(1)**

2

(b) (use of ε = $V + Ir$)

I = 5.8/10 = 0.58 (A) **(1)**

6.0 = 5.8 + 0.58r **(1)**

r = 0.2/0.58 = 0.34 (Ω) **(1)**

3

(c) need large current/power to start the car **(1)** (or current too low)

internal resistance limits the current/wastes power(or energy)/reduces terminal pd/increases lost volts **(1)**

2
[8]

13 (a) use of $E = ItV$ (or equivalent) or substitution into equation irrespective of powers of 10

C1

allow 2 for 6120 (J)

emf = 4.0 V

C1

1.22×10^4 J

A1

3

(b) Internal resistance = 1.2 (Ω)

C1

allow 2 for 0.22(6) V

Current calculated (0.19 A) or potential divider formula used 3.7(7) V

C1

A1

3

[6]

14 (a) R_{AB} = 5.0 (Ω) **(1)**
V (= 5.0 × 0.50) = 2.5 V **(1)**

(b) V_r = 12 – 2.5 + 5.0 **(1)** = 4.5 (V) **(1)**

$r = \left(\frac{V_r}{I} = \frac{4.5}{0.5}\right)$ = 9.0 Ω **(1)**

(c) $W(= EIt)$ = 12 J **(1)**

(d) $W_r(= V_rIt)$ = 4.5 (J) **(1)**

$\frac{W_r}{W}\left(= \frac{4.5}{12}\right)$ = 0.375 **(1)**

[Max 7]

15 (a) (i) electrical energy produced (in the battery) per unit charge **(1)**

[or potential/voltage across terminals when there is no current]

(ii) there is a current (through the battery) **(1)**

voltage ‘lost’ across the internal resistance **(1)**

Max 2

(b) (i) $\epsilon = V + Ir$ **(1)**

(ii) labelled scales **(1)**
correct plotting **(1)**
best straight line **(1)**
ϵ: intercept on y axis **(1)** = 9.2 (± 0.1) V **(1)**

r : (−) gradient = $\frac{9.2}{0.65}$ = 14.2 Ω **(1)** (range 14.0 to 14.3)

8

[10]

16 (a) (i) energy changed to electrical energy per unit charge/coulomb passing through
[or electrical energy produced per coulomb or unit charge]
[or pd when no current passes through/or open circuit] **(1)**

(ii) $I = \frac{6}{2.4}$ = 2.5 A **(1)**

(iii) (use of $\epsilon = I(R + r)$ gives) $\epsilon = V + Ir$ and $8 = 6 + Ir$ **(1)**

substitution gives 8 – 6 = 2.5r **(1)** **(**and r = 0.8 Ω)

4

(b) (i) (use of $P = I^2R$ gives) $P_R = 2.5^2 \times 2.4 = 15$ W

[or $P = VI$ gives $P = 6 \times 2.5 = 15$ W] **(1)**

(allow C.E. for value of I from (a))

(ii) $P_T = 15 + (2.5^2 \times 0.8)$ **(1)**

= 20 (W) **(1)**

(allow C.E. for values of P_R and I)

(iii) $E = 5 \times 2 \times 60 = 600$ J **(1)**

(allow C.E. for value of P from (i) and P_T from (ii))

4

[8]

17 (a) (i) *(use of V=Ir)*
V= 4.2 × 1.5 ✓ = 6.3 (V)

(ii) pd = 12 − 6.3 = 5.7 V ✓

NO CE from (i)

1

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

I = 5.7 / 2.0 = 2.8(5) A ✓

CE from (ii)

(a(ii)/2.0)

accept 2.8 or 2.9

1

(iv) I = 4.2 – 2.85 = 1.3(5) A ✓

CE from (iii)

(4.2 −(a)(iii))

accept 1.3 or 1.4

1

(v) R= 5.7 / 1.35 =4.2 Ω ✓

CE from (iv)

(a(ii) / (a)(iv))

Accept range 4.4 to 4.1

1

(vi) $\frac{1}{R_{Parallel}} = \frac{1}{4.2} + \frac{1}{2.0} = 0.737$ ✓

CE from (a)(v)

$R_{parallel}$ = 1.35 **Ω**

second mark for adding internal resistance

R_{total} = 1.35 <u>+ 1.5</u> ✓ = 2.85 Ω

OR

R = 12/4.2 ✓

R= 2.85 Ω ✓

2

(b) (i)

resistor	Rate of energy dissipation (W)
1.5 Ω internal resistance	$4.2^2 \times 1.5 = 26.5$ ✓
2.0 Ω	$2.85^2 \times 2.0 = 16.2$ (15.68 − 16.82) ✓
R	$1.35^2 \times 4.2 = 7.7$ (7.1 − 8.2) ✓

CE from answers in (a) but not for first value

2.0: a(iii)^2×2

R: a(iv)^2×a(v)

3

(ii) energy provided by cell per second = 12 × 4.2 = 50.4 (W) ✓
energy dissipated in resistors per second = 26.5 + 16.2 + 7.7 = 50.4 ✓
(hence energy input per second equals energy output)

if not equal can score second mark if an appropriate comment

2

[12]

18 (a) mention of pd across internal resistance **or** energy loss in internal resistance **or** emf > V ✓

pd across internal resistance/lost volts increases with current **or** correct use of equation to demonstrate ✓

2

(b) (i) *y – intercept* 1.52 V (± 0.01 V) ✓

1

(ii) identifies gradient as *r* **or** use of equation ✓

substitution to find gradient **or** substitution in equation ✓

$r = 0.45 \pm 0.02\ \Omega$ ✓

3

(c) (i) same intercept ✓

double gradient (must go through 1.25, 0.40 ± 1.5 squares) ✓

2

(ii) same intercept horizontal line ✓

1

(d) (i) (use of $Q = It$)

$Q = 0.89 \times 15 = 13$ ✓ C ✓

2

(ii) use of $P = I^2r$ ✓

$P = 0.89^2 \times 0.45$

$P = 0.36$ W ✓

2

[13]

19 (a) as the temperature of T increases its resistance decreases /more charge carriers are released

B1

increasing the current in the circuit /changing the ratio of resistance/reducing pd across T

B1

(so that so that the pd across the resister increases)

2

(b) T/ 20.0 = 1.0/5.0 **OR** 5.0/6.0 = 20/(20+T) **OR** equivalent (Therefore T = 4.0 ohms)

Note T = (1/5)20 just ok but T = 20/5 not enough

M1

1

(c) Use of $V_{out} = R_1/(R_1 + R_2) \times V_{in}$ **OR** I = 6/44.5 = 0.135 A

C1

V = 2.7 V

A1

2

(d) (i) V/6.0 = 20.0/(20.0+4.0+3.0) **OR** I = 0.222 A

C1

V = 4.4V

A1

2

(ii) The measure temperature would be lower because the pd across the resistor would be less *(ie 2.53V)*

B1

1

[8]

20 (a) (i) (use of $V = IR$)

R_{total} = 1 (ohm) ✓

$V = 1 \times 1 = 1.0$ V ✓

2

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

$R = 9.0/1.0 = 9.0\ \Omega$ ✓

$r = 9.0 - 1.0 - 6.0 = 2.0\ \Omega$ ✓

or use of ($E = I(R + r)$)

$9.0 = 1(7 + r)$ ✓

$r = 9.0 - 7.0 = 2.0\ \Omega$ ✓

2

(iii) (use of $W = VIt$)

$W = 9.0 \times 1.0 \times 5 \times 60$ ✓

$W = 2700$ J ✓

2

(iv) energy dissipated in internal resistance = $1^2 \times 2.0 \times 5 \times 60 = 600$ (J) ✓

percentage = 100 × 600/2700 = 22% ✓ CE from part aii

2

(b) internal resistance limits current ✓

hence can provide higher current ✓

or energy wasted in internal resistance/battery ✓

less energy wasted (with lower internal resistance) ✓

or charges quicker ✓

as current higher or less energy wasted ✓

or (lower internal resistance) means higher terminal pd/voltage ✓

as less pd across internal resistance or mention of lost volts ✓

2

[10]

21 (a) emf is the work done / energy transferred by a voltage source / battery / cell ✓per unit charge✓
OR
electrical energy transferred / converted / delivered / produced✓
per unit charge✓
OR
pd across terminals when no current flowing / open circuit✓✓

not in battery

accept word equation OR symbol equation with symbols defined if done then must explain energy / work in equation for first mark

2

(b) (i) by altering the (variable) resistor✓

1

(ii) reference to correct internal resistance✓

e.g. resistance of potato (cell)

terminal pd = emf – pd across internal resistance / lost volts✓
pd / lost volts increases as current increases OR as (variable) resistance decreases greater proportion / share of emf across internal resistance✓

accept voltage for pd

3

(iii) draws best fit straight line and attempts to use gradient✓
uses triangle with base at least 6 cm✓
value in range 2600 – 2800 (Ω)✓

3

stand-alone last mark

(c) total emf is above 1.6 V✓
but will not work as current not high enough / less than 20 mA✓

2

[11]

22 (a) power increases to a maximum / (up) to 3.0 (2.8 -3.4) Ω / / (up)to 3.0 W ✓
then decreases ✓

2

(b) (i) (*use of* $P = I^2R$)
when R = 0.8 Ω power = 1.95 W ✓
$1.9 = I^2 \times 0.8$ ✓
$I = \sqrt{2.375} = 1.5(4)$ (A) ✓

Range
1.9 - 2.0 W for power (first mark)
Current 1.5 – 1.6 A

3

(ii) (*use of V = IR*)
V = 1.54 × 0.8 ✓
V = 1.2 V ✓
CE from part (i)

2

(iii) (*use of ε = V + Ir*)
6.0 = 1.2 + 1.54 × r ✓
r = (6.0 – 1.2) / 1.54 = 3.1 (2.9 – 3.2)(Ω) ✓
use of maximum power theorem (quoted) as alternative method can get both marks i.e. read peak maximum from graph
CE from part (ii)

2

(c) power would decrease (as R increased) ✓
pd / voltage across R is now constant / equal to emf ✓
and so power proportional to 1 / R / inversely proportional to R OR
can quote P = V^2 / R but only if scored second mark ✓

3
[12]

23 (a) (i) Voltmeter across terminals with nothing else connected to battery / no additional load. ✓

1

(ii) This will give zero / virtually no current ✓

1

(b) (i) $\frac{VI}{\varepsilon I}$

Answer must clearly show power: εI and VI, with I cancelling out to give formula stated in the question ✓

1

(ii) Voltmeter connected across cell terminals ✓

Switch open, voltmeter records ε
Switch closed, voltmeter records *V*
Both statements required for mark ✓

Candidates who put the voltmeter in the wrong place can still achieve the second mark providing they give a detailed description which makes it clear that:

To measure emf, the voltmeter should be placed across the cell with the external resistor disconnected

<u>And</u>

To measure V, the voltmeter should be connected across the external resistor when a current is being supplied by the cell

2

(c) Vary external resistor and measure new value of *V*, for at least 7 different values of external resistor ✓

Precautions - switch off between readings / take repeat readings (to check that emf or internal resistance not changed significantly) ✓

2

(d) Efficiency increases as external resistance increases ✓

Explanation
Efficiency = Power in R / total power generated
$I^2R / I^2(R + r) = R / (R + r)$
So as *R* increases the ratio becomes larger or ratio of power in load to power in internal resistance increases ✓

Explanation in terms of V and ε is acceptable

2

[9]

Examiner reports

1 Students familiar with the characteristic for a fixed resistance were probably led to answer B without reading the question. This proved to be the most popular answer despite it being incorrect. Approximately 20% were sufficiently careful with their reading, or sufficiently familiar with the practical, to give the correct answer, A.

5 This calculation was fairly demanding with only 27% of students giving the correct answer. In fact answers B, C and D proved to be almost equally popular, suggesting a fair amount of informed guessing was going on. It may have been made easier had a circuit diagram been provided. In the absence of one, students should be encouraged to draw their own in the spaces on the paper.

6 A question which discriminated well between the good and the very good candidates, while many of the less able candidates found it difficult to gain more than one or two marks at best.

(a) Many candidates were unable to give a good definition of electromotive force. The examiners had hoped to see statements referring to total energy transfer per unit charge as it is moved around a circuit. While a high impedance voltmeter can be used to measure the emf of a supply, on an open circuit this does not define electromotive force.

(b) A few more candidates were able to give a satisfactory answer here than in part (a).

(c) (i) As the emf was given to 3 significant figures in the question, the reading was expected to also be to 3 significant figures. This proved to be harder than expected.

(ii) Many candidates simply divided the voltage by the current.

(iii) Few candidates were able to provide a satisfactory answer to this part. A statement to the effect that the battery needs to provide more energy to do the extra work was all that was required, but very many candidates wrote vaguely about decreased resistance and/or greater voltage.

7 The response to this question was very disappointing, especially in view of the fact that this topic has been examined several times previously, including questions on the graphical nature of the quantities involved. Rearranging the equation in part (a) was intended as a guide to drawing the graph in part (b). The majority of candidates did rearrange the equation correctly, but some candidates failed to do this and ended up with a quotient.

Sketching the *I*-*V* graph in part (b) was, quite literally, a disaster area. The large majority of candidates drew a straight line of positive gradient passing through the origin. Obviously this was the easiest line to draw without applying any thought to the question. No marks were awarded for such attempts. If a line of positive gradient was drawn, and did not pass through the origin, then 1 mark was awarded. A large number of curved lines, some starting at zero, others at a positive value of V and decreasing to zero, were also presented. Of the candidates who drew a straight line with a negative gradient, many lost marks by either extending the line into negative values of *V*, or negative values of *I*. It must be pointed out that when carrying out an experiment to obtain this graph, it is not possible to obtain zero values of *V* or *I*. However, since some textbooks do show the graph extending to the *V* axis, this was accepted, but graphs extending to the *I* axis were not.

Most candidates gained at least one mark in part (c), but the impression gained was that candidates had learned the answers parrot fashion with no reference to the graph. The gradient of a curved graph was often given as the answer.

8 (a) Barely 10% of students knew the definition of potential difference.

(b) This was poorly understood; just over 50% of students gained no credit here. Students who did identify that the voltmeter reading decreased hardly ever gave an accurate reason.

9 This question was answered well by many. Those with low scores rarely gave the examiners much of a hint of what they were thinking. Too often a set of fairly random electrical symbols would appear with no underlying physical thread.
Only the better candidates were able to find the terminal p.d. of the cell. Commonly, an equation from the formula sheet would be used with an incorrect current. A substantial number were able to find the 'lost' p.d. but did not then go on to subtract this from the e.m.f. of the cell.

10 Most candidates were able to explain what is meant by internal resistance but were less clear about the meaning of the emf of a battery. Most appreciated that it was connected to energy but their answers were far from convincing.

Part (b) (i) produced some good responses although a number calculated the potential difference across the internal resistance as opposed to the terminal potential difference which meant that the answer 4.0 V was commonly seen.

Part (b) (ii) was generally answered well and the unit J s^{-1} or W did not seem to present too many problems.

Part (c) is an application mentioned in the specification and there was good evidence that this is something that has been considered by most centres. The most common answer was that the current would be reduced. The effect of a reduced current was sometimes not clearly expressed and candidates tended to say things like it would take longer to start or that it would be more difficult to start rather than making a definite statement about the car not starting.

11 Students enjoyed success in part (a) and (b)(i) but the requirement for two significant figures in the answer to part (b)(ii) meant many students failed to get this mark. Students need to be aware of the number of significant figures used in data provided and to ensure that their answer agrees with this.

Part (c) proved difficult, this may have been due to the inclusion of the oscilloscope making many students doubt their knowledge of this topic. It was surprising to see the number of students who stated that when switch S2 was closed that the resistance increased causing the current to decrease. These students had a very limited understanding of basic circuit theory never mind being able to produce a reasonable answer involving internal resistance and lost volts. Many other students were able to state that the reading on the oscilloscope decreased but they were unsure of the reason why this happened.

As with the other calculations in the paper, grade A students dealt competently with parts (d) and (e). Lower grade students were unsure about how to determine the current in the battery, choosing to divide 6 V by 18 ohms was common here. Lower standard working in part (e) was often muddled and hard to follow due to the number of mistakes made in part (d); these students often confused terminal pd with emf and had no real idea about how to make headway in this part of the question.

12 Candidates' performance in this question was generally poor and it appears that the effect of internal resistance on terminal pd is not well understood. While many came up with an acceptable definition of emf few were able to explain convincingly the effect on the voltmeter if the switch is closed. A significant proportion of candidates assumed a current was flowing when the switch was open and it was quite common to see statements such as '*when the switch is closed voltage stops flowing through the voltmeter and so its reading decreases*', which supports the view that potential difference in circuits is a concept that many candidates struggle with. Further evidence of this was provided by the explanations given in part (c).

Many candidates did not seem to appreciate the reason why a car battery needs to have a low internal resistance.

13 It was common for candidates to use an emf of 2.0 V in (a) but most correctly used the relationship of energy = emf × current × time. A minority of candidates used a time of 60 s rather than the correct 3600 s and a few misinterpreted 850 mA.

In (b) it was common for candidates to use the 850 mA given in (a) as the current; few calculated the correct current (or to correctly use the potential divider formula) and of those that did about half went on to find the 'lost volts' rather than the terminal pd.

14 Most candidates could successfully analyse the circuit in this question. and the answers were quite good on the whole. Even though some candidates had problems in calculating the effective resistance of the parallel combination of resistors they were able to do the rest of the question effectively.

15 Explaining what is meant by emf in part (a) is still beyond the capabilities of a very large number of candidates. The most popular acceptable definition was that of the voltage across the terminals when no current flowed. Many candidates attempted to define emf in terms of the energy produced in the battery, but either forgot, or did not know, that it was the energy per unit charge. In part (a)(ii), the majority of candidates were aware that the reason involved the internal resistance, but merely quoting internal resistance on its own was not sufficient to gain a mark. There must be some reference to the voltage or pd across this resistance when a current flows.

The graph section in part (b) was answered well by the large majority of candidates, who drew excellent graphs. Some candidates missed out by using almost impossible scales in their bid to use the full page of the exam paper. Again, most candidates, having produced the correct equation in (i), knew how to obtain $\in$ and r from the graph. Some candidates, having produced an acceptable value for $\in$, proceeded to insert values in their equation. This was not acceptable. Another incorrect method was to obtain $\in$ from the area under the graph.

16 Candidates found this question very accessible and many gained full marks. In part (a) the meaning of emf seems to be reasonably well understood with most candidates opting for the voltage when no current passed through the circuit. Others defined it correctly in terms of energy per unit coulomb. There were, unfortunately, many candidates who, apparently, had not encountered the definition of emf and merely quoted electromagnetic force, or even tried to define it in terms of a force in the circuit. The calculation of the current in part (ii) was well done and in part (iii) correct substitution of values into the equation $\in = V + Ir$ gave $r = 0.80\ \Omega$.

Part (b) was involved with calculation of power and energy and although the majority of candidates obtained the correct answer for the power dissipated in the 2.4 Ω resistor, fewer had the correct answer for the total power dissipated in the circuit and a disappointing number had the correct value for the energy wasted the battery. The usual answer to the last part was to give the energy in the complete circuit. Whether this was due to inaccurate reading of the question or due to lack of understanding could not be decided.

17 Part (a) was highly structured and led candidates through a full circuit calculation in stages. This approach appeared to have helped them and more successful solutions were seen than has been the case in the past with this type of circuit.

The part that caused the most problems was (a) (ii) with a significant proportion of candidates not appreciating that the pd across the 2.0 Ω resistor was the same as that across resistor R. Candidates were however, not penalized when they carried their incorrect answer to subsequent parts and consequently the remaining calculations were often carried out successfully.

Part (b) proved to be much more demanding and only about half the candidates managed to complete the table for the rate of energy dissipation successfully.

The demonstration of energy conservation in part (b) (ii) provided an even greater challenge and only about a third of candidates provided a convincing analysis of energy conservation in the circuit. A fifth of candidates made no attempt at this part of the question.

18 Part (a) of this question generated some of the poorest responses in the paper with over three quarters of the candidates obtaining no marks. The evidence suggests that candidates find the concept of internal resistance and its relationship with terminal pd quite challenging and were unable to convincingly explain what was happening in this circuit as the current increased. A significant number of candidates assumed that the terminal pd decreased because the internal resistance was increasing due to an increase in temperature of the cell. There was also a lack of precision in answers making it hard to determine which resistance was being referred to in many explanations.

In part (b), the majority were able to find the emf of the cell correctly but the determination of internal resistance, r, proved to be much more discriminating. The more able candidates appreciated that the gradient of the graph was equal in magnitude to r and those who did, for the most part, produced acceptable answers. Alternative solutions using the equation, $\varepsilon = IR + Ir$, were less successful as there were often careless mistakes made when this approach was used – an example being the calculation of R using terminal pd and current and then using this value with a different value of current to find r.

Part (c) required candidates to add lines to the existing graph. Most appreciated that these two lines had the same intercept as the original line and a significant number realised that the line for the cell with double the internal resistance would have a gradient double in magnitude. The line for the cell with zero internal resistance caused more problems and less than half the candidates drew horizontal lines.

Part (d) produced some mixed responses. The calculation of charge was successfully answered by the majority and the unit for charge is clearly well known. However, the calculation of energy dissipated in the internal resistance per second caused far more problems and over half the candidates did not score any marks in this section – many applied the wrong equation and this resulted in them either multiplying the terminal pd or the emf of the cell by the given current.

19

Another difficult question when judged by the candidates. responses: more candidates failed to score on this question than any other. The calculations proved to be beyond most candidates. abilities.

Many good answers to part (a) were seen, and the better candidates scored on part (b) as well, although the idea of *showing* something mathematically is unfamiliar with many.

It was quite clear that very few candidates understood what was being asked in part (d)(ii).

20

Students fared better in the circuit analysis involved in this question than they did in question 6. Parts (a) (i), (ii) and (iii) were answered well with a significant proportion of students able to correctly find the total circuit resistance. The calculation of the parallel network was done correctly by the majority of students, although the working shown by many was sometimes not set out properly with the reciprocal of total resistance being equated to the total resistance. This was in part due to the combined resistance being equal to 1 Ω.

Part (a) (iv), in which students had to calculate the energy transformed by the battery in 5.0minutes, was not answered as well. A significant proportion of students did not appreciate that this was found by multiplying the emf of the battery by the appropriate time. Part (a) (v) caused students even more problems and only a minority of the more able students were able to correctly calculate the energy dissipated in the internal resistance of the battery.

The final part of this question was well answered with most students giving sensible suggestions. However, one out of two marks was quite common due to students mixing up an explanation with a reason; an example being 'has a higher terminal pd' and 'provides large current'.

21 This question required students to analyse a circuit, which included a potato cell. Initially they had to explain what is meant by the emf of a power supply. Answers to this were often vague and did not explain where energy transfer took place. When it came to explaining the results most students appreciated that the internal resistance meant that the terminal pd was less than the emf but convincing explanations as to why the difference between terminal pd and emf increased with current were rare. Many seemed to think that the internal resistance increased as the external resistance decreased. The determination of the internal resistance from the graph was not well done and a significant number of students failed to use the gradient of the graph. Many failed to realise that the current was in milliamps and so finished up with internal resistance, which were much too small.

The final part of this question required an analysis of whether two potato cells in series would enable a LED to light. Only the most able students approached this in a logical way by identifying the emf of the two cells would be 1.78 V but then appreciating that the current the cells were able to provide would be much less than 20 mA.

22 Candidates often find circuit analysis questions challenging if the power supply in the circuit has an internal resistance. This certainly proved to be the case in this exam.

Most candidates were able to interpret the graph in part (a) but when it came to the calculations in part (b) (i), only about half of the candidates appreciated that the pd across resistor R was not 6.0 V. This led them to calculate an incorrect value for current. They were allowed consequential error however, and this meant that higher marks were seen in parts (b) (ii) and (b) (iii).

Part (c) was answered very badly with only about 6% of candidates obtaining full marks and nearly 70% getting zero. The commonest mistake was the assumption that the new graph would have the same overall shape as the one shown in figure 2. Very few candidates seemed to appreciate that with negligible internal resistance, power would be inversely proportional to resistance.

23 (a) (i) Students had to make it clear that the voltmeter ‘alone’ should be connected across the cell.

(ii) A correct explanation was given by a large proportion of students.

(b) (i) Answered well by the more able students.

(ii) A proportion of students seemed to understand how to use the voltmeter but failed to show the correct position on the circuit diagram.

(c) This question discriminated well. Many students failed to give sufficient detail as required by the mark scheme for the first marking point. The second marking point proved to be more accessible, with a greater proportion of students able to suggest an appropriate precaution.

(d) As anticipated this proved to be very demanding, with only the more able students successfully stating and explaining why efficiency would increase as external resistance increases.