Questions and Answers

Q1

A 1200 W toaster is connected to the 240 V electrical mains.
[a] Calculate the current drawn by the toaster element as it operates.
[b] Calculate the resistance of the toaster heating element.

$$I = \frac{P}{V} = \frac{1200\ \text{W}}{240\ \text{V}} = 5.0\ \text{A}$$

$$R = \frac{V}{I} = \frac{240\ \text{V}}{5\ \text{A}} = 48.0\ \Omega$$

Q2

A 6 W globe draws a current of 500 mA when operating normally.
[a] Calculate potential difference across the light globe filament as it operates.
[b] Calculate the resistance of the light globe filament.

(a) $$V = \frac{P}{I} = \frac{6\ \text{W}}{0.5\ \text{A}} = 12.0\ \text{V}$$

(b) $$R = \frac{V}{I} = \frac{12\ \text{V}}{0.5\ \text{A}} = 24.0\ \Omega$$

Q3

Calculate the operating resistance of a 100 W electric mixer motor when you connect it to a 240 V mains supply.

$$R = \frac{V^2}{P} = \frac{(240\ V)^2}{100\ W} = 576\ \Omega$$

Q4

The rear window demister of a car draws 2.0 A of current from the 12 V car battery and takes 20 minutes to demist the window.

[a] Calculate the quantity of electric energy that is converted into heat energy in that time.

[b] What is the power rating of the demister?

[c] How much charge flows in the 20 minute period?

$$E = V \times I \times t = 12\ V \times 2\ A \times (20\ min \times 60\ s) = 28.8\ kJ$$

$$P = I \times V = 2\ A \times 12\ V = 24.0\ W$$

$$q = I \times t = 2\ A \times (20\ min \times 60\ s) = 2.4 \times 10^3\ C$$

Q5

A small light globe is marked 17 mA, 4 W.
[a] Is it a household lamp or for a car? What is the evidence for your answer?
[b] What is the operating resistance of the globe?

It is designed to run from a power supply of voltage, $V = \frac{P}{I} = \frac{4\ \text{W}}{0.017\ \text{A}} = 235\ \text{V}$

since household mains electricity has an RMS value of about 240 V, then it must be a household lamp since car batteries only deliver 12 V.

$$R = \frac{P}{I^2} = \frac{4\ \text{W}}{(0.017\ \text{A})^2} = 13.8\ \text{k}\Omega$$

Q6

The motor from a toy is marked 380 mA, 2.3 W.

[a] What voltage of power supply is it designed for? What is the evidence for your answer?

[b] What is the operating resistance of the motor?

It is designed to run from a power supply of voltage, $V = \frac{P}{I} = \frac{2.3\ \text{W}}{0.38\ \text{A}} = 6.1\ \text{V}$

This is typical of a battery or maybe a transformer.

$$R = \frac{P}{I^2} = \frac{2.3\ \text{W}}{(0.38\ \text{A})^2} = 15.9\ \Omega$$

Q7

A typical headlight globe in a car operates at 12 V and dissipates 55 W of heat and light.

[a] Calculate the current passing through the globe filament under normal operating conditions.

[b] Calculate the resistance of the globe under normal operating conditions.

$$I = \frac{P}{V} = \frac{55\ \text{W}}{12\ \text{V}} = 4.6\ \text{A}$$

$$R = \frac{V}{I} = \frac{12\ \text{V}}{4.6\ \text{A}} = 2.6\ \Omega$$

Q8

The unit by which electrical energy is sold and paid for is called the kilowatt-hour (kW h). The electricity bill delivered to your house is for the number of kW h of electricity you have used multiplied by the price of one kW h. The price is currently around 13c per kW h. Calculate how much it costs to operate the following devices at home:

[a] A 60 W desk lamp for 3.0 hours per day, 5.0 days per week, for 9.0 weeks.

[b] An 11 W fluorescent 'energy saver lamp' in the same light fitting as part [a] of this question for the same number of hours.

[c] A 2400 W fan heater for four hours.

[d] A 1700 W electric kettle for the five minutes it takes to boil water to make tea.

(a) E (in kWh) = P (in kW) x t (in h) = 0.060 kW x (9 weeks x 5 days x 3 h) = 8.1 kWh

so the cost = 8.1 kWh x 13c kWh^{-1} = 105c (or $1.05)

Q8 continued

(b) E (in kWh) = P (in kW) x t (in h) = 0.011 kW x (9 weeks x 5 days x 4 h) = 1.49 kWh

so the cost = 1.49 kWh x 13c kWh^{-1} = 19c

(c) E (in kWh) = P (in kW) x t (in h) = 2.4kW x 4h = 9.6 kWh

so the cost = 9.6 kWh x 13c kWh^{-1} = 125c (or $1.25)

(d)

$$E \text{ (in kWh)} = P \text{ (in kW)} \times t \text{ (in h)} = 1.7 \text{ kW} \times \left(\frac{5 \text{ min}}{60 \text{ min h}^{-1}}\right) = 0.14 \text{ kWh}$$

so the cost = 0.14 kWh x 13c kWh^{-1} = 1.8c

Q9

Calculate the cost of running each of the following from the 240 V mains:
[a] an electric fan heater rated at 2 kW, for 3 hours;
[b] an electric water heater whose element has a resistance of 26 Ω, for 4 hours;
[c] an electric drill rated at 8 A, which is run for 30 minutes.

(a) E (in kWh) = P (in kW) x t (in h) = 2kW x 3h = 6 kWh

so the cost = 6 kWh x 13c kWh^{-1} = 78c

(b)
$$P = \frac{V^2}{R} = \frac{(240\ V)^2}{26\ \Omega} = 2215\ W \text{ or } 2.22\ kW$$

E (in kW h) = P (in kW) x t (in hrs) = 2.22kW x 4hrs = 8.88 kW h

so the cost = 8.88 kW h x 13c kWh^{-1} = 115c (or $1.15)

(c) P = I x V = 8 A x 240 V = 1920 W

$$E \text{ (in kWh)} = P \text{ (in kW)} \times t \text{ (in h)} = 1.92\ kW \times \left(\frac{30\ min}{60\ min\ h^{-1}}\right) = 0.96\ kWh$$

so the cost = 0.96 kWh x 13c kWh^{-1} = 12.5c

Q10

Estimate the cost of electric lighting in your house for one year. You will need to list the power ratings of all the globes and fluorescent tubes, and estimate the times for which they operate in one year.

For a house which has 18 ceiling lights @ 100 W each and 12 table lamps @ 75 W each, the total power = (18 x 100 W) + (12 x 75 W) = 2700 W (2.7 kW)

During autumn / winter they could all be on for 6 h each evening,

so t = (6 months x 30 days x 6 h) = 1080 h

During spring / summer they may only all be on for 2 h each evening,

so t = (6 months x 30 days x 2 h) = 360 h

E (in kWh) = P (in kW) x t (in h) = 2.7kW x (1080 h + 360 h) = 3888 kWh

so the cost = 3888 kW h x 13c kWh^{-1} = 50500c (about $500)

Q11

You fit a 150 W floodlight lamp globe in a 240 V outlet in preparation for a party.
[a] Calculate the current in the filament when the lamp is operating normally.
[b] What is the lamp's resistance?
[c] If it converts 95% of the electrical energy used into heat, how many joules of light energy will it produce in 1.0 h?
[d] Calculate the cost of leaving the light on for 5 hours, at a cost of 13 cents per kilowatt-hour.

(a) $$I = \frac{P}{V} = \frac{150\ \text{W}}{240\ \text{V}} = 0.625\ \text{A or } 625\ \text{mA}$$

(b) $$R = \frac{V}{I} = \frac{240\ \text{V}}{0.625\ \text{A}} = 384\ \Omega$$

Q11 continued

(c) total energy produced each hour, E = P x t = 150 W x (1 h x 3600s) = 240 kJ

light energy produced each hour = 5% of 240 kJ = 0.05 x 240 kJ = 27 kJ

(d) E = P x t = 0.15 kW x 5 h = 0.75 Wh

so the cost = 0.75 kW h x 13c kV $^{-1}$ = 9.8c

Q12

If it costs $800 to insulate the roof of a small apartment, with the result that the 4000 W air conditioner, when needed, is operated for an average of three hours less per day:

[a] calculate how many days' use it will take for the electrical savings to cover the cost of the insulation;

[b] hence estimate how long it will take (in weeks, months or years) for the electrical savings to cover the cost of the insulation.

Energy saving each hot day, $E = P \times t = 4\ \text{kW} \times 3\ \text{h} = 12\ \text{kWh}$

which is equivalent to a monetary saving of $= 12\ \text{kWh} \times 13\text{c}\ \text{kWh}^{-1} = 156\text{c}$ (or $1.56)

so the number of hot days to recoup the $800 insulation cost $= \dfrac{\$800}{\$1.56\ \text{day}^{-1}} = 513\ \text{days}$

In Australia, we probably have 3 months (about 90 hot days) each year when we use our air conditioners. So, the cost of the insulation should be covered in $\dfrac{513\ \text{days}}{90\ \text{days year}^{-1}} = 5.7\ \text{years}$

Q13

Batteries are given a form of energy rating – the ‘amp-hour’. It is not really an energy rating but when multiplied by the emf of the battery it tells us how much energy can be obtained from the battery before it is ‘flat’. For example, a battery might be rated at 10 amp-hours. This means that it can deliver 2 A for 5 hours, or 1A for 10 hours, before its emf drops to a useless level.

[a] A standard 12 V car battery is rated at 40 amp-hour. How much energy, in joules, can it provide before it is ‘flat’?

[b] A more expensive 12 V battery is rated at 75 amp-hour. For how long can it be used for emergency lighting comprising of two 55 W headlight globes?

(a) E = V x I x t = 12V x 1A x (40 h x 3600 s) = 1.73 MJ (using a combination of 1 A for 40 hours)

(b) E = V x I x t = 12V x 1A x (75 h x 3600 s) = 3.24 MJ (using a combination of 1 A for 75 hours)

time to operate 2 emergency lights, $t = \frac{E}{P} = \frac{3.24 \times 10^6 \text{ J}}{2 \times 55 \text{ W}} = 2.95 \times 10^4 \text{ s or } 8.2 \text{ h}$

Q14

A nickel metal hydride rechargeable AA cell is rated at 2.3 amp-hour and has an emf of approximately 1.4 V when fully charged. Suppose one such cell is used in a small 3 W ‘key light’. How long will the cell last until it needs to be recharged?

$E = V \times I \times t = 1.4\text{V} \times 1\text{A} \times (2.3\text{ h} \times 3600\text{ s}) = 11.6\text{ kJ}$ (using a combination of 1 A for 2.3 hours)

time to operate a ‘key light’, $t = \frac{E}{P} = \frac{11.6 \times 10^3\text{ J}}{3\text{ W}} = 3.87 \times 10^3\text{ s}$ or 64.5 min