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GCE AS / A LEVEL – EMF, INTERNAL RESISTANCE & POTENTIAL DIVIDERS QUESTION PACK

Legacy PH1 · New spec Unit 2 Topic 3b · AS unit, 20% of A-level

REVISE

.wales

PHYSICS – UNIT 2 · EMF, INTERNAL RESISTANCE & POTENTIAL DIVIDERS

PH2.3 D.C. Circuits – EMF, internal resistance & potential dividers

EMF and terminal p.d., effect of internal resistance r on dissipated power, plus loaded and unloaded potential dividers (including LDR / thermistor sensor circuits).

NEW 2015 SPEC · UNIT 2 TOPIC 3B

Estimated time for entire question pack: ~2 h 42 min

Derived from the legacy PH1 paper's pace of 80 marks in 1¼ hours.

You are advised to **not** attempt to complete all of this in one sitting.

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every question from the legacy WJEC PH1 papers (2008 modular spec) that maps onto new-spec Unit 2 Topic 3b (2.3).

Questions are ordered chronologically within each section.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

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Q	Source	Max	Mark	Q	Source	Max	Mark
5	PH1 Jan 10 Q3	9		11	PH1 Jun 13 Q3	12	
6	PH1 Jun 12 Q3	9		12	PH1 Jun 16 Q5	11	
7	PH1 Jun 10 Q5	9		13	PH1 Jan 13 Q7	15	
8	PH1 Jun 14 Q3	9		14	PH1 Jun 09 Q3	9	
9	PH1 Jan 09 Q6	12		15	PH1 Jan 13 Q2	11	
10	PH1 Jun 11 Q6	10					
Total						116	

EMF, Internal Resistance & Potential Dividers – what the new spec asks

WJEC GCE AS / A Level Physics (from 2015) · Unit 2: Electricity & Light · Topic 2.3.

EMF & terminal p.d. **A**

- Define EMF ϵ as energy transferred per unit charge in the source.
- Terminal p.d. $V = \epsilon - Ir$; relate to power dissipation.

Internal resistance **A**

- Identify r from V-I graphs (gradient = $-r$, intercept = ϵ).
- Practical measurement using a variable load.
- Power maximum-transfer at $R_{\text{load}} = r$ (energy efficiency separate).

Potential dividers **B**

- Output of an unloaded divider: $V_{\text{out}} = V_{\text{in}} \times R_2 / (R_1 + R_2)$.
- Loaded divider: effect of finite load impedance.
- Sensor circuits using LDR / thermistor for light or temperature sensing.

EMF, Internal Resistance & Potential Dividers in one page

Quick-reference notes – revisit before each section.

EMF

ϵ = energy transferred per unit charge by source.

Units $V = J C^{-1}$.

Not the same as terminal p.d. (unless $I = 0$).

Internal r

$V_{\text{term}} = \epsilon - Ir$.

Plot V vs I : gradient = $-r$, y-intercept = ϵ .

Power & efficiency

$P_{\text{load}} = I^2R$; $P_{\text{internal}} = I^2r$.

Max power transfer when $R = r$ (50% efficient).

Pot. divider (unloaded)

$V_{\text{out}} = V_{\text{in}} \times R_2 / (R_1 + R_2)$.

If $R_1 = R_2 \Rightarrow V_{\text{out}} = V_{\text{in}}/2$.

Loaded divider

Load R_L in parallel with R_2 lowers effective R_2 .

If $R_L \gg R_2$, very little change.

Sensor circuits

LDR R drops in light $\Rightarrow V$ across LDR drops.

Thermistor R drops with $T \Rightarrow V$ across thermistor drops.

Pick which arm to tap based on whether you want V to rise or fall.

Section index

Use this index to jump straight to the section you need.

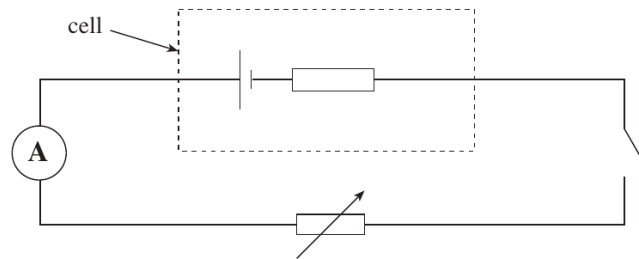
Section	Questions	Marks
A EMF & internal resistance	Qs 5–13	96 marks
B Potential dividers	Qs 14–15	20 marks

3. (a) Define the *e.m.f.* of a cell. [2]

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- (b) A student sets up the following circuit to find the e.m.f. and internal resistance of a cell. Complete the circuit diagram by adding a voltmeter. [1]

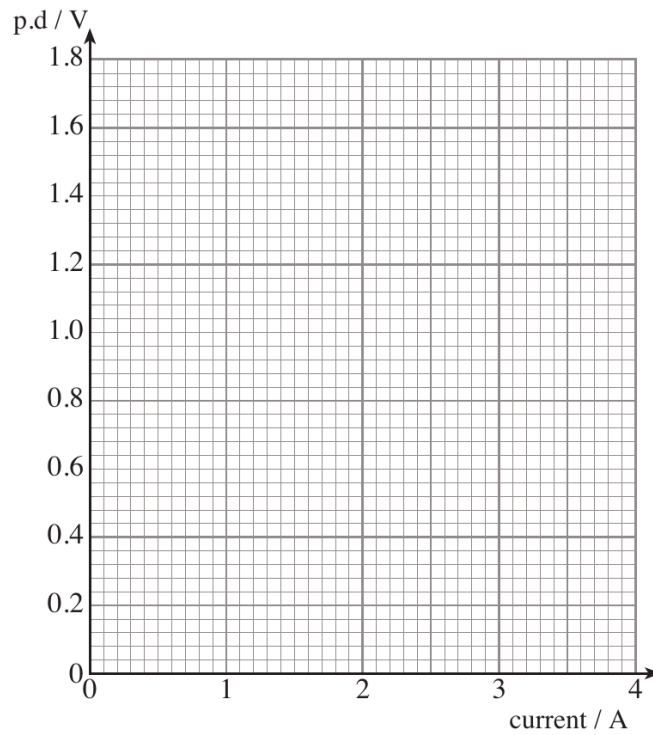


- (c) With the circuit complete the student obtains the following results. Plot these results on the grid and draw a line through your points. [3]

p.d. across cell terminals /V	Current /A
1.4	0.6
1.2	1.2
1.0	1.8
0.8	2.4
0.6	3.0

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Examiner only



(d) Use your graph to determine

(i) the e.m.f of the cell; [1]

.....

(ii) the internal resistance of the cell. [2]

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3. A car battery has an emf of 12.0 V. When the car is started the battery supplies a current of 120 A to the starter motor. The potential difference between the battery terminals [terminal pd] drops at this time to 8.4 V due to the internal resistance of the battery.

(a) Explain, in terms of energy,

(i) what is meant by ‘an emf of 12.0 V’, [2]

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(ii) why the terminal pd drops when the battery supplies a current. [1]

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(b) Calculate the internal resistance of the battery. [2]

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(c) The manufacturer warns against accidentally short-circuiting the battery. Calculate the current that would flow if the battery terminals were short-circuited with a spanner of negligible resistance. [1]

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(d) The battery will become ‘flat’ (i.e run out of energy) if it is continually run for a long period of time. It can then be fully recharged by a current of 3.0 A supplied for 16 hours.

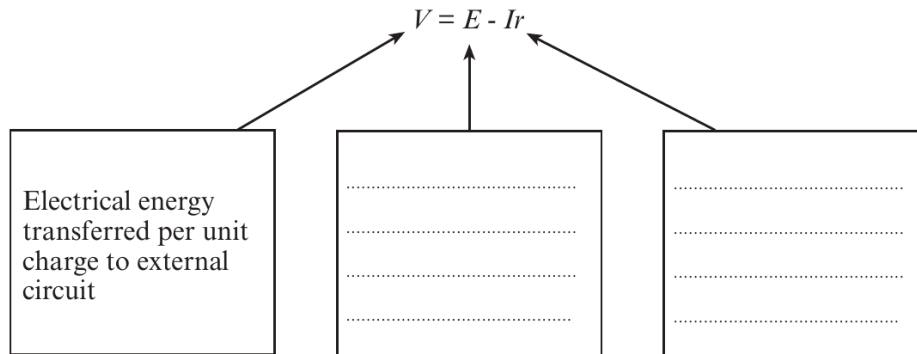
(i) Calculate how much charge flows through the battery in this time. [2]

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(ii) Estimate how long the starter motor could be operated on a fully-charged battery. [1]

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5. (a) An equation which can be applied to a circuit containing a cell of e.m.f. E and internal resistance r is shown. Fill in the boxes to explain each quantity in **terms of energy**. The first has been completed as an example. [3]



- (b) A torch battery transfers 4750 J of chemical energy into electrical energy while supplying a current of 0.22 A for 1 hour (3600 s) and delivering 4500 J of energy to the bulb. Calculate

- (i) the charge that flows; [1]

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- (ii) the e.m.f. of the battery; [1]

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- (iii) the p.d. across the bulb; [1]

.....

- (iv) the p.d. across the internal resistance (the 'lost volts'); [1]

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- (v) the battery's internal resistance. [2]

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Examiner
only

3. (a) A list of electrical units is given below:

VA^{-1} Cs^{-1} Js^{-1} JC^{-1} As

From the list, choose the unit for:

(i) electrical power; [1]

(ii) electrical resistance; [1]

(iii) electrical charge. [1]

(b) A torch battery converts 6480 J of chemical energy into electrical energy while supplying a current of 0.15 A for 2 hours. In this time only 5832 J of this energy is supplied to the bulb. Calculate:

(i) the charge that flows; [2]

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(ii) the emf of the battery; [1]

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(iii) the potential difference across the bulb; [1]

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(iv) the battery's internal resistance. [2]

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Examiners
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6. An equation which can be applied to a circuit containing a cell of e.m.f. E and internal resistance r is

$$V = E - Ir$$

- (a) Explain carefully, in terms of energy, the meanings of V , E and Ir . [4]

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- (b) Four cells, each of e.m.f. 1.5 V and internal resistance $0.2\ \Omega$, are connected in series to make a battery of e.m.f. 6.0 V . A $4.0\ \Omega$ resistor is connected across the battery.

- (i) Draw a circuit diagram of this arrangement which includes the internal resistance of the battery. [1]

- (ii) Calculate the current. [2]

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- (iii) Calculate the p.d. across the $4.0\ \Omega$ resistor. [1]

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- (c) After the resistor has been left connected for some time, one of the cells starts to show signs of running down. Its e.m.f. has dropped to 1.20 V and its internal resistance has risen to 0.40 Ω.
Investigate whether or not, in order to maximise the current through the 4.0 Ω resistor, it would be better to remove the run down cell, leaving the other three in series. [4]

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6. (a) An equation which can be applied to a cell of emf E and internal resistance r is

$$V = E - Ir$$

- (i) What does V represent? [1]

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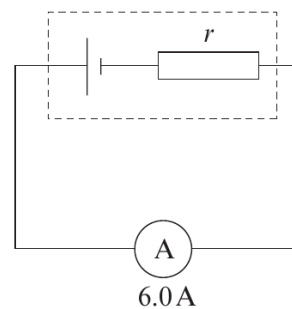
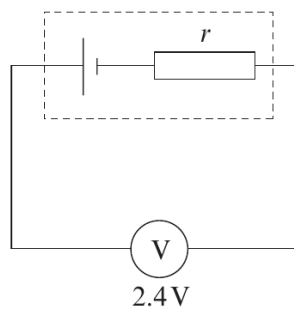
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- (ii) What does Ir represent? [1]

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- (b) A voltmeter connected across the terminals of a cell reads 2.4 V. An ammeter (whose resistance is zero) reads 6.0 A when connected briefly across the cell.



- (i) Write down the emf of the cell. [1]

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- (ii) Calculate the internal resistance of the cell. [1]

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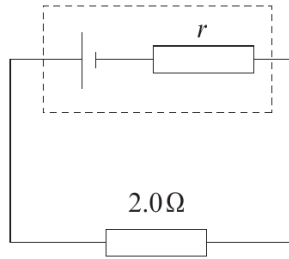
- (iii) Give one reason for not leaving the ammeter connected to the cell. [1]

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- (c) Calculate the current through a 2.0Ω resistor when it is connected across the cell. [2]



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- (d) Determine the number of cells of this type which, when connected in series with the 2.0Ω resistor, will produce a current of 3.0A . [4]

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3. (a) Define the *emf* of a cell.

[2]

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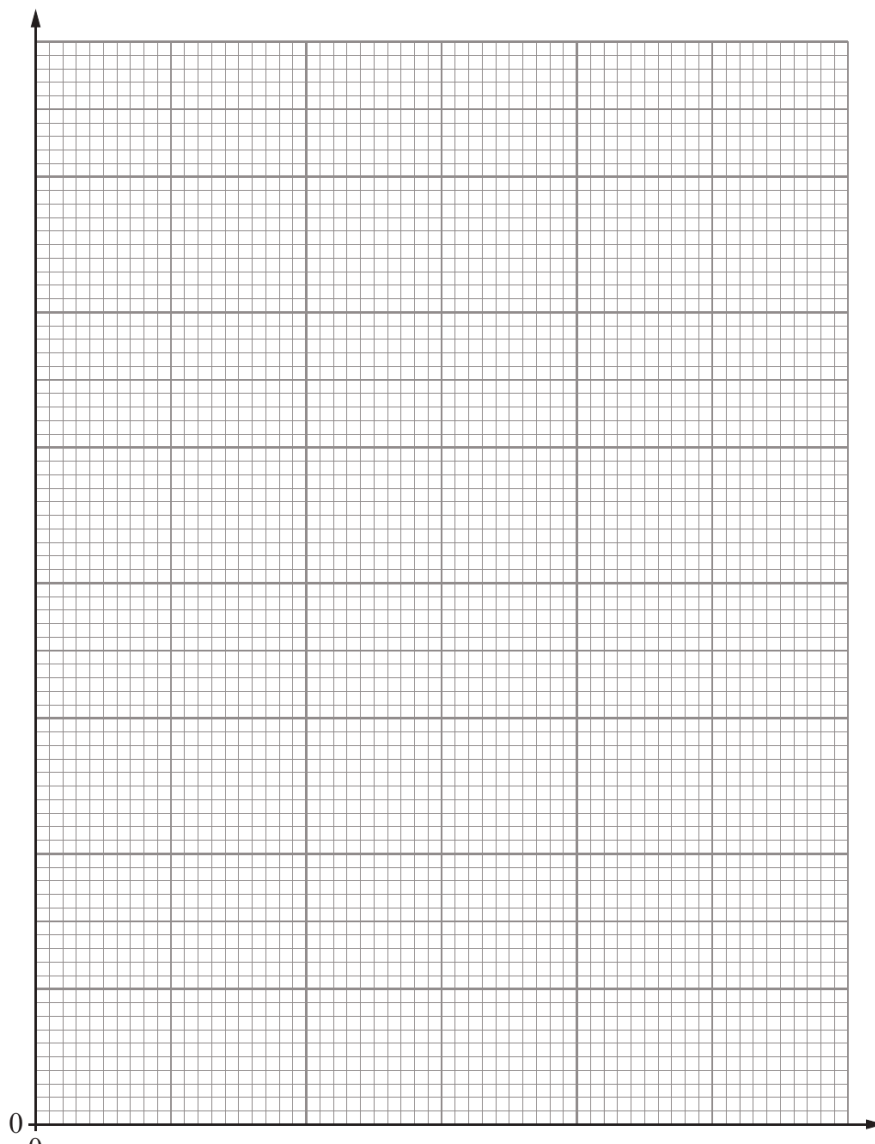
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(b) A student carries out an experiment to determine the *emf* and internal resistance of a cell. The pd across the cell is measured when it is supplying various currents. The following readings are obtained. Plot these results on the grid (pd on the *y*-axis and current on the *x*-axis) and draw a line through your points. [3]

Current / A	0.20	0.42	0.66	0.96	1.20
pd / V	1.31	1.13	0.93	0.68	0.48





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only

(c) Use your graph to determine:

(i) the emf of the cell;

[1]

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(ii) the internal resistance of the cell.

[2]

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(d) The cell is then connected to a torch bulb of resistance 6.0Ω for 20 minutes. Calculate the charge that flows through the bulb in this time. Assume the emf remains constant.

[4]

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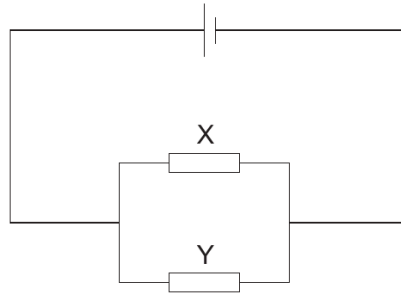
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5. (a) In the following circuits the resistance of X is **greater than** the resistance of Y.

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Circuit A



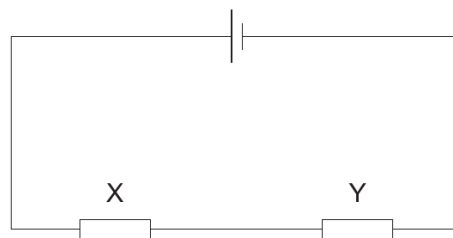
- (i) For Circuit A, compare the current through, and the potential difference across X and Y. [1]

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- (ii)

Circuit B



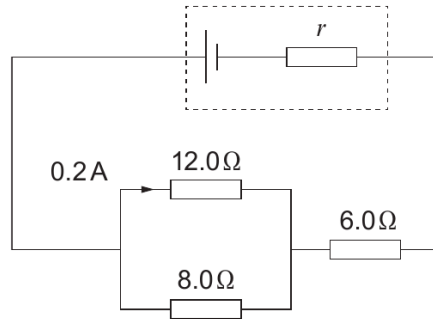
- For Circuit B, compare the current through, and the potential difference across X and Y. [1]

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- (b) The diagram below shows three resistors connected together as part of a circuit. The internal resistance, r , of the cell is also shown.



- (i) Show in clear steps that the current in the 8.0Ω resistor is 0.3A . [2]

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- (ii) Show that the potential difference across the combination of three resistors is 5.4V . [3]

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- (iii) Explain why the potential difference across the combination of three resistors is less than the emf of the cell. [2]

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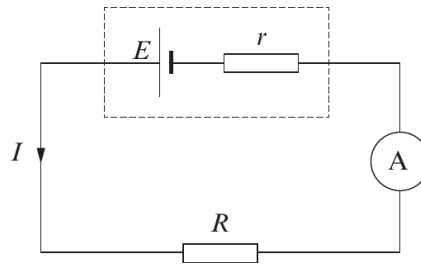
- (iv) Calculate the internal resistance, r , of the cell given that its emf is 6.0V . [2]

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7. A student sets up the following circuit using a cell of emf E and internal resistance r .



- (a) An equation which can be applied to the above circuit is

$$V = E - Ir$$

Explain, **in terms of energy**, the meanings of V , E and Ir .

[4]

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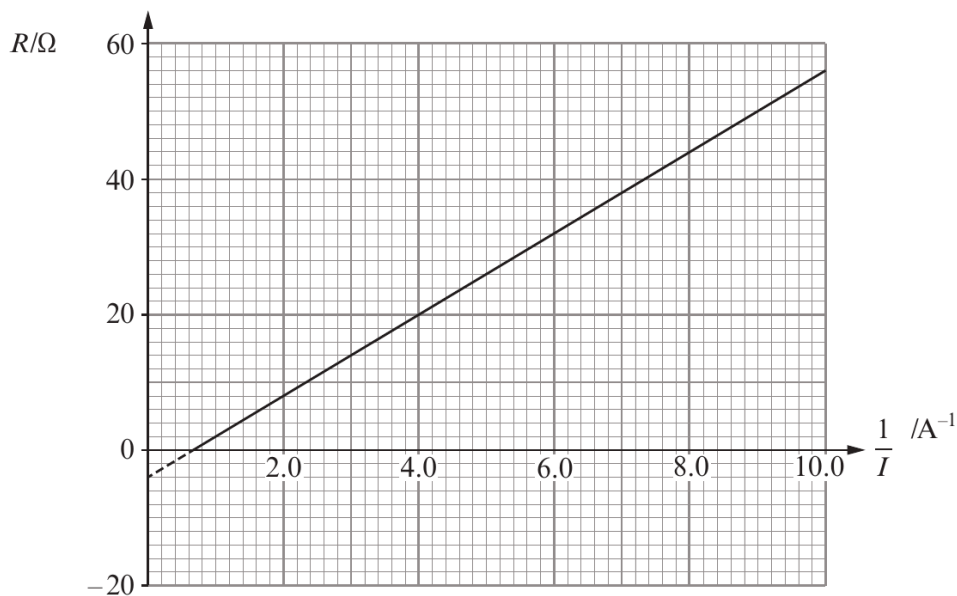
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- (b) The student measures the current I for different values of R . She then plots a graph of R against $\frac{1}{I}$.



The equation for this graph is

$$R = \frac{E}{I} - r$$

- (i) Use the graph to find the internal resistance, r , of the cell. [1]
-
- (ii) Determine the emf of the cell. [2]
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- (iii) Referring to the graph, calculate the power dissipated in the resistor R when there is a current of 0.25 A. [4]
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(c) A second identical cell is added in series with the original cell and the experiment is repeated.

(i) Write down the emf and the internal resistance of the new combination of cells. [1]

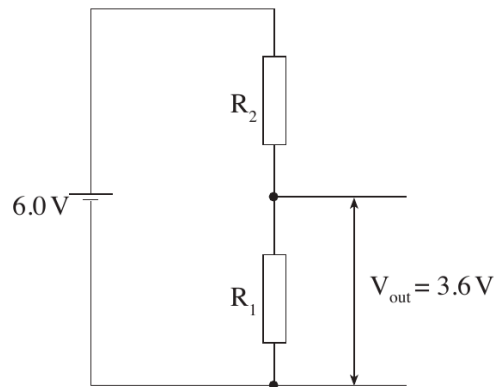
emf = internal resistance =

(ii) Hence, using the equation $R = \frac{E}{I} - r$, determine the value of R for this experiment when there is a current of 0.2 A. [1]

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(iii) **Draw on the graph** the result of this experiment. [2]

3. A technician wishes to obtain a voltage of 3.6 V from a battery of e.m.f. 6.0 V and negligible internal resistance. He uses the following potential divider circuit where resistor R_1 has a resistance of 225 Ω .



- (a) (i) State what a voltmeter would read if it were placed across resistor R_2 .

..... [1]

- (ii) Calculate the value of R_2 .

.....

 [4]

- (b) In order to conserve the life of the battery, the technician replaces resistor R_1 with one which has resistance 2250 Ω .

- (i) Describe one other change he should make to the potential divider circuit in order to maintain the desired output voltage.

..... [1]

- (ii) Show clearly the effect that these changes have on the current in the circuit.

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4. (a) A student writes the following:

Superconducting wires do not become hot because electrons can flow through them without there being any transfer of energy.

Explain carefully, in terms of electrons, how energy is transferred in a normal conductor and why it does not occur in superconductors.

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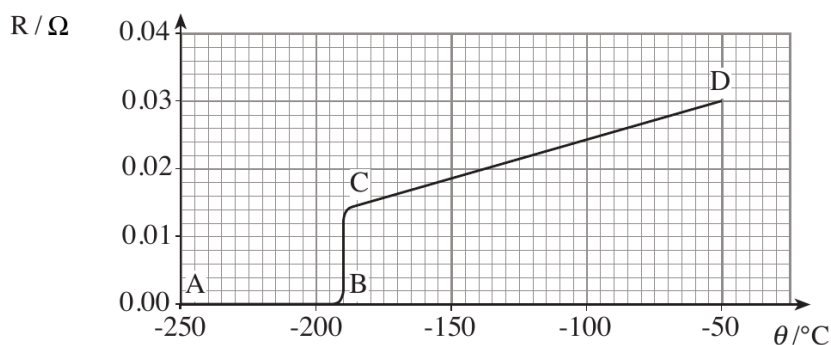
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[3]

- (b) The graph shows how the resistance, R , of a compound of europium varies with temperature, θ , for very low temperatures.



- (i) Determine the superconducting transition temperature of the compound of europium.

.....

[1]

- (ii) In what region of the graph would a potential difference of 0 V be required to maintain a current?

.....

[1]

- (c) Certain ‘high temperature superconductors’ have transition temperatures which are above -196°C . State how these materials can be kept in their superconducting state.

.....

[1]

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2. (a) (i) Define resistance.

[1]

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(ii) The unit of resistance is the ohm (Ω). Show that it is possible to express the Ω as

[3]

$$\text{J s C}^{-2}$$

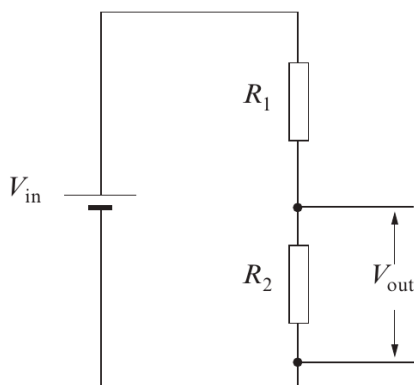
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(b) The diagram shows a potential divider.



(i) Write down an equation for the current through resistors R_1 and R_2 when the input pd V_{in} is applied as shown. [1]

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(ii) Hence show that the output pd V_{out} is given by the equation [2]

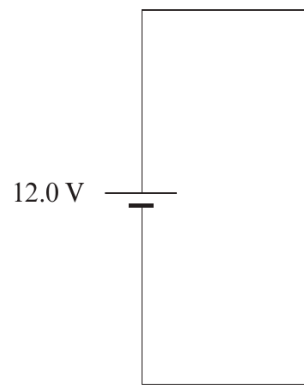
$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$$

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- (c) Three resistors are available with values $40\ \Omega$, $40\ \Omega$ and $80\ \Omega$.
- (i) Draw a diagram showing how **two** of these resistors can be connected together to give a combined resistance of $20\ \Omega$. [2]
- (ii) Hence, using all three of the resistors, complete the following potential divider circuit for which $V_{\text{out}} = 2.4\ \text{V}$ when $V_{\text{in}} = 12.0\ \text{V}$. Clearly label the resistor values and V_{out} on your diagram. [2]



END OF QUESTION PACK

11 questions · 116 marks · ~2 h 42 min

Source: WJEC PH1 (2008 modular spec)

Curated for WJEC Physics 2015 spec AS Unit 2 – Topic 3b (2.3)

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