A-Level Physics

Circuits

Mark Scheme

Time available: 89 minutes
Marks available: 65 marks

Mark schemes

1. (a) Use of

$$V_0 = \frac{R_1}{R_1 + R_2} \times V_{in}$$

OR

$V_1 : V_2 = R_1 : R_2$ ✓

(R =) 1.7 (Ω) ✓

Alternative MP1:

pd across the variable resistor = 11.25 V

OR

current = 0.45 A

2

(b) use of $V = IR$ ✓

(R =) 4.7 (Ω) ✓

2

(c) Temperature increases so resistance increases ✓

Vibration of the lattice ions increases (with temperature) ✓

More collisions between the (conduction) electrons and the lattice ions (at higher temperature) ✓

3

(d) use of $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ ✓

(R =) 4.8 (Ω) ✓

Alternative MP1:

determines I_T current in battery (I_T = 2.48 A) ***and*** *uses $V = IR$*

2

(e) use of $P = \frac{V^2}{R}$ ✓

(P =) 30 (W) ✓

Ecf from ***(d)***

2

(f) Voltage range is wider 0–12 V (in Figure 4's circuit)

OR

bulb won't light at lower range so control is unaffected ✓

Efficiency is less because more power dissipated in Figure 4 (for any particular voltage across the lamp compared to this voltage across the lamp in Figure 2) ✓

At any voltage across the lamp there is always 12 V across the resistor in Fig 4 which produces heating whereas only the remaining portion of 12 V is across the resistor in Fig 2 ✓

3

[14]

2. (a) The amount of energy is transferred from **chemical energy** to **electrical energy** (for every coulomb of charge)✓

Alternative first mark:

The work done in moving (1 coulomb of) charge ***whole*** *way round circuit*

5.30 J of energy per coulomb of charge✓

2

(b) 5.30 – 1.05 = 4.25 (V) seen

or

4.25 V across 640 Ω resistor seen

or

use of $V = IR$✓

Allow use of $V = IR$ to find the current in the 320 Ω resistor. ($I = 3.28 \times 10^{-3}$ (A))

$(I = \frac{4.25}{640} =)\ 6.6(4) \times 10^{-3}$ (A)

Where candidates assume voltmeter has resistance 320 Ω , their answer = 6.56×10^{-3} A. Do not credit this.

2

(c) Use of $V = IR$ seen (finds total resistance of circuit)
Or
Use of $V = IR$ for parallel section seen ✓

R_T = 798 (Ω) (expect to see 757 (7 mA) or 803 (6.6 mA) or 807 (6.56 mA)

Allow their R_T or their total resistance of the parallel section

Use of $R_T = R_1 + R_2$ **or** $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2}$ seen (finds resistance of voltmeter)✓

(R =) 312.6 (Ω) or 313 (Ω) or 310 (Ω) seen ✓

$I = 3.28 \times 10^{-3}$ (A) (evidence for this may be seen in (b))

Alternatively:

Use of $V = IR$ seen (finds current in 320 Ω resistor)✓

Allow their I_T and their current in the 320 Ω resistor.

Use of $I_T = I_1 + I_2$ seen (finds current in voltmeter)✓

(R =) 312.6 (Ω) or 313 (Ω) or 310 (Ω) seen ✓

Answer is:

316 Ω where I = 6.6 mA

282 Ω where I = 7 mA

320 Ω where I = 6.56 mA

Must see working to support their answer.

No workings = zero marks.

3

(d) Use of $P = V^2 / R$ ✓

*Allow their V along with R from **part (c)***

Allow V = 5.3 with their R

Alternative 1st MP

*Use of $V = IR$ **and** $P = I^2R$ **or***

*$V = IR$ **and** $P = VI$* ✓

(P =) 0.090 (W)✓

Answer = 0.094 (W) where R = 300 Ω

Condone 1 sf answer where R = 300 Ω is used.

2

(e) Current in circuit changes (as voltmeter position changes) / ratio of the voltage dropped across each resistor changes as voltmeter position changes. ✓

Because resistance in the circuit decrease / changes✓

Allow maximum of 1 mark for the reading will only be the emf if the voltmeter is across both resistors. ✓

2

[11]

3. (a) R_{LDR} without light = 300 kΩ ✓

$I = \frac{V}{R} = \frac{5}{310 \times 10^3}$ = 16.1 × 10^{-6} A ✓

Allow ecf for their R

2

(b) V with without light = IR = 16.1 × 10^{-6} × 300 × 10^{3} = 4.84 V✓

*ecf from **(a)***

Allow 92–100 kΩ

With light $V = \left(\frac{93}{93+10}\right)$ × 5.0 = 4.51 V ✓

Conclusion and calculate of change in voltage and comparison with 1.25 V✓

4.8 – 4.5 = 0.3 V so no.

Allow 1 sf (allow ecf)

3

[5]

4. (a) Work done in moving 1 C of charge through the cell ✓
1.5 J of work is done in moving 1 C of charge through the cell ✓

OR

Amount of energy converted from other forms to electrical energy per 1 C of charge ✓

1.5 J of energy converted from other forms to electrical energy per unit charge (passing across the emf) ✓

OR

Work done in moving 1 C of charge (whole way) round circuit ✓

1.5 J of work is done in moving 1 C of charge the (whole way) round circuit ✓

2nd marking point obtains both marks

***Max 1 mark** available for the following:*

The emf is the terminal pd when there is no current in the cell (and this equals 1.5 V)

1.5 J of energy per 1 C of charge.

Allow a statement of Kirchhoff's 2 nd law for 1 mark. Where the law is in symbol form, the meaning of the symbols must be stated. Need a clear communication of internal and external resistances.

2

(b) P = VI

And

(P) = 0.465 (W) ✓

Seen to more than 2 sf with supporting equation with subject seen in working

1

(c) Use of appropriate power equation to determine wasted power
or
power dissipated in **R** = total power – their wasted power ✓

(P =) 0.40 W ✓

Alternative for 1 mark:

Use of $I = \frac{\varepsilon}{R+r}$

Or

pd across R = 1.5 – 0.65 x 0.31

or

pd across R = 1.2985 (V)

or

total resistance = 1.5/ 0.31

or

total resistance = 4.839 (Ω)

or R = 4.2 (Ω)

or $P = I^2$ *x their* R

or

P = $\frac{V^2}{R}$ *using their V and R* ✓

2

(d) Use of $E = P\,t$
or $E = VI\,t$
Or
$E = QV$ **and** $Q = It$ ✓

Allow use of the equation with their values.

An answer of 3.5×10^4 *is worth 1 mark*

(t =) $3.0(1) \times 10^4$ (s) ✓

2

(e) **MAX 3 from (1 to 4) or (5 to 8)**

It is suitable, because:

(1) Current required in lamp = 0.62 A or use of $I=\frac{P}{V}$ seen

(2) Resistance of lamp = 2.11 Ω or use of $R=\frac{V^2}{P}$ seen ✓

(3) current in each cell = 0.31 A ✓

(4) lost volts = 0.2 V

or

lost volts = 0.65 x 0.31 ✓

Check the diagram in part (e)

Must have the ***correct conclusion to award 4 marks.***

Conclusion: yes, terminal pd = **1.5 – 0.2** seen

or

terminal pd= 1.5 – 0.65 x 0.4 /1.3 ✓

OR

(5) total internal resistance = 0.325 Ω ✓

(6) total resistance in circuit = 2.44 Ω ✓

(7) Resistance of lamp = 2.11 Ω ✓

(8) pd splits in ratio of 0.325:2.11 ✓

Conclusion: yes, pd **across lamp is** $\frac{2.11 \times 1.5}{2.44}$ **(= 1.3 V) seen** ✓

Allow max 3 from a combination of two route [(2) and (7) worth total of 1 mark]

4

(e) (Cells must be added) in parallel ✓

Because:

more energy stored in the bank of cells / less power from each cell ✓

without increasing the voltage across the bulb (above 1.5 V)

or

without increasing the terminal pd (above 1.5V) ✓

Must link the cells being added in parallel to one or both reason to gain three marks.

Alternative:

- *In parallel*
- *Current shared by cells*
- *Takes longer to convert the energy stored in each cell.*

Alternative:

- *In parallel*
- *Less internal resistance*
- *Less power / energy wasted*

Cells in series statement means no marks can be obtained.

3

[14]

5. (a) Mention of increase in lost volts/ pd across internal resistance (in cell)✓ (because)

current has increased

OR
internal resistance is a larger proportion of total resistance
OR
ratio of internal: external resistance is larger ✓

Accept reverse arguments

Do not accept terminal pd has decreased

Treat comments about resistance of lamp as neutral

2

(b) Lost volts reduced (current remains the same, V2 > V1)

OR

Effective internal resistance is a smaller proportion of total resistance / ratio of internal: external resistance is smaller ✓

(because)

two cells in parallel behave as a single cell (with the same emf) but with half the internal resistance / reduced internal resistance ✓

Alternative:

Current through each cell is less than cell on its own ✓

Decreased current through cell decreases lost volts / pd dropped across internal resistance ✓

2

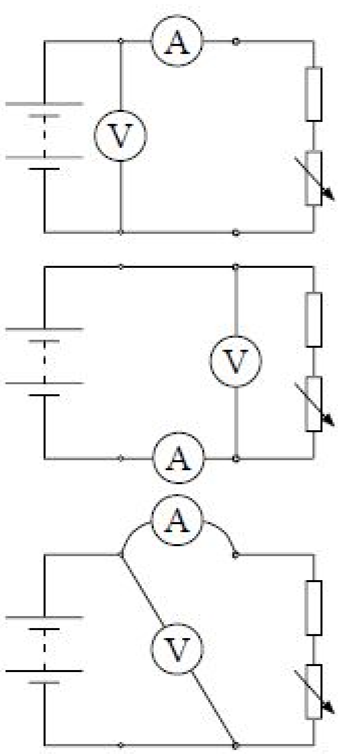
[4]

6. (a) valid continuous series circuit that includes ammeter, and one wire link (condone diagonal connections)

and

voltmeter between any two sockets that enable the terminal pd to be measured ✓

all of the following are acceptable:



links and connections

reject broken / dashed lines

tolerate diagrams with diagonal or non-straight connections between sockets if these will produce a valid circuit

don't insist on connection blobs

circuit must be continuous unless a switch is included: otherwise no gaps wider than the thickness of their links

inclusion of a switch is neutral but the length of the open switch must be ≥ length of the gap where the switch is connected: condone the whole gap between terminals vertically opposite the ammeter to be marked as an open switch

meters

correct ASE symbol for ammeter and correct ASE symbol for voltmeter are essential

one voltmeter and one ammeter only

meters must not be 'transparent'

positions of meters assume that the ammeter has negligible resistance and voltmeter has infinite resistance

1

(b) (with any switch closed) read ammeter <u>and</u> voltmeter

or

record / measure I <u>and</u> V;

adjust / vary / change resistance / (setting of) variable resistor / Q

and repeat (readings) 1✓

for 1✓ must produce a <u>range</u> of I, V values (>2 sets) and identify how this is achieved; it is not necessary to suggest range or number of sets

plot V (against) I 2✓

mark 2✓ independently of 1✓

2

ε = (vertical / y-axis) intercept 3✓

r = −gradient 4✓

2✓ 3✓ and 4✓ can be awarded for a suitable sketch graph

condone 'use the (variable) resistor to vary current and read I, V'

idea that R can be read from Q is neutral

for 2✓ (and further credit in 3✓ and 4✓) the ordinate and the abscissa must be identified;

allow 'plot V over I' or 'plot V/I'

allow 2✓ for reverse plot 'I (against) V'

then 4✓ for r = ' $r = \dfrac{-1}{\text{gradient}}$ *and 3✓ intercept =* $\dfrac{\varepsilon}{r}$

for 3✓ open circuit methods involving ε read directly using voltmeter are neutral

for 4✓ any subject but minus sign essential

2

variation

1✓ as above;

3✓ find R from V divided by I ; disconnect external circuit and measure ε directly;

4✓ plot $\frac{\varepsilon}{V}$ against $\frac{1}{R}$

2✓ gradient = r

(c) gradient calculation seen with Δn^{-1} divided by ΔI^{-1};

ε from 22 × gradient 1✓

for 1✓ do not penalise one read off error, (allow use of 0, 0) or for small steps

expect gradient ≈ 7.2(5) × 10^{-2} leading to ε = 1.594 (V)

do not allow reverse working based on answer to part (e)

1

ε minimum 3 sf; in range 1.58 to 1.61 (V) 2✓

2✓ is contingent on award of 1✓

1

(d) use of **Figure 3** to read off I^{-1} corresponding to n^{-1} = 0.25;

calculates I in range 0.23(2) to 0.24(4) (A) ✓

*do not insist on seeing evidence of working on **Figure 3***

expect I^{-1} = 4.2 ± 0.1 (A^{-1}) leading to I = 0.238 (A)

(should expect 1 more sf than in 0.25 for 'show that' but condone 0.23 and 0.24 since result based on 2 sf data)

do not allow reverse working based on answer to (e)

1

(e) circuit resistance R = 5.5 (Ω) seen in (e) working 1✓

minimum 2sf V from their I × 5.5

or

V from their ε − their I × r 2✓

for 1✓ allow R = $R = \frac{22}{4}$ or $\frac{11}{2}$; allow R^{-1} = $R^{-1} = \frac{4}{22}$ etc

for 2✓ correct R only; expect V = 1.3(1) V; use of I = 0.25 A gives V = 1.38 V

do not allow $V \geq$ their ε

r using lost volts divided by current; full substitution of their valid data

eg $r = \frac{1.58 - 1.31}{0.238}$ 3✓

or

r using formula for **Figure 3**; full substitution of their valid data

eg $r = \frac{\varepsilon}{I} - \frac{22}{4} = \frac{1.58}{0.238} - 5.5$ 3✓

or

r using either intercept on **Figure 3**; full substitution of their valid data

eg their vertical intercept ×−22 **or**

their horizontal intercept × ε 3✓

use of 'show that' or 2 sf data:

$r = \frac{\varepsilon - V}{I}$ *with* ε *= 1.6 V,* V *= 1.4 V and*

I *= 0.25 A gives r = 0.80 Ω*

$\frac{22}{n} = \frac{\varepsilon}{I} - r$ *with* ε *= 1.6 V,* I *= 0.25 A*

and n = 4 gives r = 0.90 Ω;

(can find r first, then V *using* $\varepsilon - Ir$*)*

a vertical intercept must be calculated; result is negative, eg vertical intercept = −0.053:

r = −1 × −0.053 × 22 = 1.17(Ω)

horizontal intercept = 0.73:

r = 1.6 × 0.73 = 1.18(Ω)

minimum 2 sf result in range 0.80 and 1.3(0) (Ω) 4✓

allow 4✓ only if there is clear evidence of a valid method leading to a result in range

4

(f) $n = 2$ **and** $n = 3$ 1✓

$n = 5$ **or** $n = 6$ **or** $n = 7$ 2✓

to improve distribution of points (along the line) or wtte 3✓

for 1✓ and 2✓ if suggesting more than three values for n accept only the last three

for 3✓ allow:

'spread out' / 'avoid concentrating' points'

where current / n is smaller' or wtte 'reduce distance between points (data)' / (add) detail

'most uniform distribution' / 'most equally spread out' / 'roughly evenly spaced'

reject:

'making points (data) 'equally' / 'evenly-spaced' / 'even spread' (without qualification)

'easier to plot / draw line' / 'line more accurate' / 'easier to see trend' are neutral

3

(h) both points move (by ≥ half a grid square) to the right 1✓

both points move (by ≥ half a grid square) causing the gradient of a straight line between them to be reduced 2✓

allow badly-marked points / use of arrows

ignore any best-fit line added to ***Figure 5***

for 1✓ rightwards motion of each point must be parallel to gridlines ± half small square

award of 2✓ mark is independent of 1✓ mark

for 2✓ the points do not need to move in the same direction

2

[17]