Physics Factsheet

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Why Students Lose Marks- Current Electricity

Shall we start with this question?
A 24 volt a.c. supply provides power at an efficiency of 37% to an immersion heater running for 3 hours per day and a freezer unit active for 3.5 hours per day except Sunday. Given that the supply provides a total energy of 1040 kWh over the period of a normal year and has an internal resistance of 6.4 ohms, what advantage would be gained by switching to a 48 volt supply with greater efficiency but a larger internal resistance?

Don't fancy it? (Neither do I.)

This Factsheet will not teach you how to gain full marks on impossible problems (or even very difficult ones). We all struggle with work we find difficult. But what we don't want to do is lose marks on easy questions.

We are going to concentrate in this Factsheet on two types of question commonly found within this topic – calculations and graphical work.

Let's look at calculations first. And because we are not concerning ourselves with covering the syllabus, but with our approach to mathematical problems, we will restrict ourselves to straightforward work on standard electrical circuits.

Calculations:
We can maximise our results by attacking these problems in a straightforward manner, proceeding step by step through the calculation.

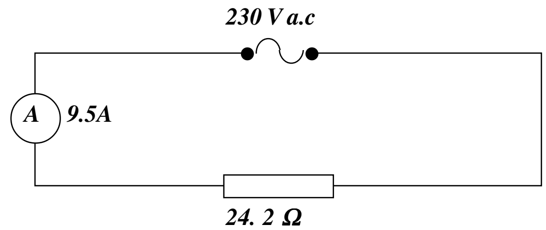
1. Make a list of the information given, and the information you are asked to work out. Draw a circuit diagram if you think that will help.
2. Write down the equations which might be useful.
3. Identify the equation you think will work. Write it down.
4. Make sure the data is in the correct units. Now solve the problem.
5. Finally, state the final answer to a sensible number of significant figures. And write down the correct unit.

Now take a look at your answer. Is it reasonable? (Does your CD player really draw a current of 500 amps? Perhaps you had better look at your calculation again.)

And remember, even if your calculation has gone wrong, if you have written down the equation, transformed it, substituted the data, stated the correct unit, etc, you may gain almost all of the marks anyway.

If all you write down is the final answer, you are taking a big chance.

Example 1 A mains (230V a.c.) electric heater draws a current of 9.5 amps. The heating element has a resistance of 24.2 ohms. If all of the electrical power is transformed into heat, what thermal energy will be produced in 12 minutes?



Solution:
What do we know?
V=230V (a.c.)
I=9.5 amps
R=24.2 ohms
t=12 minutes
E=?
P=?   (but may not be needed – energy, not power, is asked for)

Relevant equations:
$V=IR$
$P=VI$ (or $P=I^2R$)
$E=Pt$
$E=VIt$

We are given V, I and t, so it looks like the equation to use is E=VIt. It doesn't need rearranging, but notice that the time has been given in minutes.

$E=VIt = 230 \times 9.5 \times (12 \times 60) = 1\,573\,200$ joules

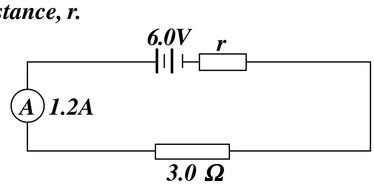
$E= 1.6 \times 10^6$ joules (to 2 s.f.)

A joule is a tiny amount of energy, so this is reasonable.

Our answer is correct, earning full marks. But even if we had, for example, forgotten to change minutes into seconds, we could still end up gaining most of the marks available for this calculation.

Sometimes you can't do everything in one step. But the same logical approach will still get you through to the answer.

Example 2: A cell of e.m.f. 6.0 volts sends a current of 1.2 amps through an external resistor, R, of 3.0 ohms. Find the power dissipated in the internal resistance, r.



Solution:

Write down the knowns and unknowns.
E = 6.0 volts
R = 3.0 ohms
I = 1.2 amps
r = ?
P = ? (power dissipated in internal resistance, r)

Relevant equations:
$E = IR + Ir$
$V = Ir$ *(voltage across r)*
$P = VI = I^2r$ *(power dissipated in r)*

We don't know V or r. But we should be able to find r from the first equation, then find P from the third equation.

$E = IR + Ir$
$6.0 = 1.2 \times 3.0 + 1.2 \times r$
This works out to r = 2.0 ohms.

Using $P = I^2r$
$P = 1.2^2 \times 2.0 = 2.88$ *watts.*

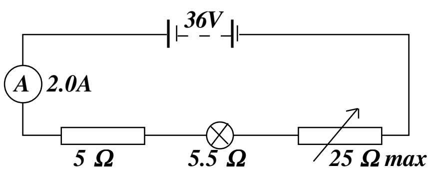
P = 2.9 watts (to 2s.f. and using the correct unit)

This seems a reasonable value for the power dissipated in the internal resistor.

And again we have shown all of our working, checked s.f. and units, and looked at the answer to see if it is reasonable.

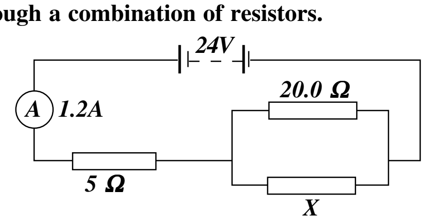
Here are a couple of questions for you to try. Work through them in this same way. Then check your solutions against those at the end of the Factsheet.

Problem 1:
A lamp requires a current of 2.0 amps to operate at its recommended brightness. Its resistance, X, is 5.5 ohms when it is operating normally. It is in series with a 36 volt d.c. power supply, a 5 ohm fixed resistor, R1, and a 25 ohm variable resistor, R2. The circuit is shown below:



(a) At what resistance should the variable resistor be set in order for the lamp to work normally?
(b) And what is the rated power of this lamp?

Problem 2
The circuit below shows a 24 volt battery supplying a current of 1.2 amps through a combination of resistors.



(a) Find the voltage across the parallel resistors.
(b) Find the current through unknown resistor X.
(c) Find the value for the resistance of X.

Now let's look at graphs.

Graphical Work

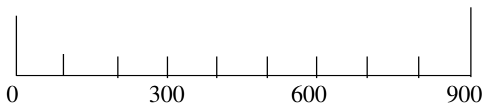
There are a lot of easy marks available for graphical work, especially on practical exams. But it's also very easy to lose these marks, as the standard demanded is far higher at A-level than at GCSE.

Here are some ideas to keep in mind:

1. Read the instructions and construct the axes the right way round. Do you think A-level students would never make such a simple mistake? You'd be in for a shock. Strange things can happen in an exam situation.
2. Don't forget to label the axes with quantities and units. **It's especially easy to forget the units.** And remember, logarithms of quantities don't have units. You can write **log (I/A)**, but not **log I/A**.
3. Use the range of the data compiled to work out the scales. If you can double the scale and still fit all the points on the graph, or if you use multiples of 3 or 7, for example, you could end up losing the scale mark and perhaps the plotting marks as well.

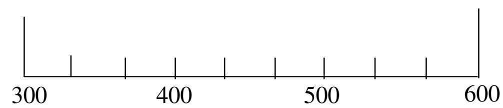
Example: Your graph paper has 90 small squares (probably 2 mm each) across the x – axis. Your data points range from 320 to 560. What scale would you choose?

(a) 0 to 900.



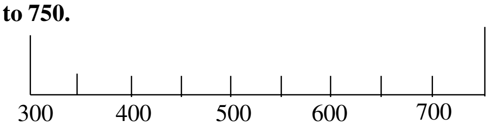
Not acceptable. Your range of values covers much less than half of this.

(b) 300 to 600.



Not acceptable. Thirty small squares on the paper would cover a range of values of one hundred. And plotting the data would be a nightmare.

(c) 300 to 750.



A good choice. The range of data really requires scale points from 300 to 600. This easily covers over half of your chosen scale, and the data would be easy to plot.

4. Plotting the points with small crosses is perhaps most suitable. Blobs will lose you marks. Small dots can easily be lost under best-fit lines. And circles are best saved for displaying anomalous data points.

5. Don't be careless when drawing best-fit lines. They may well be curves, rather than straight lines. Precision is demanded at A-level. And make sure gradient triangles cover at least half of your best-fit line.

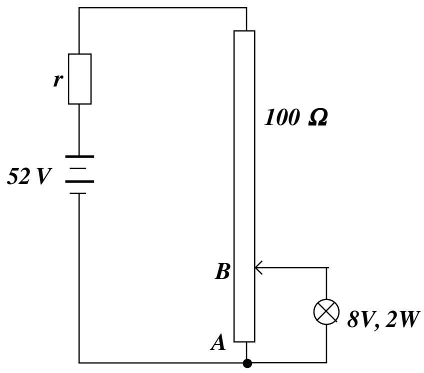
Now the final test. Here is a problem for you. Use graph paper of 9 squares against 11 squares to plot this (use part of a larger sheet if necessary). And check your graph against the suggested solution at the end of the Factsheet. But remember that there is more than one acceptable way of setting out a graph.

Problem 3: Use this data to plot the current through resistor R (y-axis) against the voltage across the resistor (x-axis). Then find the resistance of R.

Voltage/V	*Current/A*
1.0	*0.07*
2.8	*0.22*
4.2	*0.30*
6.4	*0.48*
8.1	*0.63*
10.1	*0.75*
12.2	*0.94*

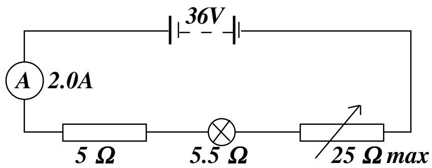
Finally, for those of you who have decided that Physics problems are little more than trivial, here's a parting question for you:

Problem 4: A potential divider of length 20 cm has a resistance of 100 ohms. It is used to illuminate a lamp designed to operate at a power of 2 watts when the potential difference across it is 8 volts. The supply is fixed at 52 volts d.c.



If the distance from A to B is 5 cm, what is the internal resistance, r, of the supply?

Problem 1 Solution:



(a) What do we know (and what would we like to know)?
V=36V
I=2.0 amps
X=5.5 ohms
R1=5 ohms
R2=? (25 ohms maximum)

Relevant equations:
V=IR
R=R1 + R2 + X (for series circuit)

To find the value of the variable resistor, X, we must first find the total resistance R (from Ohm's Law).

R=V/I=36/2.0=18 ohms.

Substituting, we have 18=5 + R2 + 5.5

So R2 = 7.5 ohms. (To 2s.f.) And we have remembered the unit.

This is within the range for the variable resistor.

(b) We now know that R2 is set at 7.5 ohms, in addition to the previous data.

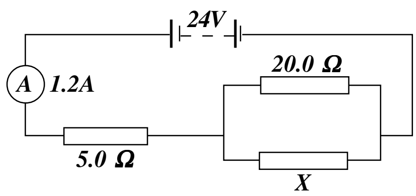
Relevant equations:
P=VI
$P=I^2R$

We have to be careful here. The current I is the same everywhere around a series circuit. But we don't know the voltage across the lamp itself. The first equation might not be useful. However we do know the lamp's resistance. This is 5.5 ohms. So we can use the second equation:

$P = I^2R = (2.0^2 \times 5.5) = 22$ watts. (Again 2s.f. is reasonable, and the unit is correct.)

And once again, a simple logical approach, writing down each step, and checking significant figures and units, will mean we don't throw away any easy marks.

Problem 2 Solution:



(a) What do we know?
V=24 volts (supply)
I=1.2 amps (through ammeter)
Resistors of 5.0 ohms and 20.0 ohms
X=?

Relevant equations:
R = R1 + R2 (series)
1/R = 1/R1 + 1/R2 (parallel)
V = V1 + V2 (series)
V = IR

We should be able to do this by just adding the voltages across the two sets of resistors. We can use Ohm's Law to find the voltage across the 5.0 ohm resistor.

$V = IR = 1.2 \times 5.0 = 6.0$ volts

Then the third equation will let us find the voltage across the parallel section of the circuit:

V (parallel) = 24.0 – 6.0 = 18.0 volts.

This seems reasonable. Units and s.f. are OK.

(b) What do we know? (concentrate on the parallel section)
V (supply) = 24.0 volts
V (parallel) = 18.0 volts
R = 20.0 ohms (in parallel branch)
I = 1.2 amps (through ammeter)
(With Ohm's Law, this might be enough.)

Relevant equations:
V=IR
I = I1 + I2 (in parallel circuit)

We should be able to use Ohm's Law to find the current through the 20.0 ohm resistor, then use the second equation to find the current through X.

I = V/R = 18.0/20.0 = 0.9 amps (through the 20.0 ohm resistor)

I = 1.2 – 0.9 = 0.3 amps through resistor X.

This seems reasonable. We can't really add any more s.f. to this value, as the current has only been given to one decimal place.

(c) What do we know? (again concentrate on the parallel section)
V(parallel) = 18.0 volts
I = 0.3 amps (through X)

We can obviously jump straight to Ohm's Law for our answer.

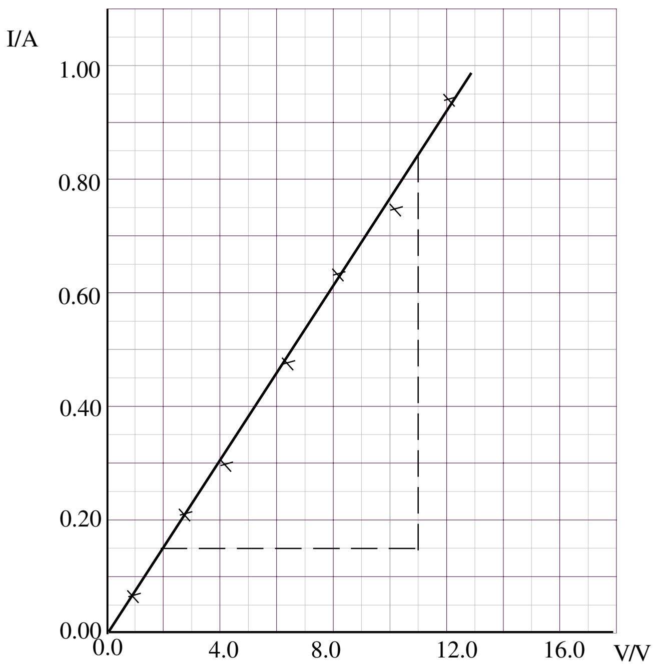
R = V/I = 18.0/0.3 = 60 ohms.

We could check this answer by using our series and parallel resistor formulae to find the effective value of R for the whole circuit, then seeing that V = IR works for the circuit. It does. And we have remembered to include the unit.

We can't really add any more s.f. to our answer as we have been using a value of current calculated to just one s.f. in our solution.

And once again, by using a simple approach, writing everything down along the way, we have given ourselves the best chance of maximising our score.

Problem 3 Solution:

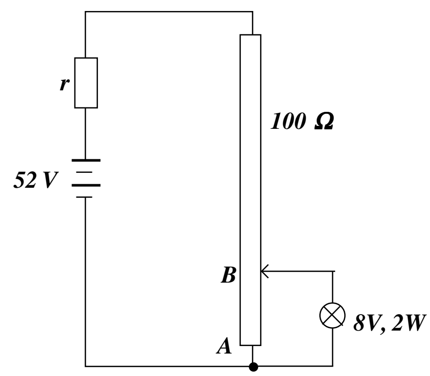


$$\text{Gradient} = \frac{(I_2 - I_1)}{(V_2 - V_1)} = \frac{(0.84 - 0.15)}{(11.0 - 2.0)} = 0.077$$

$$R = \frac{1}{\text{Gradient}} = 13.0\ \Omega.$$

What would you have scored out of ten?
Axes correct? 1
Quantities and units? 1
Acceptable scale? 1
Points correct? 2
Best-fit line? 1
Good presentation? 1
Gradient triangle? 1
Gradient correct? 1
Value and unit? 1
Anything less than 9.5 is unacceptable.

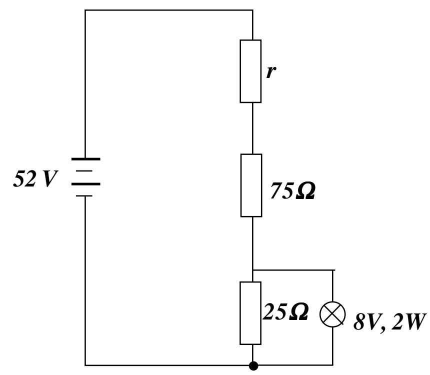
Problem 4 Solution:



Parts of this problem can be solved quickly by common sense. We can see straightaway that AB is one-quarter of the total length of the potential divider, so the resistance across AB will be 25 ohms.

And using $P = V^2/R$, we can find the resistance of the lamp to be 32 ohms (try this yourself).

It might now be useful to redraw the circuit. Don't be afraid of redrawing circuits or diagrams when you have determined values that might be usefully displayed. An up-to-date diagram can help you carry on with the problem:



Also for the lamp:
P = 2 watts
V = 8 volts

From this we know that the top section has a voltage of 52 – 8 = 44 volts across it.

It looks like one way to solve this will be by linking the current through the top section to the sum of the currents in the parallel branches below:

Top section: $I = \frac{V}{R} = \frac{44}{(75 + r)}$ *amps*

Left branch: $I = \frac{V}{R} = \frac{8}{25} = 0.32$ *amps*

Right branch: $I = \frac{V}{R} = \frac{8}{32} = 0.25$ *amps*

As the currents in the parallel branches must add up to the total current:

$$\frac{44}{(75 + r)} = 0.32 + 0.25 = 0.57$$

$44 = 0.57 \times (75 + r)$
$44 = 42.8 + 0.57r$
r = 2.1 ohms (to 2 s.f.)

And so by looking at the diagrams and using some common sense, added to some basic Physics relationships, we can find the internal resistance of the supply.

Acknowledgements: *This Physics Factsheet was researched and written by Paul Freeman*
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