

Energy and Power

Energy

Energy is the capacity to change a physical situation.

When we say we are full of energy we mean that we could do a lot of physical things

Energy can neither be made nor destroyed and all new energy on earth comes from the sun

It manifests itself in different ways e.g. by lifting, Lighting or heating objects.

So the various ways it manifests itself are referred to as forms of energy.

Some Forms of Energy

- Electrical
- Mechanical
- Heat
- Light
- Sound
- Magnetic
- Nuclear
- Chemical

All energy is measured in JOULES, which is a very small unit so in many everyday situations energy is measured in kilojoules (1000joules).

Energy can be transferred from one place to another and converted from one form to another quite readily in most cases.

Mechanical energy is transferred by levers and gears and other forms of machines

Heat energy is transferred by heated metals or sunbeams or air currents.

Electrical energy is transferred by conductors, overhead transmission lines or house wires

Energy Converters

Electrical generators convert heat or water energy to electrical energy.

Electrical motors convert electrical energy to mechanical energy.

Toasters convert electrical energy to heat.

Torches and lamps convert electrical energy to light energy

Power

Power is the rate at which energy (in any form) is transferred from one place to another or converted from one form to another. A device that can transfer or convert energy rapidly is termed powerful.

Not all high-energy sources are powerful. E.g. a reservoir contains a lot of energy but if it is fed through an electrical generating station the energy is converted fairly slowly. However, should the wall of the dam burst, the source becomes very powerful and usually results in destruction. In the electrical circuit a short circuit often turns a safe low power source into a highly dangerous powerful source.

Unit of Power

All power (irrespective of the form of energy) is measured in watts. If a source has a power of one watt it means that one joule of energy is transferred and converted every second.

Electrical devices usually have the power rating (sometimes called wattage) printed on their nameplate.

To calculate the power rating (wattage) of resistors:

$$\text{Power} = \text{voltage drop across resistor} \times \text{current}$$

[Remember that if the resistor is the only one in the circuit the voltage drop is the same as the supply e.m.f.)

Worked Examples

- What is the power rating of an electric lamp if it draws a current of 0.5A when connected to a 200 volt supply.

$$\begin{aligned} \text{Power} &= V \times I \\ &= 200 \times 0.5 \\ &= 100 \text{ watts} \end{aligned}$$

Like the Ohms *Law* formula this formula can also be transposed to calculate the voltage or the current.

$$\text{Voltage Drop} = \frac{\text{Power}}{\text{Current}}$$

- What is the voltage supplied to a 60W lamp when it draws 0.2A connected to the supply.

$$\begin{aligned} \text{Voltage} &= \text{Power/Current} \\ &= 60/0.2 \\ &= 120\text{V} \end{aligned}$$

Or to calculate the current

$$\text{Current} = \text{Power/Voltage Drop}$$

- What current would a 2-kilowatt heater draw from a 200 volt supply

$$\text{Current} = \text{Power/Voltage}$$

Since the power has to be in watts

$$\begin{aligned} 2\text{kw} &= 2000 \text{ watts} \\ \text{Current} &= 2000/200 \\ &= 10\text{A} \end{aligned}$$

- If an electric kettle draws a current of 12 amperes when it is connected to a supply of 240 volts, calculate its power rating.

$$\begin{aligned} \text{Power} &= \text{voltage} \times \text{current} \\ &= 240 \times 12 \\ &= 2880 \text{ watts} \end{aligned}$$

Current Limits

However it is often useful to learn what current a particular device will draw because most supplies have a safe current limit (and usually contain a fuse or circuit breaker to open the circuit if that value is exceeded.)

In order to decide how many appliances can be connected to a supply without overloading it the current that each appliance takes is calculated and then added to the others. The total current should not exceed the safe load current of the circuit

Lighting circuits are usually fused for a maximum current of 5 amps and power or heating circuits for 10 or 15 amps.

More Worked Examples

- If the mains supply is 250 volts how many 100 watt lamps could safely be connected to a house circuit fused for 5 amps-

$$\begin{aligned}\text{Safe Power} &= \text{Supply Voltage} \times \text{Safe Current} \\ &= 250 \times 5 \\ &= 1250 \text{ watts.}\end{aligned}$$

Therefore, number of 100 watt lamps

$$\begin{aligned}&= 1250/100 \\ &= 12.5\end{aligned}$$

- Say 12 Lamps

It is often useful to know what current will flow when the device is in operation

- If an electric heater is rated at 960 watts 240 volts how many such heaters could safely be connected to a single circuit fused for 15 amps.

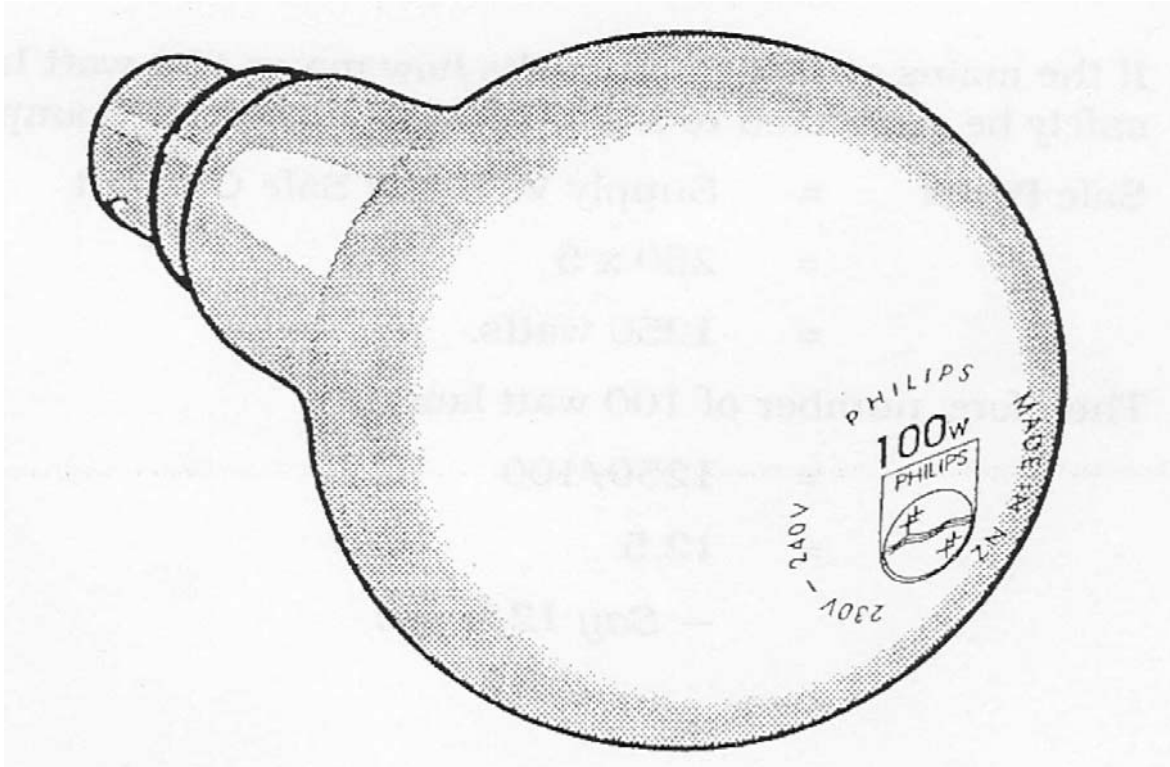
$$\begin{aligned}I &= \text{Power/Supply} \\ &= 960/240 \\ &= 4 \text{ amps}\end{aligned}$$

Therefore total number of heaters

$$\begin{aligned}&= 15/4 \\ &= 3\end{aligned}$$

If the current taken by a heater is 4 amps, it would not be advisable to plug this heater into a 15 amp socket if there were three other heaters already plugged into the same socket. It is too near the limit to be safe

- Find the value of the current taken by the lamp shown below; (Hint: Most domestic lamps usually draw a current of less than one amp, and the New Zealand mains supply is 230 volts.)



$$\begin{aligned}
 I &= \frac{\text{Power}}{\text{Current}} \\
 &= 100/230 \\
 &= 0.43 \text{ amps}
 \end{aligned}$$

Rearranging Formulas

In the previous examples, if we knew two of the values in the formula $P = V \times I$. we could calculate the other.

However, we may not know the voltage drop or the current, but only the resistance of the appliance. However it is still possible to calculate the power if we remember that Ohms Law tells us the relationship between the voltage drop across it, its resistance, and current.

So:

$$\text{Power} = \text{voltage drop} \times \text{current}$$

From Ohms Law we know that the voltage drop also equals $I \times R$.

So we substitute in the formula:

$$\begin{array}{l}
 \text{Power} \\
 (IR) \times I \\
 I^2R
 \end{array}$$

So if the resistance and current is known, power can be calculated.

Worked Examples

- A heater has a resistance of 60 ohms and when connected to the supply takes a current of 4 amperes.

Calculate the power rating:

$$\begin{aligned}\text{Power} &= I^2 R \\ &= 4^2 \times 60 \\ &= 960 \text{ watts}\end{aligned}$$

So if we know the voltage drop but not the current we can substitute in the same formula:

$$P = V \times I$$

For the value of I.

$$P = V \times V/R$$

Another way to calculate power if only the voltage drop across it and its resistance is known:

- A two-bar electric heater is 30 ohms, what is the power of the heater when it is connected to the 240 volt mains?

In other words, given R (30 ohms) and E (240 volts), find P.

$$P = V^2/R$$

$$= 240^2/30$$

$$= 1920 \text{ watts}$$

In previous examples we were able to find the current through an electric heater, given the voltage and its power rating by using the formula $I = P/E$. It is clear that we cannot find the resistance (R) of the heater from this formula because there is no R. But we can find R by using an Ohms law formula

- If a 960 watt heater draws 4 amperes from a 240 volt supply calculate its resistance.

We know that E = 240 volts and I = 4 amps and we want to find R.

We know that $R = E/I$

Substitute the known values in the Ohms Law formula

$$R = E/I$$

$$= 240 / 4$$

$$= 60 \text{ ohms}$$

The resistance of the heater is 60 ohms.

Another way is this:

If we know the power and the voltage and want to find resistance:

We know that: $P = E \times I$ But we don't know the current

And we know that: $I = \frac{E}{R}$ So we replace I in the first formula with this E / R

This gives:
$$P = E \times \frac{E}{R}$$
$$= \frac{E^2}{R}$$

Transpose
$$R = \frac{E^2}{P}$$
$$= \frac{240 \times 240}{960}$$
$$= 60 \text{ ohms}$$

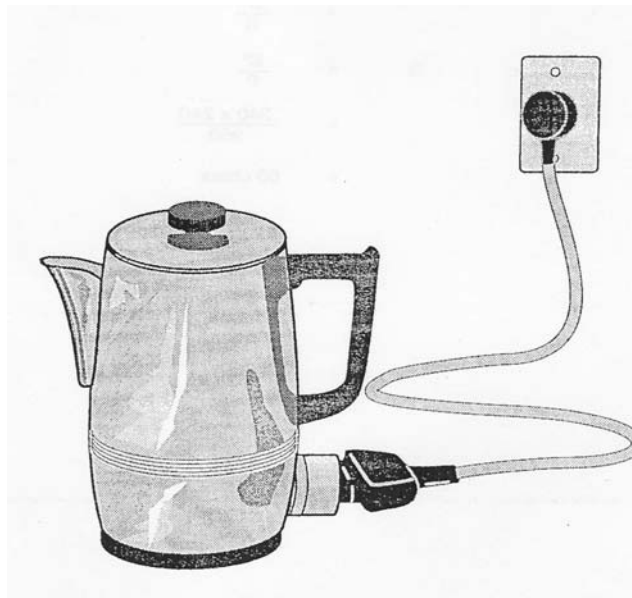
- What is the resistance of the jug below

To work out the problem:

Given Power + voltage and needing to find Resistance

The formula to use is

$$\begin{aligned} \text{Power} &= V^2/R \\ \text{Therefore } 2880 &= 240^2/R \\ R &= 240^2/2880 \\ &= 20 \text{ ohms} \end{aligned}$$



Kilowatts

Many electrical devices use large amounts of power, one example being the 11,400 watts of an electric stove.

Here are some typical examples for you to consider-

- Two bar heater 2000 watts
- Kettle 2400 watts
- Toaster 1250 watts

We can change these into kilowatts by dividing by 1000. This makes the figures shorter and easier to write.

The prefix kilo means 1000.

A kilo watt (symbol kW) equals 1000 watts

So instead of writing 2000 watts, we divide by 1000 and call the answer kilowatts.

$$2000/1000 = 2kW$$

An even larger unit of power used for power stations is the megawatt (1,000,000 watts) symbol MW.

Remember: When using Ohms Law formulas the power should always be in watts.

This is best illustrated by the following example:

- A 2 kW heater is connected to a voltage of 250V. What is the heater current?

Given power and voltage, and the need to calculate current.

$$\begin{aligned} I &= \text{Power} / \text{Voltage (in watts)} \\ &= 2000 / 250 \\ &= 8 \text{ amps.} \end{aligned}$$

The rule is, in calculations the power must be in watts.

You can change to kilowatts when you have completed all calculations and arrived at your final answer.

So the formulas for calculating power are:

$$\text{Power} = V \times I \quad \text{so } V = \frac{\text{Power}}{I} \quad \text{and } I = \frac{\text{Power}}{V}$$

$$\text{Power} = I^2 R \quad \text{so } I = \sqrt{\frac{\text{Power}}{R}} \quad \text{and } R = \frac{\text{Power}}{I^2}$$

$$\text{Power} = \frac{V^2}{R} \quad \text{so } V = \sqrt{\text{Power} \times R} \quad \text{and } R = \frac{V^2}{\text{Power}}$$

