A-Level Physics

Electromotive Force

Mark Scheme

Time available: 72 minutes
Marks available: 55 marks

Mark schemes

1. (a) Use of power equation

OR

Power equation and $V = IR$

To give $R = 8.5$ (Ω) ✓

1

(b) Calculation of parallel pair resistance = 5.0 Ω ✓

Calculation of circuit current = 6.2 / 5.0 = 1.24 A

emf = terminal pd + Ir = 6.2 + (1.24 × 2.5) ✓

9.3 V ✓

*Allow ecf from **(a)***

Allow alternative methods

3

(c) $A = \pi (d / 2)^2 = 2.84 \times 10^{-8}$ ✓

Use of resistivity equation = RA/l ✓

To give 5.0×10^{-8} ✓

Allow POT error in MP1

And MP2

3

(d) Resistance increases ✓

Reduces current through lamp

Lamp dimmer ✓

2

(e) (Resistance increases)

Reduces current in battery ✓

Reduces lost volts and increases terminal pd

lamp brighter. ✓

Give 1 max for arguments dealing with initial dimming of bulb when wire attached.

2

[11]

2. (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 x 10^4 *is worth 1 mark*

(t =) 3.0(1) x 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

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3. (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]

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

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

2

(b) (i) *y – intercept* 1.52 V (± 0.01 V) ✓ **1**

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

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

$r = 0.45 \pm 0.02\ \Omega$ ✓ **3**

(c) (i) same intercept ✓

double gradient (must go through 1.25, 0.40 ± 1.5 squares) ✓ **2**

(ii) same intercept horizontal line ✓ **1**

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

$Q = 0.89 \times 15 = 13$ ✓ C ✓ **2**

(ii) use of $P = I^2r$ ✓

$P = 0.89^2 \times 0.45$

$P = 0.36$ W ✓ **2**

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

(or pd across terminals when no current passing through
cell or open circuit) **1**

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

hence a pd/lost volts develops across the internal resistance **(1)** **2**

(b) (use of $\varepsilon = V + Ir$)

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

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

$r = 0.2/0.58 = 0.34$ (Ω) **(1)** **3**

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

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

2

[8]