AQA A-LEVEL PHYSICS · 7408

PHYSICS



MARK SCHEME

3.5.1 CURRENT ELECTRICITY

SCORE	PERCENTAGE
/315	%

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Q1.

(a) resistance of lamp B and D = $3.5^2/4.1$ = 3.0 (2.98)(Ω) ✓
resistance of lamp A and C = $6.0^2/6.0$ = 6.0 (Ω) ✓
pd across lamp B and lamp D = 3/9 × 9.0 = 3.0 (V) OR pd across lamp A and C = 6.0 (V) ✓
hence A and C normal brightness ✓

Can justify in terms of current i.e. current needed by A and C is 1 A provided resistance values calculated

Must have some correct working for conclusion mark

1
1
1
1

(b) the pd across new lamp = 0 / E does not light ✓
no current in E ✓
other lamps are not affected ✓
because the current in the lamps/pd across lamps does not change ✓

2nd and 3rd marks conditional on 1st mark

1
1
1
(MAX 3)

(c) in first circuit current in battery = 9.0/4.5 = 2.0 A ✓
in second circuit current in battery = 9.0/7 = 1.2857 A ✓
hence current in battery decreases ✓

Allow ecf from (a)

Original current = 2A can come from (a) and score here

If say circuit resistance increases so current decreases and no other marks awarded score 1 mark

1
1
1

[10]

Q2.

(a) Mass of alpha particle = $\frac{2\times1.6\times10^{-19}}{4.81\times10^{7}}$ =6.6(53) × 10^{-27} (kg)

Allow mass = 2 × m_p + 2 × m_n = 6.696 × 10^{-27} kg

Allow mass = 4 × 1.66 × 10^{-27} kg = 6.64 × 10^{-27} kg

Allow mass = 4 × 1.67 × 10^{-27} kg = 6.68 × 10^{-27} kg

Allow slight rounding on mass (must be correct to 2 sf)

OR

Correctly re-arranged k.e. equation (with v^2 or v as subject) with 8.1 × 10^{-13} (J) substituted correctly$_1$✓

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1.56×10^7 seen $_2$✓

*Condone **incorrect mass** in otherwise correct substitution **with v or v^2 recognisable** as subject .*

Alternative approaches are:

$$v = \sqrt{\frac{E_k \times \text{specific charge}}{e}}$$

$$v = \sqrt{\frac{2 \times E_k}{m_\alpha}}$$

Must see answer to at least 2 sf

Must see attempt to use one of the alternative approaches to support correct answer

2

(b) Use of $W = Fs$, $F = 8.1 \times 10^{-13} \div 3.5 \times 10^{-2}$ $_1$✓

(F=) 2.3×10^{-11} (N) $_2$✓

Condone POT error

Correct answers gets 2 marks

OR

Use of an appropriate equation of motion to find a **and** $F = ma$

(allow their mass and their velocity in this sub) $_1$✓

Condone POT error

(F=) 2.3×10^{-11} (N) $_2$✓

Condone POT

OR

Use of an appropriate equation of motion to find t **and** $F = \Delta mv/t$

(allow their mass and their velocity in this sub) $_1$✓

(F=) 2.3×10^{-11} (N) $_2$✓

[answer is

$$\frac{(\text{their speed})^2 \times (\text{their } m_\alpha)}{0.070}$$

Using 2×10^7 m s^{-1} yields(5.71×10^{15} × their m_∞) – allow 1 sf answer in this case

Expect to see 3.8×10^{-11} (N) or 4×10^{-11} (N)]

2

(c) (Number of ions formed over range =)

$5.1 \times 10^4 \times 3.5$ seen **or** 1.785×10^5 (ions) seen

OR

8.1×10^{-13} converted to eV seen $_1$✓

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$8.1 \times 10^{-13} \div 1.785 \times 10^{5}$

OR

$5.06 \times 10^{6} \div 1.785 \times 10^{5}$ seen $_{2}$✓

Condone POT error in first mark
Ignore units
$8.1 \times 10^{-13} \div (5.1 \times 10^{4} \times 3.5)$ is worth 1st and 2nd marks
Condone POT errors in second mark
Correct answer obtains 3 marks

28 (.4) (eV) $_{3}$✓

99(.3) (eV) scores 1 mark

3

(d) (Q =) $0.85 \times 10^{-3} \times 1.2 \times 10^{-9} = 1.02 \times 10^{-12}$

OR

n = (their Q) $\div 1.6 \times 10^{-19}$ $_{1}$✓

$n = 6.4 \times 10^{6}$ (c.a.o.) $_{2}$✓

Condone one POT error for one mark

2

(e) At 3.5 cm the pd drops / the current begins

OR

When the source is 10 cm away no ionisation occurs in the air gap (because the alpha particles have insufficient range to reach the air gap)

OR

When the radioactive source is close enough (approx. 5 cm) ionisation occurs ✓

OR

When beyond 3.5 cm no change in pd / current equals zero

Must be sense of abrupt change
MAX 3

When ionisation occurs / charge carriers are liberated in the air gap:

Allow more ionisation for second mark

resistance has decreased

OR

current increases (from zero)

OR

the potential difference decreases (with a maximum current) (to its minimum value) (across the air gap)✓

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From 10 cm separation until 5 cm (approx) separation nothing changes / appreciates that pd is 4500 V / pd across gap = 4500 V until ionisation occurs ✓

Current is produced: the pd across 5 MΩ resistor is 4250 V / most pd is across the 5 MΩ resistor / small pd across air gap ✓

Current is produced and the pd across the air gap is 250 V✓

Current is produced and the pd across the air gap is 250 V✓

3

[12]

Q3.

A

[1]

Q4.

D

[1]

Q5.

C

[1]

Q6.

A

[1]

Q7.

A

[1]

Q8.

B

[1]

Q9.

B

[1]

Q10.

(a) Length of resistance wire = $50 \times 2 \times 3.14 \times 4 \times 10^{-3} = 1.26$ m ✓

or $50 \times 3.14 \times 8 \times 10^{-3}$

1

Substitution of data in resistance formula

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or $A = \rho L/R$ seen ✓

ecf for incorrect length from attempt at a calculation

1

Area of cross section = 2.1(1) × 10^{-9} (m^2) ✓

1

(b) Maximum possible pd across 0.25 kΩ is 9 V ✓

1

(Max power dissipated) = $9^2/250$ = 0.32 W so resistor is suitable ✓

1

OR

When resistor dissipates maximum power

V^2 = 0.36 × 250 so max V = 9.5 V ✓

This is higher than the supply pd so this power dissipation so will not be reached ✓

OR

Power dissipated when output is 5 $V = 4^2/250$ = 0.064 W ✓

Which is below the max power dissipation of 0.36 W ✓

$9^2/250$ = 0.32 W with incorrect conclusion scores 1

Second mark implies the first

$9^2/0.36$ = 225 Ω alone is not a useful calculation in the context. Still need to explain the effect of using the 250 Ω

First mark is for a valid useful calculation

(c) Use of potential divider formula to determine resistance of parallel combination ✓

0.313 kΩ ✓

Use of equation for resistors in parallel ✓

540 Ω ✓

Alternative to find resistance of combination

Current in circuit at room temp = 4/250 = 16 mA ✓

Resistance of combination = 5/16mA = 313 Ω ✓

OR

$$\frac{V_{combination}}{V_{250}} = \frac{R_{combination}}{250}$$

$$\frac{5}{4} = \frac{R_{combination}}{250}$$

$R_{combination}$ = 313 Ω

OR

Current in circuit at room temp = 4/250 = 16 mA ✓

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Current in thermistor = 5/750 = 6.7 mA ✓

Current in R = 9.3 mA ✓

R = 5/9.3 = 540 Ω ✓

2sf answer ✓

(only allowed with some relevant working leading to a resistor value)

Max 5

(d) Resistance of thermistor decreases ✓

Output pd decreases since

resistance of the parallel combination /circuit decreases

1

OR

lower proportion of pd across the parallel combination (or higher proportion across 250Ω)

OR

higher current so greater pd across the 0.25 k resistor ✓

Accept correct consequences for R increasing with temperature for 1 mark

1

[12]

Q11.

B

[1]

Q12.

C

[1]

Q13.

B

[1]

Q14.

D

[1]

Q15.

C

[1]

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Q16.

(a) An increase in current / voltage leads to an increase in temperature (more heat generated) ✓

Ignore 'of particles' in first mark

Do not condone 'particles' in second mark

This causes an increase in the movement of the lattice/ions/atoms ✓

And therefore an increase in the rate of collisions with electrons ✓

Allow more frequent collisions

So the resistance increases as shown by V / I changing/V not proportional to I (on the graph) ✓

Allow correct reference to gradient of I / V curve unless the answer suggests that this is the resistance or inverse of resistance.

Max 4

(b) 14.3 (Ω)

Allow range 14 to 15

but calculated answer must lie between 14 and 15

1

(c) Determination of pd across either filament or resistor from graph ✓

Pd across resistor can be calculated from resistance value in (b)

Eg V = 0.18 × 14.3 = 2.6

Determination of pd across the other component, and values added ✓

Use of V = IR to give 3.4 (V)

Allow ecf if either value is wrong allow 2 max

Or

Clear attempt to determine total resistance and multiply by 0.18 ✓

Condone small rounding error

(Resistance of lamp at 0.18A = 4.4 Ω)

Total resistance = 18.7 Ω ecf from 2,2 ✓

3.4 V (ecf from 2.2) ✓

Allow for small rounding errors (eg allow range 3.3 to 3.5)

3

(d) Determination of current through either filament or resistor from graph ✓

Allow calculation of resistor current using 4/(answer to 2.2)

Determination of current through the other component, and values added ✓

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(Current through resistor = 0.28 A

Current through filament = 0.36 A)

R = V/I = 4/ (0.28 + 0.36) = 6.25 (Ω)

If either value wrong allow 2 max

Condone small rounding errors.

Or

Calculation of filament resistance or statement of resistor resistance ✓

Resistance of filament = 11.1 (Ω)

Calculation of other resistance and use of parallel formula
(allow ecf from part b) ✓

Either resistance gets the first mark

6.2 -6.3 (Ω) ✓

3

(e) Calculation of area, ignoring power of ten errors.

$A = 8.0 \times 10^{-10}\ m^2$

Correct resistivity 3.1×10^{-8} ✓

Allow ecf for A (for example use of d for r gives 3.2×10^{-11} for A and 1.2×10^{-7} for answer)

Ω m ✓

Some working must be shown for award of unit mark.

3

[14]

Q17.

(a) 15(.0) (Ω) ✓

Only acceptable answer

Must be on answer line or clearly identified as (largest)R

by R = 15 (.0) (Ω) seen.

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

If not on the answer line, units must be stated.

1

(b) 1.4(1) (Ω) ✓✓

Only selects 2.2 Ω and 3.9 Ω in parallel ✓

Accept evidence from working or a clear labelled sketch of 2.2 Ω and 3.9 Ω in parallel

Possible allowed combinations include:

$(\frac{1}{R} =) \frac{1}{2.2} + \frac{1}{3.9}$

Condone $R = \frac{1}{2.2} + \frac{1}{39}$

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$$(R =)\frac{1}{\frac{1}{2.2}+\frac{1}{3.9}}$$

$$(R =)\left(\frac{1}{2.2}+\frac{1}{3.9}\right)^{-1}$$

$$\left(\frac{1}{R} =\right)\frac{5}{11}+\frac{10}{39}$$

$$(R =)\frac{2.2 \times 3.9}{2.2 + 3.9}$$

Accept 1.407 Ω but not >4 sf

Must be on answer line or clearly identified as (smallest) R

by R *= 1.4 (1) (Ω) seen.*

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

Common wrong answer = 0.71 (Ω) is worth one mark with correct supporting working

2

(c) Any of the following statements:

Power supply is on open circuit (so current is zero)

OR

Voltmeter has a (very) large resistance (so current is zero)

OR

No current (load) (so no lost volts)

OR

(Current is zero) so no lost volts

Accept 'negligible' current for zero current

Accept 'very large' resistance; don't penalise 'voltmeter has very large internal resistance'

Do not allow:

Resistance is zero

Only resistance is the internal resistance

No other component (this implies that the internal resistance is zero)

1

(d) (Current through power supply leads to)

lost volts (across the internal resistance)

OR

(Current through power supply leads to)

voltage drop across the internal resistance

OR

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(Current through power supply leads to)

Some of the emf is used in the internal resistance

OR

Voltage is shared between the internal and external resistances

Allow correct 'energy transfer in the internal resistance' arguments

Must refer to a voltage across the internal resistance or r except when the term "lost volts" is used.

Do not allow:

The current decreases

1

(e) $\varepsilon - V$ = (1.62 – 1.14 =) 0.48(0) (V)

and

$\frac{V}{R} = \left(\frac{1.14}{9.0} =\right) = 0.13(\text{V}\Omega^{-1})$ ✓

Both results required for ✓; accept 0.127 or 0.1267 for $\frac{V}{R}$

Do not allow answers expressed in terms of unknown variables

Answers must be on answer line or clearly identified as answer by using correct subject and equals sign

Allow an answer just above (or below) the answer line in cases where a previous answer has been crossed out.

1

(f) Point correctly plotted to nearest 1 mm (half a grid square)

and

continuous ruled best fit line for the 5 (originally printed) points ✓

Withhold mark if point is hidden or if best fit line is of variable thickness or has discontinuities.

Data point should be marked with a cross. Both × and + marks are acceptable.

***Do not allow** points plotted as dots / dots in circles*

If point is wrongly calculated in Part 1.5 allow CE for an accurate plot of this but this should then be treated as anomalous when judging the best fit line.

The best fit line must intersect each of the 5 originally printed X symbols.

Allow no plot where ECF (even as algebraic equation) point won't fit on the grid and student has stated that it can't be plotted.

If no answer / no plottable answer in 1.5 but student chooses to plot a point then it must be the correct point only (0.13,

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0.48)

1

(g) Gradient triangle for **Figure 3**; correct read-offs for points (± 1 mm) from triangle with the $\varepsilon - V$ step at least 0.5 V

Allow $\frac{y2-y1}{x2-x1}$ *seen or gradient triangle drawn with* $\frac{\Delta y}{\Delta x}$ *seen, read-offs must be substituted into* $\frac{y2-y1}{x2-x1}$ *or* $\frac{\Delta y}{\Delta x}$

Condone one read-off error in four read-offs for gradient method

(common error: candidates miss non-origin on ordinate axis)

(common error: makes a power of 10 error on abscissa)

r in range 3.49 to 3.95 (Ω)

Any correct method other than gradient method (no read-off errors here) allow 1 mark

i.e. allow 1 mark for the accurate use of 1 point from their line

r *must be quoted to a minimum of 2 significant figures*

ecf *for* r *(their gradient from their best fit line)*

r *must be supported by correct working*

2

(h) The **Figure 1** method is better **because** more R values are available ✓

6 values of R (possible) for method (seen) in Fig 4 ✓

Do not allow:

The 2nd method has a wider range

The 2nd method has a larger maximum resistance

The 2nd method has a smaller minimum resistance

The 2nd method only goes up to 8.2 Ω

(resistances available in Fig 4: 2.0 Ω, 3.2 Ω, 4.3 Ω, 4.6 Ω, 5.0 Ω, 5.3 Ω)

2

[11]

Q18.

D

[1]

Q19.

B

[1]

Q20.

C

[1]

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Q21.

B

[1]

Q22.

B

[1]

Q23.

C

[1]

Q24.

D

[1]

Q25.

(a) emf is the intercept on the pd / y axis ✓
gradient of the graph is –r / internal resistance is minus the gradient of the graph/modulus of gradient is r / absolute value of gradient is r / magnitude of gradient is r ✓

1
1

(b) figure 2 circuit supplies 50 mA ✓
figure 3 circuit has emf of 1.4 V ✓
and internal resistance of 12 Ω ✓
hence current of 78 mA which is >75 mA ✓

Can use different routes independently for fig 2 and fig 3

If candidates calculated current is not 50 mA or 75 mA allow CE for correct conclusion relating to 75 mA

Must explain which circuit is suitable. If their calculation shows neither circuit suitable must explain why both circuits not suitable

OR

calculate required pd is 0.45 V (0.075 × 6.0) ✓
show pd for cell in fig 2 is 0.1 V ✓
show pd across parallel cells in fig 3 is 0.4 V ✓
show total pd in fig 3 is 0.5 V which is greater than 0.45 V ✓

OR

calculate emf needed for 75 mA in fig 2 (1.05) ✓
calculate emf needed in fig 3 (1.35) ✓
comment on emf needed in fig 2 is larger than cell provides ✓
comment on emf in fig 3 being close to what is required ✓

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from graph for current for current of 75 mA
from graph for current of ½ of 75 mA i.er. 37.5 mA
i.e. 0.1 V from single cell and 0.4 V from parallel cells

4

(c) useful power dissipated = $(75 \times 10^{-3})^2 \times 6$ ✓ (= 0.03375 (W))

Condone use of 78 mA gives answer of 285 W
If used resistance of 18 Ω then lose first mark but CE to give answer of 791 W

input power (at the cells) = 0.03375/.04 = (W) ✓

solar power = 0.8437 /(32×10^{-4}) = 260 (263.7 or 264) W m^{-2} ✓

CE from power calculation but not from % calculation
if incorrect % calculation at any stage only qualify for useful power mark

1
1
1

[9]

Q26.

C

[1]

Q27.

B

[1]

Q28.

B

[1]

Q29.

C

[1]

Q30.

B

[1]

Q31.

B

[1]

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Q32.

B

[1]

Q33.

C

[1]

Q34.

(a) peak (to peak) voltage = 6.3(0) (V) ✓

accept any answer that rounds to 6.3 V

do not allow power of ten errors, eg 0.0063 V

1

(b) period = 8 divisions

(= 8 × 0.5 × 10^{-3} (s))

= 4 ms $_1$ ✓

$\left(f = \frac{1}{T} = \frac{1}{0.004}\right)$

= 250 (Hz) $_2$ ✓

award both marks if 250 Hz seen

accept 4.0(0) ms for $_1$ ✓ but reject 4.05, 3.95 etc

ecf$_2$ ✓ for wrong period

2

(c) any valid approach leading to *RC* in range

2.1 ×10^{-4} to 3.4 ×10^{-4} or 3 ×10^{-4} (s)

OR

their *T* in 02.2 × 0.069 ± 10 % $_{12}$ ✓ ✓

1 mark can be awarded for use of any valid approach in which *RC* is seen with substitutions or with rearranged equations, eg

$0.5 = 6.3e^{\frac{-6\times10^{-3}}{RC}}$ or $RC = \frac{-t}{\ln\left(\frac{V}{V_0}\right)}$ or

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$$RC = \frac{t}{\ln\left(\frac{V_0}{V}\right)}$$

OR

$1.75 \times 10^{-4} = RC \times \ln 2$

OR

$$RC = \frac{t_{0.5}}{\ln(2)}$$

valid approaches;

reads off t when C starts to discharge and t at a lower value of V:

$$V = V_0 e^{\frac{-\Delta t}{RC}}$$

rearranges to calculate RC

for ecf ✓ *Δt used must correspond to interpretation of time base used in determining the frequency in (b); there is no ecf for misinterpretation of the voltage scale*

OR

reads off t when C starts to charge and t at a higher value of V:

$$V = V_0\left(1 - e^{\frac{-\Delta t}{RC}}\right)$$

rearranges to calculate RC etc

OR

determines half-life $t_{0.5}$ *and finds RC from* $\frac{t_{0.5}}{\ln(2)}$

for ecf ✓ $t_{0.5}$ *used must correspond to etc*

OR

uses idea that during discharge V falls to $0.37V_0$ *in one time constant: determines suitable V and reads off RC directly*

for ecf ✓ *time interval used must correspond to etc*

OR

uses idea that during charging V rises to $0.63V_0$ *in one time constant: determines suitable V and reads off RC directly*

reject idea that V falls to zero in 5RC

2

(d) qualitative comment

idea that the waveform will stretch horizontally ✓

quantitative comment

by a factor of $\left(\frac{0.5}{0.2} = 2.5\right)$ ✓

OR

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half a cycle now covers 10 (horizontal) divisions on the screen $_2$ ✓ (and also earns $_1$ ✓)

(so the) resolution of the time axis has increased $_3$ ✓ (and also earns $_1$ ✓)

measuring larger distance / across more divisions from the screen reduces (percentage) uncertainty in reading the time (constant / interval / half life) $_4$ ✓

for $_1$ ✓ look for reference to time axis or direction waveform is re-scaled

accept 'graph is longer/stretched' or 'will not see whole cycle' or 'fewer cycles shown' or 'period takes more space' or 'distance being measured is larger' or 'time per division is less' or 'larger in x direction' or 'time is stretched'

reject 'waveform becomes larger' or 'may not see whole cycle' or 'measuring larger time'

for $_2$ ✓ there needs to be valid quantitative detail

award $_{12}$ ✓ ✓ for 'half a cycle now fills the screen' or 'half a cycle is displayed' as these clearly recognise the stretching is along the time axis and 'half' is quantitative

accept 'new distance (on screen corresponding to half life or time constant) is 2.5 × answer shown in working for (c)'

the candidate who realises that half a wave now covers the complete width of the screen cannot claim this is a disadvantage; they would still be able to bring either half cycle into view by using the X-shift and find RC for $_3$ ✓ uses technical language correctly

ignore (but do not penalise) 'times are more precise' or 'more accurate'

reject 'smaller resolution' or 'lower resolution'

for 4 ✓ there needs to be a qualifying explanation for the comment about uncertainty

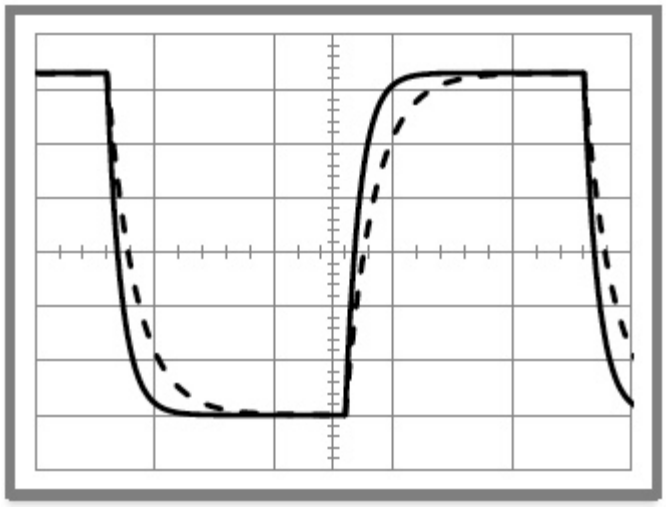
reject 'advantage because the (time) scale is easier to read'

3 MAX

(e) valid sketch on **Figure 7** showing discharge time to 0 V reduced and charging time to peak voltage reduced (see below) $_1$ ✓

connecting resistor in parallel with R halves [reduces by 50%] circuit [total] resistance [time constant] $_2$ ✓

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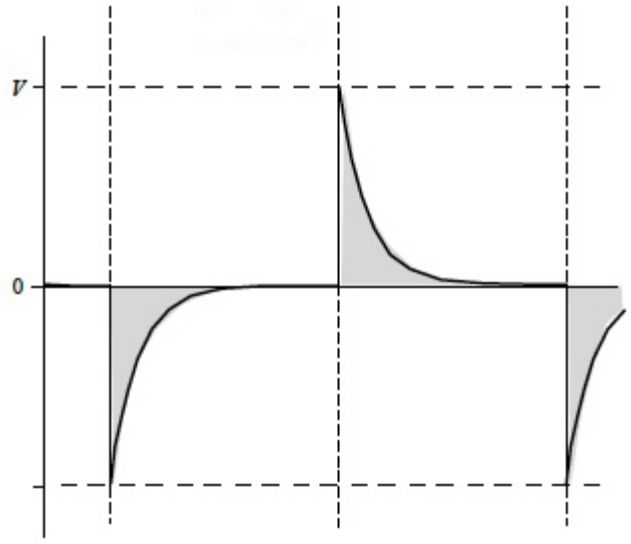
do not insist on seeing second discharge although if shown this must look correct

2

(f) amendment to **Figure 8** showing waveform across R with approximately the correct shape, amplitude ± *V* and the correct phase

correct waveform shown while signal generator output is low (0 V): only the complete negative half cycle needs to be shown but if second negative half cycle is included it must be correct $_1$ ✓

correct waveform shown while voltage across signal generator output is high; condone no signal or signal = 0 V before going to –V for the first time $_2$ ✓



don't insist on seeing vertical lines

2

(g) <u>reduce</u> the (sensitivity of) (Y-voltage)) <u>gain</u> $_1$ ✓

(change) to <u>2 V</u> division^{-1} $_2$ ✓ (and earns $_1$ ✓)

adjust the <u>Y</u> (vertical) <u>shift</u> $_3$ ✓

'make (Y-) gain smaller' or 'increase the volts per division' or

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'reduce the Y-resolution' are acceptable substitutes for 'reduce the (Y-)gain'

increase the (Y-) gain to 2 V division^{-1} $_2$ ✓ *not* $_1$ ✓

reduce the (Y-) gain to 0.5 V division^{-1} $_1$ ✓ *not* $_2$ ✓

ignore any comment about time base or 'X-gain'

if all positive waveform is given for (f) allow sensible comment about triggering/stability control, eg

waveform may not be stable $_1$ ✓ *; adjust triggering* $_2$ ✓

2 MAX

[14]

Q35.

(a) correct general shape ✓

accurate plotting to within $\frac{1}{2}$ square ✓

2

(b) 12 (V) ✓, 30 (W) ✓

2

(c) $R = \left(\frac{6}{1.9}\right) = 3.2\ (\Omega)$ ✓

1

(d) Resistance increases ✓

Temperature increases ✓

More collisions / interaction of electrons with lattice ions ✓

Condone 'atoms', 'molecule'.

*Do **not** allow electron−electron collisions.*

3

(e) Can attain neither maximum nor minimum voltage ✓

Explanation of either maximum OR minimum ✓

2

[10]

Q36.

(a) 0.5 mm [0.05 cm, 0.0005 m] ✓

only acceptable answers

1

(b) 8.65 mm [0.865 cm, 0.00865 m] $_1$✓

the micrometer reads zero when the jaws are closed $_2$✓

only 3sf answers are acceptable for $_1$✓

accept no zero error for $_2$✓

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2

(c) L = (403 − 289 =) 114 mm ✓

1

(d) absolute uncertainty = 1 mm $_1$✓

percentage uncertainty = $\frac{1}{114}$ × 100 = 0.88%$_2$✓

accept 2 mm for ab. uncertainty $_1$✓

allow ecf for wrong L and / or wrong ΔL

accept 1.75%

2

(e) should move wire directly over / closer to scale on the ruler to avoid <u>parallax</u> error ✓

both statement and explanation required for this mark

1

(f) five values of *R*/*L* correct, recorded to 3 sf [last row to 3sf or 4sf]; accept values in Ω cm^{-1} ✓

mean based on <u>first four</u> rows only; result 9.94 Ω m^{-1} [9.94 × 10^{-2} Ω cm^{-1}] ✓

L/cm	*R/Ω*	*(R/L)Ωm^{-1}*
81.6	*8.10*	*9.93*
72.2	*7.19*	*9.96*
63.7	*6.31*	*9.91*
58.7	*5.85*	*9.97*
44.1	*4.70*	*10.66 (10.7)*

2

(g) cross-sectional area = $\frac{\pi d^2}{4}$ $_1$✓

resistivity from $\frac{R}{L} \times A$, correct substitution of result from 01.6 $_2$✓

1.10 × 10^{-6}3 ✓

Ω m $_4$✓

resistivity from $\frac{R}{L} \times \frac{\pi d^2}{4}$ *earns* $_{12}$✓✓

allow $_2$✓ *if* $\frac{R}{L}$ *value is not based on mean or on a mean from all five rows of table in 01.6*

condone 1.12 × 10^{-6} for $_3$✓ *if fifth row in 01.6 was not*

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rejected
withhold ✓ *for POT error*

4

[13]

Q37.

B

[1]

Q38.

C

[1]

Q39.

B

[1]

Q40.

B

[1]

Q41.

A

[1]

Q42.

B

[1]

Q43.

(a) The current through a conductor between two points is directly proportional to the potential difference across the two points

(provided the temperature remains constant) ✓

Or ratio of voltage / current is constant

1

(b) 75 (mA) ✓

1

(c) ***MAX 4***

voltmeter position is incorrect because it is across the cell ✓

voltmeter should be connected across the putty ✓

the 10 Ω resistor is not suitable to control the current ✓

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because its resistance is only half that of the putty✓

pd range is 1.0 to 1.5 V, this is insufficient for experiment✓

MAX 4

(d) Substitution of $V = A \times l$ into $\rho = \frac{R \times A}{l}$ ✓

(leading to $\rho = \frac{RV}{l^2}$)

Complete argument needed

1

(e) $V = 60 \times 10^{-3} \times \pi \times (10 \times 10^{-3})^2$

$(= 1.88 \times 10^{-5}\ m^3)$ ✓

$\rho = 20 \times 1.88 \times 10^{-5} / (60 \times 10^{-3})^2$

$= 0.10$ ✓ Ωm ✓

Will not gain this mark only if POT error correctly followed through.

Stand alone unit mark

3

[10]

Q44.

B

[1]

Q45.

D

[1]

Q46.

C

[1]

Q47.

D

[1]

Q60.

(a) *(use of R = ρl/A)*

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$A = 9.7 \times 10^{-8} \times 0.50/0.070$ ✓

1

$A = 6.929 \times 10^{-7}$ (m^2) ✓

1

diameter = $\sqrt{(6.929 \times 10^{-7} \times 4/\pi)} = 9.4 \times 10^{-4}$ (m) ✓

CE for third mark if incorrect area

1

(b) R = 1.5/0.66 = 2.3(Ω) (2.27) ✓

1

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

I = 1.5/(22 + 1.2) = 0.065✓(A) (0.0647) ✓

1

(d) current in R_1 = 0.66 − 0.0647 = 0.595 (A) ✓

CE from 4.2/4.3

1

resistance of R_1 and probe = 1.5/0.595 = 2.52 (Ω) ✓

alternative method: 1/2.3 = 1/23.2 + 1/(R_{probe} + 2.4) ✓

1

resistance of probe = 2.52 − 2.4 = 0.12 (Ω) ✓

correct rearrangement ✓

range 0.1 – 0.15 ✓

accept 1 sig. fig. for final answer

1

(e) cross-sectional area must decrease OR R α 1/A

indicated by downward arrow or negative sign which can be seen on answer line

1

area decreases by 1.6% hence diameter must decrease by 0.8% ✓

accept 1%

1

(f) ANY TWO FROM

correct reference to lost volts OR terminal pd OR reduced current ✓

reference to resistors not changing OR resistors constant ratio ✓

reference to voltmeter having high/infinite resistance (so not affecting circuit) ✓

reference to pd between AB being (very) small (due to closeness of resistance ratios in each arm) ✓

voltmeter (may not be) sensitive enough ✓

1

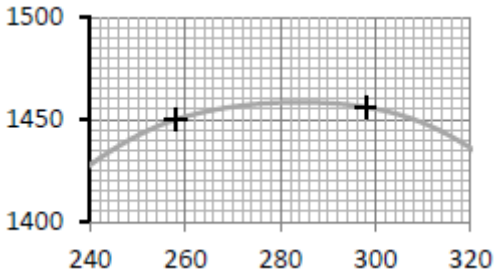
1

[12]

Q61.

(a) 2 missing points plotted, each to nearest 1 mm (half a grid square); points marked + or × or ⊙; reject thick points, blobs or uncircled dots ✓

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1

(b) continuous smooth best fit line through all 7 points to 1 mm ✓

allow mis-plotted points to be treated as anomalies; multiple lines or points of inflexion lose the mark

1

(c) candidate's value from Figure 2 ± ½ grid square ✓

if multiple lines are drawn condone value if ± ½ grid square of all lines

1

(d) finding θ_N from Figure 3 is easy since the result is read off where $G = 0$ $_1$✓

or

finding θ_N from Figure 2 is difficult since θ has a range of values for which ε is a maximum $_2$✓

accept evidence that $G = 0$ used shown on Figure 3; physics error about how Figure 3 used means no credit for any further valid comment about Figure 2

accept 'curve is shallow at peak' for $_2$✓

MAX 1

(e) method:

correctly determines gradient of Figure 3 or uses gradient result with any point on line to determine (vertical) intercept $_1$✓

result in range 9.8 to 10.9 $_2$✓

gradient values in the range −0.040 to −0.034 for $_1$✓ (minus sign essential)

for $_1$✓ allow the substitution of at least one pair of correct values of G and θ into $G = \beta\theta + \alpha$ to obtain α using simultaneous equations

condone 2sf '10' for $_2$✓

2

(f) full scale pd = 100 × 1000 = 100000 or 10^5 μV ✓

allow 100 mV or 0.1 V if μV deleted from answer line ✓

1

(g) idea that resolution of the meter is not satisfactory $_1$✓

because the largest pd that will be measured is less than 1500 μV

OR

only uses 1.5% of the range

OR

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pd across meter at full-scale deflection ÷ divisions = $\frac{10^5}{50}$ = 2000 μV per division ₂✓

condone use of 'sensitivity' or 'precision' for 'resolution'; ignore 'meter is not accurate'

allow 'hard to tell different readings apart'

for ₂✓ allow ce for incorrect 02.6

allow 'unable to measure to nearest <u>micro</u>volt'

allow 'resolution of scale should be 1 μV'

2

[9]

Q62.

(a) Top line: 234 4 ✓

bottom line: 2 ✓

the first mark is for the nucleon numbers correct

the second mark is for the correct proton number of the alpha particle

2

(b) use of $\frac{\text{electrical power output}}{\text{power generated by decay}}$ = 6% = 0.06

to give: power generated by decay = $\frac{100}{0.06}$ = 1700 W ✓

allow 2000, 1670, 1667 etc

1

(c) current = $\frac{P}{V} = \frac{100}{32}$ = 3.1 A ✓

allow 3, 3.13 and 3.125; condone 3.12

1

(d) each component requires $I = \frac{P}{R} = \frac{32}{45}$ = 0.71 A ✓

number of components = $\frac{3.1}{0.71}$ = 4.4; thus n = 4 ✓

alternative 1: use of power formula $\frac{V^2}{R} = \frac{32^2}{45} = 23$ W ✓

number of components = $\frac{100}{23}$ = 4.3; thus n = 4 ✓

condone '4' for both marks; if the answer is not rounded down to the greatest whole number, lose the last mark

if P = 1700 used rather than 100 allow ce

alternative 2: use of total resistance formula

$R_T = \frac{V^2}{P} = \frac{32^2}{100}$ *or* $\frac{P}{I^2} = \frac{100}{3.1^2} = 10.24$ ✓

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$$\frac{1}{R_T} = \frac{1}{10.24} = \frac{n}{45} \therefore n = \frac{45}{10.24} = 4.4 \text{ ; thus } n = 4 \checkmark$$

2

(e) energy = 1000 kW h
= 1000 × 1000 × 3600
= 3.6×10^9 J ✓

average power = $\frac{3.6 \times 10^9}{265 \times 24 \times 3600}$ = 114 W ✓

allow 1 sf 100 W

for solution using Watt-hours

$\frac{10^6}{265 \times 24}$ ✓ = 114 W ✓

2

(f) (as Sun's intensity is similar) area needed = (similar to that of UK domestic solar power installation =) 10m^2 (to an order of magnitude) ✓

allow ce for average power ie $\frac{1000}{\text{answer to 04.5}}$

1

[9]

Q63.

B

[1]

Q64.

A

[1]

Q65.

C

[1]

Q66.

A

[1]

Q67.

D

[1]

Q68.

A

[1]

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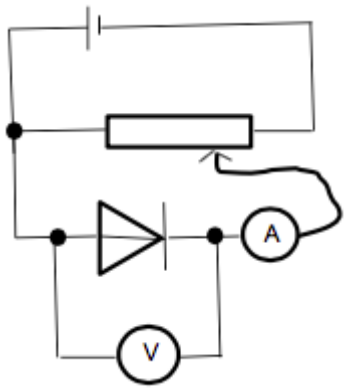
Q69.

D

[1]

Q70.

(a) (i)



correct diode bias for variable supply, must have some attempt to vary pd ✓

Condone variable resistor (condone missing arrow) don't allow thermistor symbol

correct symbols and positions for voltmeter, ammeter:
voltmeter in parallel with diode only
ammeter in series with diode ✓

Allow mA symbol instead of A symbol for ammeter

Allow symbols for diode without line through triangle and / or with a circle

Diode symbol must consist of a triangle and a straight line at nose perpendicular to wiring in circuit.

allow voltmeter across ammeter and diode



2

(ii) **The candidate's writing should be legible and the spelling, punctuation and grammar should be sufficiently accurate for the meaning to be clear.**
The candidate's answer will be assessed holistically. The answer will be assigned to one of three levels according to the following criteria.

High Level (Good to excellent): 5 or 6 marks
The information conveyed by the answer is clearly organised, logical and coherent, using appropriate specialist vocabulary correctly. The form and style of writing is appropriate to answer the question.
Candidate explains how to obtain sufficient values of I and V. They mention the need to limit the current through the diode and give an indication of the range and frequency of measurements. They discuss an advantage of using a data logger. Voltage does not exceed 1.0V, diode is forward biased

Intermediate Level (Modest to adequate): 3 or 4 marks
The information conveyed by the answer may be less well organised and not fully coherent. There is less use of specialist vocabulary, or specialist vocabulary may be used incorrectly. The form and style of writing is less

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appropriate.
Candidate explains how to obtain sufficient values of I and V. Includes mention of diode is forward biased or suitable voltage for switch on mentioned or advantage of data logger

Low Level (Poor to limited): 1 or 2 marks
The information conveyed by the answer is poorly organised and may not be relevant or coherent. There is little correct use of specialist vocabulary. The form and style of writing may be only partly appropriate.
vary pd obtain several readings of *I* and *V*
or an advantage of using data logger
or forward biased
low level safety may include switch off / avoid overheating type arguments / don't touch

The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case.
means of controlling pd across diode
indication of range and frequency of measurement
mention of limiting current to avoid damage to diode
a consideration of the advantages of a datalogger e.g. many readings, computer display of results
use of potential divider instead of series resistor

All signs of quality that could lift mark

Lower band

vary pd obtain several readings of I and V

or an advantage of using data logger or low level safety and action to minimise risk

Middle band

vary pd and obtain several readings of I and V, at least 6 different values ***including*** *an advantage of using data logger or mention of forward bias or mention of switch on voltage (0.6V) or safety*

Top Band

Mention of how to vary pd (seen in viable circuit) obtain several readings of I and V, at least 6 different values (range given where maximum value of pd does not exceed 1.0V)

mention of limiting current through diode using protective resistor

consider advantage of data logger

mention forward bias

must include potentiometer for 6 marks

must have voltage as independent, no current led arguments in Top band

Data logger advantages:

Not more accurate

Not removes human error

6

(iii) reverse connections to the power supply / battery / cell / reverse diode ✓

not switch wires around (need clear link to reversing

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connections at supply's terminals)

1

(b) (i) divide *V* by *I* for a reading from graph **or** uses $R = {}^{V}/_{I}$ for a reading from graph ✓

Treat gradient = $\frac{1}{R}$ *as TO*

repeat for different values of *V* and *I* ✓

Must score 1st mark to achieve 2nd

2

(ii) (Resistance) decreases ✓

Or resistance starts off very high and then becomes much lower

1

[12]

Q71.

(a) (i) $230 \times \sqrt{2} = 325$ (V) ✓

(2 × 325 =) 650 to 651 V ✓

allow doubling their incorrect peak voltage (162.6 × 2) by use of $\sqrt{2}$*2 as an attempt to find peak-to-peak for 1 mark but not just 2 × 230*

2

(ii) *(use of* $P = V^2/R$*)*

$P = 230^2/12$ ✓

$P = 4.4 \times 10^3$ (W) ✓ cao

2 sig. figs. Incorrect <u>answer must be supported by working</u> ✓

Allow their incorrect answer (a)(i)$^2 \div 12$

Or $325^2 \div 12$ *as a use of for 1 mark*

Alternative

For first mark

$I = \frac{V}{R}$ ***and*** *P=VI allowing their incorrect answer (a)(i) or 325 as sub for V for 1 mark*

Answers 8.8 kW (325V) and 35 kW (650V)

3

(b) (i) there is a pd / voltage across the cable ✓

pd / voltage across cooker is 230 V minus this pd / voltage ✓

2nd mark depends on 1st mark in all

The current is lower due to the resistance of cable / The current is lower as circuit resistance increases ✓

pd across oven is lower <u>since</u> V=I × Resistance of element ✓

or

Resistance of the cable is in series with element ✓

Voltage splits (in ratio) across these resistances ✓

2

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(ii) resistance of cable = 2 × 3.15 × 0.0150 = 0.0945 ✓

Allow power 10 error here

$$V = \frac{12}{12 + R_{cable}} \times 230$$ ✓

Or $I = \frac{230}{12 + R_{cable}}$ **and** $V = \left(\frac{230}{12 + R_{cable}}\right) \times 12$

=228 V ✓ cao

Allow their incorrect R_{cable} correctly substituted for 2nd marking

3

(iii) 230 − their (b) (ii) or 19 (A) quoted for current or equivalent seen in equation (230 / 12.0945) ✓

(P =) 34.2 to 42.3(W) ✓ correct working

ecf as P = (230- (b)(ii))^2 / their R_{cable}

2

(iv) minimise power loss / maximise efficiency of oven / ensure element gets as hot as possible ✓
avoid overheating / fires ✓

not just to carry a large current / larger pd across element

Either order

2

[14]

Q72.

(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

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(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]

Q73.

Resistance is zero at (or below) critical temperature

"Negligible resistance" is insufficient

[1]

Q74.

(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]

Q75.

(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

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(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 $I=RA/\rho$ 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

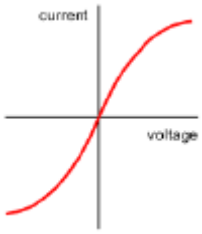
Condone use of 174 for T for C1 and B1 marks

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

3

[15]

Q76.

(a) 

✓ ✓

first mark for linear at origin and decreasing gradient in either quadrant (linear region can be very small)

second mark for symmetry plus no dip at end or extended horizontal section at end

straight line scores zero

2

(b) (i) resistance (of filament lamp) increases✓

1

(ii) filament lamp is a non-ohmic conductor as current is not (directly) proportional to voltage / resistance is not constant✓

proportionality can be shown using graph

1

(c) either

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circuit / total resistance increases✓
(hence) current decreases and pd / voltage across R decreases✓
OR
resistance of PQ combination increases✓
(hence) greater share of pd / voltage across lamp P✓

implication that current is different in different parts of series circuits scores 0
implication that new total current is greater scores zero
voltage flowing loses second mark

2

(d) (i) (use of *energy* = *VIt*)
(energy converted by X = 60 × 120 × 3600 =) 2.59×10^7 J ✓
(energy converted by Y = 11 × 120 × 3600 =) 4.75×10^6 J ✓

Accept answers to 1 sig. fig.

2

(ii) in lamps energy is wasted as heat / thermal energy✓
specific lamp considered e.g. in lamp, X / filament lamp more energy is wasted OR in X / filament lamp less energy is converted to light / luminosity✓

2

[10]

Q77.

(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✓

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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]

Q78.

(a) Use of $\rho = RA / l$)
cross sectional area= × $(3.7 \times 10^{-3})^2 = 4.3 \times 10^{-5}$ (m^2)✓

$\rho = \frac{3.3 \times 4.3 \times 10^{-5}}{1000}$ ✓ = 1.4(2) × 10^{-7}✓Ω m✓

area : lose first mark if use diameter as radius or fail to convert to m^2 (if both errors still only lose 1 mark)
CE area for next two marks but if uses diameter in place of area then lose first two marks
if leave length in km lose 2nd mark but CE for answer
UNIT stand-alone 4th mark

4

(b) (current in) steel wire (is less than the current in an) aluminium wire as it has a higher resistivity / resistance OR aluminium is better conductor✓
the six aluminium wires are in <u>parallel</u> OR <u>total</u> cross-sectional area of aluminium is 6 times greater than steel wire✓
each aluminium wire carries three times as much current as the (single) steel wire✓

3

(c) resistance of 1 km of 6 Al cables in parallel = $\frac{1.1}{6}$ = 0.183 Ω✓

if ignored the steel wire then can score first and third mark

total resistance of the cable = 0.174 Ω✓
power loss per km = 32.3 kW (or 30.7 kW if they ignore the steel)✓
OR
power loss in 1 km of steel = 1.70kW✓
power loss in 1 km each of Al cable = 5.11 kW✓
total power loss per km = 32.4 kW (or 30.7 kW if they ignore the steel)✓
OR
calculate current in steel wire and aluminium wire (22.7 and 68.2) ✓
calculate power loss in aluminium wire and steel wire (1700 and 5115) ✓
calculate total power loss (1700 + 6 × 5115 = 32,4 kW) ✓

accept range 32 kW to 33 kW
if ignored steel wire
range for third mark is 30 kW to 31 kW

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if wires treated as series resistors then zero

3

[10]

Q79.

(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

And

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]

Q80.

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D

[1]

Q81.

(a) (i) Use of $P = VI$ with pair of valid coordinates from graph

C1

0.52 (W)

Allow 1sf if within 0.49 to 0.52

A1

2

(ii) Correct general shape

M1

Linear rise between 0.0 – 0.5 V <u>and</u> falls to zero at 0.71 V

A1

2

(iii) Use of *efficiency* = $\frac{\text{useful power out}}{\text{total power in}}$

C1

Use of $I = \frac{P}{A}$

C1

Their (i) / 67.5 (m^2) (7.7×10^{-3} if correct)

A1

3

(b) (i) 0.7 J of work done (by cell) per 1 C of charge (when moved round circuit)
OR
(Terminal) pd across (solar) cell with no load / current is 0.7 V

Not "per unit charge"

B1

1

(ii) 20 cells in series (to produce 14 V)

B1

Series arrangement has internal resistance of 15.6 Ω

B1

Cells in parallel (needed to reduce total internal resistance of array)

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B1

80 cells / 4 parallel sets of 20 cells in series

B1
4

(c) The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question.

Descriptor ∇ an answer will be expected to meet most of the criteria in the level descriptor.

Level 3 – good
-claims supported by an appropriate range of evidence;
-good use of information or ideas about physics, going beyond those given in the question;
-argument is well structured with minimal repetition or irrelevant points;
-accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling.

Level 2 – modest
-claims partly supported by evidence;
-good use of information or ideas about physics given in the question but limited beyond this;
-the argument shows some attempt at structure;
-the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling.

Level 1 – limited
-valid points but not clearly linked to an argument structure;
-limited use of information about physics;
-unstructured;
-errors in spelling, punctuation and grammar or lack of fluency.

Level 0
-incorrect, inappropriate or no response.

Some points:

Use on communication satellite:

Continuous supply of energy from Sun
No need for fuel (for power purposes)
Large area of solar cells not needed (but possible)
Low mass
Can be unfolded (after launch)
No environmental hazard
Reliable/no moving parts

Continuous operation:

Arrays need to track sun (to maximise absorption)
Shielding required as can be damaged by meteors or cosmic rays
Need storage system (rechargeable batteries / capacitors) for back up (if in shadow)
Limit use of energy-intensive operations

Use on space probe:

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Light intensity / energy too low at large distance
Intensity falls as inverse-square
Area of array would be too large
Solar cells will have degenerated too much over this time

B6
6

[18]

Q245.

(a) calculation of (0.718V − 0.619V) / 100 °C (= 99mV / °C)

1

(b) a series resistor to the inverting input,
a series resistor to the non-inverting input,
a resistor from the output to inverting input,
a resistor from the non-inverting input to 0V

4

(c) voltmeter will display 5V for 50°C change = 0.1V / °C

diode produces 50mV for 50°C change = 1mV / 1°C

so voltage gain needed is 0.1V / 1mV or 5V / 50mV (= 100)

Use of Vout / Vin given an appropriate temperature range

3

(d) use of difference amplifier formula rearranged
substitution 15k × 100
= 1.5 MΩ (1,500k)

For 3 marks must have units

3

[11]

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Q1.

This question required students to analyse a parallel circuit and predict the effect of changes in the circuit.

(a) As is often the case, students struggled to analyse this parallel circuit correctly. The commonest successful approach was to work out the resistance values for the lamps and then use these values to determine the potential difference across each lamp. A minority of students, having found the resistance values of the lamps, calculated the current in each branch and then compared this with the current required for normal operation. Only about a third of students were able to adopt either of these two approaches.

(b) Only a minority of students appreciated that the potential difference across lamp E would be zero and so there would be no current in the lamp. This meant that there were a considerable number of flawed arguments which assumed there was a current in E. Over 10% of students made no attempt at this question; in addition, 78.9% scored zero.

(c) The overall performance in this part of the question was also disappointing. The most accessible mark was the calculation of the initial current in the battery – which some students had already done in (a). Appreciating that lamp B failing resulted in a parallel and series circuit was not well understood and it was rare to see correct calculations of the new circuit resistance. A significant proportion of students did appreciate that the resistance had increased and this would reduce the current, but were unable to support this with correct calculations. A very high proportion of students (22.7%) failed to attempt this question.

Q2.

(a) There were a number of stages to this “show that” question. Because of its level of demand the mark scheme was less stringent than usual about how “show that” calculations should be presented. However, students should be encouraged to ensure they have fully demonstrated how the answer is obtained. These pieces of advice should be considered:

- any equations used should be written with subjects seen at each stage of the calculation;
- mid-calculation rounding should be avoided;
- the answer should be quoted to more significant figures than the value they have been asked to find.

(b) The main error seen, when using F = ma and equations of motion, was not taking into account speed changing when calculating the time to stop. Students who identified the questions as being set up for a “work done = change in kinetic energy” generally obtained all marks (27.3%).

(c) Good students were able successfully to complete this calculation (23.1%) whereas lower performing students appeared to have little appreciation of the problem and were able to make only limited progress, by perhaps finding the number of ions or converting the energy into electron volts.

(d) Students failed to gain marks here for a number of the following common reasons: dividing the current by the time, using $2 \times 1.6 \times 10^{-19}$ for each charge carrier rather

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than 1.6×10^{-19}, and misremembering the prefix nano- as 10^{-12}.

(e) This question proved to be inaccessible to all but the very best students. Only 10.7% of students managed to score anything on this item. The number of factors they had to consider proved too challenging for most. Where students realised that ionisation occurred when the alpha source was close enough, they often got confused about the effect this had on the current in the circuit and the resistance and potential difference across the air gap. Many students thought that an increase in current could only occur when the potential difference across the air gap increased.

Q3.

Students most frequently selected C as their answer. Unfortunately, students seemed unaware of the need for V to be a constant when inspecting $P = VI$ and assumed direct proportionality. As a result, only 28.8% gained this mark.

Q4.

Most students selected B as their answer by converting 1 kW to 1000 W and dividing by 1.6×10^{-19}. These students seemed unaware of the kWh as a unit of energy; this was evidenced by their disregard of the 1 hour in their calculation. Students would improve performance by checking the specification content including section 3.1 (Measurements and their errors). Just under a quarter of students were successful here.

Q5.

Despite this idea being tested last year, students still seem to be unaware of how to determine resistance at a point on a curved V-I graph. The resistance is the ratio of the voltage and current at that point and not the gradient of the tangent to the curve. Distractor B was the most common answer selected by students; 32.1% of them gained the mark.

Q6.

Electricity remains a topic that students find challenging. Just under 20% of students selected the correct answer. The most commonly selected incorrect answer was distractor B. Students seemed unaware of the fact that the potential difference across the lower part of the circuit would be unaffected by an increase in the resistance of the thermistor.

Q7.

This question proved more accessible to higher performing students, with 34.5% selecting the correct answer. Those students who selected D (most common incorrect response) added the emfs of the cells despite the fact that the cells were connected in parallel. Students would do well to revisit rules for combining cells in series and identical cells in parallel.

Q8.

This question tested students' knowledge of formulae, units and their ability to rearrange. Over 30% were able to identify the correct answer. There were a number of pitfalls along the way and many students did not manage to deal with the s^{-1} in Cs^{-1} (the unit for the ampère); in this case they selected distractor A.

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Q9.

This question proved a challenge (28.3% correct); the most common incorrect answer selected was distractor C. These students reasoned that the pd must be divided between the voltmeter and the 20 Ω resistor in a 1:1 ratio despite the voltmeter having an infinite resistance. Similarly, they were unaware that the total resistance in the circuit was 20 Ω rather than 10 Ω.

Q10.

(a) The problem that has been discussed in question 03.4 was evident in this question too but there was a high proportion of correct solutions (58.9% scored full marks) to this relatively familiar problem.

(b) Many students were able to make some progress by doing a relevant calculation. The most common one was to calculate the pd across the resistor that would produce the maximum power dissipation of 0.36 W in the 025 kΩ resistor. However, very few could follow this up with a sensible conclusion. The most common statement was that since the pd from the calculation was 9.5 V, the resistor would be unsuitable as the 0.25 Ω resistor would not be operating at its rated power. What students needed to state was that it is suitable: since the maximum pd possible for the circuit was 9.0 V, the maximum possible power dissipated in the resistor (0.32 W) was lower than 0.36 W. There were other possible useful calculations, but providing a clear correct conclusion was relatively rare. Just under a quarter of students gained both marks.

(c) This was generally answered well and there were many completely correct responses including the significant figures in the final answer (27.6% of students). There were, however, many who complicated matters by trying to do all the algebra first. These students combined the formula for the parallel resistors and the potential divider aspects into one equation. This often led to a page of manipulation and frequently errors crept in. Those who wrote $\frac{1}{R} = \frac{1}{R} + \frac{1}{750}$ for the parallel resistors ended up with difficulties as they lost track of which R represented the total resistance of the parallel combination and which was the resistance they were trying to determine. Students who first worked out the resistance of the parallel combination from the potential divider formula (or otherwise) and then used the formula for parallel resistances could complete it in a few lines and avoided these mistakes.

(d) Many students appreciated that the thermistor resistor would decrease, but fewer gave a satisfactory explanation of why this led to the decrease in output voltage. There were many misconceptions shown in the responses. One which was quite common was “because the resistance of the thermistor decreased, the pd across it would decrease therefore there would be more of the pd across the other resistor therefore a higher output potential difference”. Just over a third of students failed to score on this question.

Q11.

46.6% correct

Q12.

58.3% correct

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Q13.

75.4% correct

Q14.

46.1% correct

Q15.

76.3% correct

Q16.

This question gave students the opportunity to demonstrate their skills reading graphs, as well as their knowledge and understanding of electricity.

(a) Several misconceptions were clear in some of the answers to this question. Many students misinterpreted the graph as a V-I graph and, of the rest, many suggested that gradient is equal to 1/R: teachers are encouraged to emphasise that the value of V and I at the point (or 1/gradient of the line from the point to the origin) gives the resistance of the filament. Other problems were related to lack of detail or ambiguous terminology. Many students lost a mark for being unclear about 'which particle moves more', and the requirement for an increase in the *rate* of collisions (rather than just the collisions) also proved to be a hurdle to many. Many answers were seen that suggested students applied little more knowledge or understanding than that required at GCSE level.

(b) This straightforward calculation was correctly performed by the large majority of students, suggesting that many who misinterpreted the axes in 02.1, were still able to use them correctly in this question.

(c) There were several different routes students could take to obtain the correct answer here, and all of them were given full credit. With many students not obtaining all three marks in what is a relatively straightforward calculation, it is suggested that teachers encourage students to sketch a small circuit diagram where one isn't provided if it assists them in answering questions. The most straightforward, and rarely seen, method was to simply read the value of the pds for both components at 0.18 A, and add them together. Many students embarked on complex analyses that almost inevitably led to errors and marks being lost.

(d) Many students have greater difficulties with parallel than series circuits and, again, the sketch of a simple circuit diagram would probably have assisted them here. The significant difference in performance between this and the previous question was seen in the award of 1 or zero marks: many more students were unable to make enough of an attempt to gain any credit. This was often due to an assumption that the 0.18 A current was still applicable here, with students then performing a simple V/I calculation for the wrong answer. Other common errors included difficulties adding resistances in parallel, a problem that would not have existed had these students realised that the total current could be obtained from the graph, and the resistance calculated from V/I.

(e) It was pleasing to note that this multi-step calculation was completed successfully by a large proportion of the students and that the correct unit was well known. Those who had difficulty tended to make power of ten errors or mistakenly use diameter for radius in the calculation of area, either of which still allowed for an 'error carried forward'. It should be emphasised that a correct unit on its own was not credited,

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and that some working, and an answer, had to be seen.

Q17.

(a) The success-rate on this question was more than 90%. Common wrong answers seen included 21.1 Ω and 8.2 Ω, both suggesting that the students did not read the question carefully enough. (21.1 Ω is the sum of all four resistors while 8.2 Ω is the value of the largest single resistor.)

(b) This showed a much greater range of attainment by students; over 60% of students obtained 2 marks. Many students offered 6.1 Ω as the answer, treating the series combination of 2.2 Ω and 3.9 Ω as the lowest possible value. Other students did not invert the sum of in the final step, leaving their answer as 0.71 Ω.

A significant number of candidates were unable to add two fractions:

$\frac{1}{2.2}+\frac{1}{3.9}$ and believed the answer to be $\frac{1}{6.1}$.

Another common incorrect response was

$\frac{1}{8.2}+\frac{1}{6.8}=0.27$

This error clearly demonstrated a poor understanding of the effect on resistance of combining resistors in parallel, and a lack of knowledge of the mathematical process used to determine the resistance of two resistors in parallel.

(c) Students' level of achievement in questions involving internal resistance would be improved if they were encouraged to concentrate on the effect the current has on the terminal pd. Students are expected to treat voltmeters as ideal, that is having infinite resistance. This being the case, students should recognise that the current is zero and therefore the terminal pd equals the emf.

Students had difficulty with this question, suggesting significant gaps in their understanding of emf, terminal pd and resistance. Many students stated that resistance between X and Y is zero when there is no resistor connected between X and Y.

This misunderstanding led students to believe that a current was flowing and/or all the voltage was across the internal resistance. Others stated that the voltmeter was the only component in the circuit without stating why this meant that it read the emf, or students stated that without a resistance between X and Y there was nowhere else the voltage could be lost than across the internal resistance.

Students need to be made aware of the fact that the voltmeter cannot directly read the lost volts and should be encouraged to consider the formula in this form:

Terminal pd = $\varepsilon - Ir$

A significant number of students believe that in a parallel circuit, or a series circuit that includes a voltmeter connected in parallel, resistance increases when a switch is closed. These students will state that current decreases when a switch is closed thus neglecting the fact that the resistance between the contacts of the open switch can be considered infinite compared to resistance elsewhere in the circuit.

High quality answers addressed the very high resistance of the voltmeter and the

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effect this had on the current and the lost volts.

(d) Many students thought that the resistance in the circuit increased when the resistors were added between X and Y. These students often stated that the current in the circuit decreased when resistors were added.

Other students stated that the voltage decreased because it was now shared between these (external) resistors. This response showed a lack of appreciation of the fact that the voltmeter was connected across both resistors, as well as demonstrating a lack of awareness regarding the impact of the internal resistance. Students were required to relate the sharing of the voltage between the internal and external resistances.

The focus of many answers was incorrect. This question is about terminal pd, internal resistance and current. Students should remember to make sure their answers address these main points; too often the answer centred on limited descriptions of what would happen to the two resistors connected between X and Y.

(e) Students should be aware of the need to quote numerical answers in section A to an appropriate number of significant figures. Students did not obtain the mark when they quoted $\frac{V}{R}$ as 0.126 rather than as 0.13.

(f) Many students plotted (0.115, 0.48) instead of (0.13, 0.48). Reading of scales needs to be done with care to avoid this type of error. The line of best fit needs to be drawn with due care. Students should be encouraged to draw lines of uniform thickness without any discontinuities.

(g) It is considered good practice to draw a gradient triangle on the line of best fit. Students were expected to draw a suitably large gradient triangle where the change in voltage was at least 0.5 V. In general, the triangle should be as large as possible, choosing points that can be read accurately. The points used should be indicated by labelling of the values on the line and subsequent working should be clearly presented.

In cases where a student used a single point from the line and substituted this into the equation of the line they received a maximum of 1 mark.

Common errors seen included:

- Read-off error of the y co-ordinate at the point the line cuts the x-axis;
- Read-off error of the x co-ordinate at the point the line cuts the x-axis;
- Choosing to use a gradient triangle that was too small.

(h) The first mark was straightforward, awarded for stating that the number of values available was less in the new method. Many students were under the impression that in the second method the resistors could not be connected in parallel. Answers that discussed the range were treated as neutral because the question asked the students to consider the number of different values of R available in method 2 compared to method 1. The second mark was harder to achieve; the students had to appreciate that this method yielded 6 values for R. Less than 20% of students obtained both marks.

Q18.

Many students found this question a challenge with just over 50% selecting the correct answer. Students should be encouraged to check specification content and ensure they

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understand each statement. This type of calculation will be expected knowledge across the life of this specification.

Q19.

This proved one of the most accessible questions in section C, with nearly 80% of students selecting the correct answer. However, it was noted that the supporting working was not particularly convincing. Many students used the ratio of 4:2:1 for the current ratio rather than the ratio ¼: ½: 1. This error may have resulted in students obtaining the wrong answer if asked for the current in either the 4 Ω or 1 Ω resistor.

Q20.

This calculation was performed correctly by over 70% of students. The most frequently selected incorrect answer was distractor B. Students applied little physics here and simply found the product of 12, 6.5 and 5.

Q21.

Most students correctly identified B as the correct statement regarding superconductors. Distractor A proved a popular choice as many students are reluctant to recognise that superconductors have no resistance and prefer statements that suggest that superconductors have almost zero resistance.

Q22.

40% of students selected the correct answer. The most popular distractor was C; students had difficulty dealing with the fact that doubling the radius quadrupled the cross-sectional area. Where students had supporting working, with the resistivity formula, they had usually performed the calculation correctly.

Q23.

The low level of success here was surprising; less than 50% of students correctly identified the correct answer. In preparation for the exam, students would do well to be able to sketch all such graphs from memory, making any such graph instantly recognisable in questions like this.

Q24.

Over 10% of students did not select any answer. It is important that students develop exam technique to include a final page check to ensure all questions have been seen. Only 35% of students selected the correct answer; this demonstrates a lack of familiarity with the properties of LDRs and potential divider circuits.

Q25.

A quite detailed circuit analysis was required for this question and some very impressive answers were seen.

In question (a) the commonest reason for losing a mark was a failure to indicate that the gradient of the graph gave the negative value of internal resistance. Identifying which circuit would be suitable to power the road sign involved a detailed analysis; while over a third of students were able to do this successfully, a significant proportion of these then failed to score the conclusion mark because they did not state clearly that the circuit in **Figure 1** was suitable because it provided a current greater than 75 mA. Less able

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students struggled when dealing with the series and parallel combination of cells. Of those who could correctly identify the combined internal resistance as 12 Ω, few were then able to give the combined emf as 1.4 V.

The analysis of the circuit in **Figure 2** was much more straightforward and nearly 80% of students were able to do this. There are of course alternative approaches to the analysis and any correct method was given full credit.

Question (c) involved an efficiency calculation. A large number of students were able to calculate the useful power output but a surprising number did not deal with the 4.0% efficiency correctly. It was quite common to see the input power multiplied by 0.96 rather than divided by 0.04. There were also, as is frequently the case, power of ten errors when dealing with the surface area.

Q34.

This question addressed the ideas behind assessed practical activity 9. Students who had seen the second set of specimen questions should have been well prepared for the parts relating to the use of the oscilloscope. It was clear from the descriptive parts of this question, however, that many students had not had direct experience of using an oscilloscope, as shown by the lack of much, if any, use of correct terminology to describe the controls.

Even if some students thought the waveform shown in Figure 1 showed an ac signal, the instruction to determine the peak to peak voltage should have made question (a) straightforward. However, a disappointing number of students found a variety of ways to get this wrong and were similarly unsuccessful with question (b).

Those students who obtained 6.3 V and 250 Hz were well-placed to score in question (c) and a popular and successful approach was to use $V = V_0 e^{\frac{-\Delta t}{RC}}$; a transparent, viable attempt along these lines could earn a mark, even if the final answer fell outside the required range. Others read off the time interval for *V* to fall to 37% when the capacitor was discharging, but poor communication often made it harder to give any credit, if the final result obtained by this method was unsuccessful. Those using the idea that the capacitor would completely discharge in five time constants were almost invariably unsuccessful due to difficulty in accurately pinpointing the time for 5RC from Figure 5.

In question (d), most students knew what would happen to the waveform displayed in the oscilloscope when the time-base was adjusted, but often struggled to give a convincing explanation. Stating that the ‘waveform would not fit’ left examiners looking for further evidence to decide whether the student was referring to vertical or horizontal direction. Some students referred to the ‘wavelength increasing’, or equivocated by suggested that the waveform ‘might not fit’. While better answers suggesting that either the charging or discharging parts (but not both) would now be displayed, very few students took a quantitative approach, e.g. that the discharge curve would now be 2.5 times wider. Here and elsewhere in the paper, some students explained that uncertainty would be reduced, but without supporting reasoning this gained no credit.

Question (e) discriminated well, with better students stating that the resistance, and hence the time constant, is halved, and spotted the opportunity to give the quantitative detail suggested by the information in the question. The sketches on Figure 7 showed that some students thought that adding the extra resistor would change the amplitude or the period of the waveform; relatively few students supplied the sketch examiners were looking for.

In the sketch for question (f), examiners wanted to see a complete half cycle while the signal generator output was *V*, and a complete half cycle when the output was zero.

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Students were generally more successful with the latter, but often failed to consider how Figures 8a and 8b could be used in combination to deduce the other part of the waveform.

In question (g), “reduce Y-gain”, or “increase volt per division” could score but an equivocal “change the Y-gain” could not. Once again, extra credit was available for quantitative detail such as “set the gain to 2 V per division”. Some students clearly failed to appreciate that Figure 8c showed a graph and was not the way the waveform would appear on the oscilloscope; these students stated that the waveform was already fully visible, so no changes were necessary.

Q60.

Experience from past physics exams at this level indicates that students are better at answering quantitative questions involving electric circuits and this is supported by evidence from this question where the calculations were frequently done well. Part (a) required students to calculate the diameter of the wire and a high proportion of students were able to do this successfully. Full marks were obtained by over 70% of students. There was more variation in parts (b), (c) and (d). While the majority of students were able to calculate the resistance of the circuit, analysing the parallel arrangement was more discriminating. In particular, calculating the resistance of the probe proved challenging. A common mistake was the assumption that the current divided equally in the two branches and therefore the current in the probe was the same as that calculated for R3. Many students found (e) difficult and tried to determine the percentage change in diameter using extended calculations which frequently led to arithmetic errors. The first mark was for recognition that the diameter must decreases and any indication of this such as a downward arrow or negative sign was accepted. The marks obtained for part (f) were disappointing in spite of the mark scheme being expanded to accept a greater range of answers. Very few students picked up that the question referred to the voltmeter reading rather than the pd between A and B. The first marking point was for explaining the effect the internal resistance would have on the circuit by for example reducing the current or terminal pd. The second mark was for a sensible suggestion explaining why the voltmeter reading did not change such as realizing that the closeness of the resistance ratios would make the pd being measured very small. Having the bridge circuit slightly off balance did mean that a comment on the high resistance of the voltmeter was relevant and some did identify this point.

Q61.

(a) Students should expect to be required to interpolate between grid lines when plotting points. Most students were able to do this satisfactorily, but errors reading the ε scale were surprisingly common. Another issue was associated with the style of point used. The standard has been long established in the legacy EMPA and ISA tests: thick points or blobs were not accepted.

(b) Thick, discontinuous, faint or straight lines forfeited this mark. Whilst some excellent lines were seen in answer to this question, some lines were thick enough to obscure the points. The line was expected to pass within half a grid square of all of the points. It was common to see careless drawing near the last point (392,1241), which lost the mark. Where it was clear that the points were incorrectly plotted far from the trend line it is surprising that students did not go back and check their answer to (a).

(c) An error was carried forward from their answer to (b) and most students were able to read the maximum correctly to half a grid square. However, it was common to see 1456 (the maximum in the table) even when the line on the graph did not support this value. 1335 was a common incorrect answer, suggesting that students were treating the ε axis as a number line.

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(d) This question discriminated in favour of those who could write without ambiguity. Examiners were looking for an answer that explained that θ_n could be found from figure 3 simply by reading off where the value of G was zero (280 °C). Answers that discussed the difficulty of reading the value from figure 2 as there is a range of values for which ε is at, or close to, a maximum, also gained credit. Unfortunately many students implied that the gradient of figure 3 was easier to measure, or stated that finding where the gradient was zero was easier on figure 3 (seeming to suggest that there is such a point on figure 3). Some erroneously wrote about the relative difficulties of reading a point from a straight line rather than a curve. It was also relatively common to see comments referring to the different scale ranges in the two diagrams.

(e) Many very good answers to this question were seen, clearly demonstrating an understanding of the equation of a straight line and an ability to obtain data, such as the gradient, from a graph. An alternative acceptable approach was to use the values from two points and solve the two simultaneous equations produced. Many students incorrectly thought α was the value of G where the line touched the y-axis, and extrapolated the line back and extended the axis to find this point. Others mistakenly took α to be the gradient.

(f) Although many correct answers were seen, some suggested that several students were unfamiliar with the term “full scale deflection”, despite this being defined in the question. Others did not spot the μ on the answer line, writing down a value of 0.1 without changing the unit to match.

(g) There were many answers expressed so poorly that credit could not be given. Common examples were “the scale is too large”, “the divisions are not small enough” and “the scale does not have enough divisions”. Discussions related to accuracy gained no credit either. The best answers made it clear that the resolution of the meter was unsatisfactory, supporting this with a relevant calculation, such as the change in pd represented by one division (2000 μV). There was consideration made for answers based on an incorrect answer to (f). For example, those who had calculated the full-scale deflection to be 0., could gain credit for arguing that the range of the meter was inadequate. Several unsuccessfully argued that it was the susceptibility of the analogue meter to parallax error which made it unsuitable.

Q62.

This question linked several parts of the AS specification together, including radioactivity, electricity and energy. It also allowed for the testing of some parts of the first chapter of the specification: “measurements and their errors”.

(a) This question caused few students any difficulty. The few errors seen tended to be linked to using 2 for the nucleon number of the alpha particle.

(b) The equation needed for this question is on the data sheet, and it was therefore disappointing to see how many students were unable to perform the calculation correctly. Most commonly students confused output and input powers, obtaining an answer of 6W. A moment’s reflection should have shown that this could not be sensible. Due to the use of 100 W in the stem, answers were accepted regardless of the number of significant figures but any rounding down had to be correct and recurring notation was rejected.

(c) This was much more accessible with only a few students being unable to get the correct answer. The few errors seen included answers that used 1700 W (i.e. the answer to (b)), perhaps carrying on the problem with input and output power in this context.

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(d) There were several routes through this question and all were given credit. A popular solution was to calculate the total circuit resistance (10.24 Ω) for an output power of 100 W, then reverse-working using the parallel resistor formula (or perhaps just dividing 45 by 10.24) to find the (non-integer) result for number of resistors. Rounding down gave the required result but a few rounded up and forfeited a mark. Those using their result from 04.2 rather than 100 W were able to get some credit.

(e) There was evidence to suggest that many students were unfamiliar with this conversion and that some centres may have overlooked this part of the specification. The most popular approach was to find the equivalent J value of the kW h and divide by the number of seconds in a year but the same idea using energy in W h was also successful. Many near misses involved mixing units, dividing W h by 3600. Disappointingly many students did not attempt this question.

(f) Answers to this question suggested very few students were familiar with the idea of an 'order of magnitude' calculation. Many students who produced an answer for (e) did not then realise that the solar panel on Mars produced the same average power output as that on Earth. Given that the intensity of solar radiation was about the same in both situations they were looking for a solar panel with a surface area about the same as that in a typical domestic setup on Earth. Having grappled with this very few then appreciated that the answer required was to be given to the nearest power of ten (10 m^2 was the expected result). Again, many did not attempt the question.

Q63.

54% of students were able to perform this relatively straightforward calculation. Surprisingly D was the least popular distractor, suggesting students had more problems with correctly using seconds rather than minutes than dealing with the m in mA.

Q64.

With 55% of students giving the correct answer, this question proved to be reasonably accessible. This may be because the experiment is often carried out with a protective resistor in series with the diode. The most popular distractor, D, indicates some confusion between current and pd. A relatively high number of students opted for C, suggesting some difficulties working out whether the diode was reverse biased or not.

Q65.

Many students have difficulties with electricity questions. Using multiple choice questions such as this one may help deal with some misconceptions. The correct answer was given by 40% of students, but nearly 50% believed that adding a resistor in parallel would reduce the current (and hence the charge) through R, despite being told that the cell has negligible resistance. Presumably the students believed that the current through the cell does not change, and therefore the current is shared between the two resistors.

Q66.

It is clear from answers to this question that few students (approximately 13%) had much understanding of how using high voltage power lines reduces energy loss. In fact the correct answer proved to be the least popular of the choices. The current through a transmission line is found from the power being delivered and the voltage of the line ($P = IV$). Hence higher voltages result in lower currents. The power dissipated is then related to the current in the line, and the resistance of the line. Students were expected to use $P = IV$ to calculate the current in the line, and then use the power loss $(1\%P) = I^2R$ to calculate the resistance. Responses suggested that many students believe that the 132 kV is

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dropped across the line, rather than between the line and earth.

Q67.

This proved to be more demanding than expected, with more students choosing A than the correct answer (D). This was perhaps due to students realising that thermistors had something to do with temperature, without realising that the higher the temperature the lower the resistance. It may be that these students rejected the other answers without checking them as an understanding of resistors in series and parallel should have led to the correct answer.

Q68.

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.

Q69.

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.

Q70.

This question was poorly answered by the majority of students. There were very few potentiometers seen in part (a)(i) with most students opting for a simple series loop containing a diode, rheostat and battery. Lots of students were unsure about the symbol for a diode or could not draw the diode in forward bias for the supply shown.

Part (a)(ii), the QoWC answer, was often limited with most students producing a standard *VI* method without any real idea of ranges or safety considerations for this experiment. Students were awarded some marks for setting out a *VI* experiment where they had given details that attempted to match the criteria set out in the question. Higher quality responses typically were ones that made reference to an appropriate voltage range and increments, the importance of a protective resistor, appropriate advantages of using a data logger.

Part (b)(i) contained an extremely common incorrect answer. The vast majority of students thought that the gradient of the *IV* graph was the reciprocal of the resistance. It is important for students to be aware that the resistance is the ratio of potential difference to the current at a particular point rather than the gradient of a *VI* graph. The gradient of a *VI* graph is the ratio of the rate of change of potential difference to the rate of change of current and this is not the same as resistance.

Q71.

Most students were able to determine the peak voltage of 325 V in part (a)(i). Unfortunately a considerable proportion of students neglected to double this value to determine the peak-to-peak voltage.

In part (b)(ii), students were told that the rms voltage across the heating element was less than 230 V and asked to explain why this was the case. Many weaker responses restated

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information that had been given without adding any new detail. Others would state that there was a voltage drop across the connecting cable without developing this point to explain why this meant that the rms voltage would be lower across the element. Better responses were able to produce a two stage argument to support their explanation.

The calculation in (b)(ii) was challenging for most students. The working seen was often unclear with students carrying forward non-relevant data from (a)(i) and (a)(ii). Grade A students generally produced work that was well laid out and direct in approach. Some students used incorrect methods for determining the current such as dividing 230 V by 12 ohms or dividing 4400 W by 230 V, neither of these approaches took account of the new resistance in the circuit and how this would impact on the current value.

Similarly, part (b)(iii) caused problems for all but the most able students. Many students took the answer to part (b)(ii) and substituted this into $P = \frac{V^2}{R}$ with no clear appreciation of the task. This perhaps indicated a mechanical approach to calculations by some students in which preceding parts are blended to get the final answer without really understanding the nuances of the task.

Q72.

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.

Q73.

Students needed to use the term “critical temperature” in their definition.

Q74.

(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.

Q75.

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(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.

Q76.

The first parts of this question examined ideas which were only a slight extension of GCSE knowledge. Students were required to sketch the *I-V* characteristics of a lamp and many responses were spoilt due to a lack of care and attention to detail. Characteristics drawn often lacked symmetry or finished off as horizontal lines. A significant number drew straight lines or lines which curved in the wrong direction. The majority of students did appreciate that the resistance of the lamp increased but only about half were able to identify the lamp as non-ohmic.

(c) required students to analyse a circuit qualitatively. This proved to be quite a challenge for many of them. Answers such as the voltage was shared between the two parallel lamps and now all goes to one or an implication that the current is different in the two lamps when they are in series were common. There was also the tendency to answer in vague terms rather than focus on how the resistance of the circuit changes. Many appreciated that current in lamp P would increase but failed to reconcile this with the fact that the overall current decreases because the total resistance increases.

(d) also proved to be quite challenging and this came as something of a surprise. More than half of the students could not calculate the electrical energy converted by the lamps and explanations of why different power ratings could give the same light intensity output were for the most part disappointing. Many gave explanations as why the power ratings might be different such as different resistance elements and did not address the essential point about the efficiency of the energy conversion.

Q77.

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.

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Q78.

The calculation of resistivity was well done and the correct unit for resistivity was often seen. The only common error was the calculation of cross-sectional area, which caused the usual issues such as using the diameter as the radius or failing to convert millimetres to metres.

(b) and (c) however, proved to be much more challenging. In both parts many students failed to appreciate that the wires making up the cable were connected in parallel. This meant they were unable to give a full explanation as to why only a small percentage of current went through the steel wire or to calculate the power loss in the cable correctly.

Q79.

(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.

Q80.

The synoptic (or "common sense") element in answering this question made the question more difficult than it really should have been. With a facility of 43% it was the most difficult question in this test. When studying power transmission, students should know that it is essential to minimise I^2R losses from the cables. This is done by using high voltage (to reduce the current for a given amount of power) and by employing cables of low resistance. However, the cables also need to be mechanically strong so that they will help to support their own weight. The electrical good conductors such as copper and aluminium tend to be mechanically weak, so in practice the cables are reinforced by incorporating a stronger material. 37% of the students thought that the principal reason for the steel core was that it would reduce the power lost from the cables (distractor C).

Q81.

Just over half the candidates scored full marks in part (a)(i). The common error by candidates who failed to score any marks was to simply take the maximum values of current (0.9 A) and voltage (0.7 V), rather than read off a pair of corresponding values, for which they would have gained at least 1 mark.

In part (a)(ii) about one-third of candidates correctly interpreted and sketched an initially linear portion for the graph, peaking at about 0.6 V and then dropping to zero just past 0.7 V. A further third of candidates gained 1 mark for a sketch that began at the origin, peaked and returned to 0 W at some voltage.

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Nearly 25% of candidates successfully dealt with the 2 calculations required to find the area of the solar cell in part (a)(iii), but dealing with the efficiency proved to be the biggest difficulty to many candidates. The common error was to multiply their power output (from (a)(i)) by 0.15. These candidates would have helped themselves by initially writing the efficiency equation and then substituting the data.

Most candidates had not learnt the definition of emf sufficiently well to apply it to the context given in part (b)(i). Very few high-quality answers referring to “moving charge around the circuit” were seen.

Applying knowledge of the behaviour of emf and resistance in series and parallel circuits in part (b)(ii) proved challenging for a high majority of the candidates, with only about 10% gaining 3 or more marks. Many candidates appreciated that a series arrangement of 20 cells would provide the required emf of 14 V but failed then to consider that the addition of the resistances would be too great and therefore a parallel arrangement, to lower the internal resistance, was necessary.

Good comprehension skills were rewarded in part (c) which quite clearly asked candidates to address 3 points regarding the use of solar cells. High marks were obtained by candidates who did so with clear paragraph structure. Others failed to respond to the question in sufficient detail and addressed only 1 or 2 of the points, thus limiting their mark. Common, correct answers pointed out the continuous availability of sun light, the need for an energy storage system, and the very low intensity of light at the edge of the solar system. Many low-achieving candidates evaluated the use of solar cells in terms of terrestrial use and addressed limitations of such resources as HEP and wind power.

Q245.

(a) A few responses appeared to manipulate meaningless numbers to magically produce the value given. This question was a good test of comprehension, and many found the correct change in voltage but forgot that this was for a change of 100 degrees centigrade (not 1).

(b) This part was answered well with many clear circuits drawn neatly.

(c) Again, a few responses appeared to manipulate meaningless numbers to magically produce the value given. Those who connected a 50 degree centigrade change to a 50mV change went on to use the basic gain formula to score full marks.

(d) Several candidates copied the difference amp formula but were at a loss to know how to make use of it. Those who realised the Rf / Ri part relates to the gain arrived at the correct answer.

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