Additional worked examples

The structure of matter, page 3

If a charge of 150 C flows through a switch in a circuit in half a minute, what is the current flowing through the switch?

So what do we know?

Q = 150 C

t = 30 s

$$I = \frac{Q}{t}$$

So:

$$I = \frac{150}{30}$$

Therefore:

I = 5 A

Or, if 150 coulombs passed through a switch in half a minute you would measure 5 amperes.

Multiples and sub-multiples, page 9

Worked example 1

Convert 0.0000034 W into a number with a prefix.

Multiply by 1000 it becomes: 0.0034 mW or 0.0034×10^{-3}

If you multiply by 1,000,000 it becomes: 3.4 μW or 3.4×10^{-6}

Worked example 2

Convert 0.0000035 mA in to pA.

Note: 0.0000035 mA is the same as 0.0000000035 A so it might be easier to do this conversion first.

pA means $\times 10^{-12}$ so move the decimal point back 12 positions to give:

3500×10^{-12} or 3500 pA

Basic mathematical concepts, page 11

$(7 \times 4 - 3 + 1)^2 \times 3 + 3$

Brackets:

There are several things going on inside the brackets so we need to use BODMAS inside the brackets first to get the priorities right. There are no *Operations* inside the brackets so the next things to look for are division and multiplication:

Division and Multiplication:

$(7 \times 4 = 28\ldots)$

Addition and Subtraction:

The next function is addition and subtraction (remember to start from the left):

$(28 - 3 + 1) = (25 + 1) = (26)$

Now all the brackets have been completed we can move back to operations:

Operations:

$(26)^2 = 676$

Division and multiplication:

There is no division so move on to multiplication (starting from left!):

$676 \times 3 = 2028$

Addition and subtraction:

Final solution is:

$2028 + 3 = 2031$

Pythagoras' theorem, page 13

The number 3 comes up a great deal in electrical science, as does the use of triangles to represent certain electrical ideas. Pythagoras' theorem tells us that in a right angled triangle, the square of the hypotenuse is equal to the sum of the squares of the other two sides.

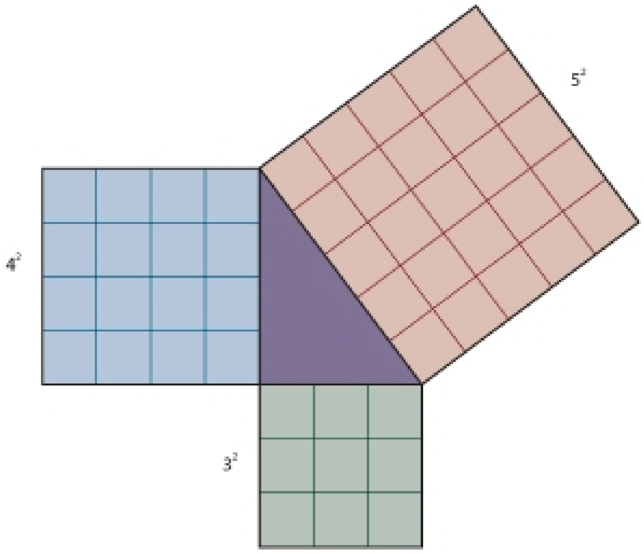
The hypotenuse is always the longest side of a triangle.

From the diagram you can see that $4^2 + 3^2 = 5^2$ or to put it another way:

$16 + 9 = 25$

This can be confirmed by simply counting up the individual squares.

Pythagoras' theorem can be used for a number of electrical concepts, so it is worth practising transposition.



Worked example 1

By using the simple rules of transposition previously discussed, it should be possible to rearrange to find all sides of the formula.

$5^2 = 4^2 + 3^2$

If you wanted to rearrange to make ‘3’ the subject you take the 4^2 to the other side.

Rule: when a number or symbol moves from one side of the ‘equals’ to the other, its sign must change from +ve to –ve or vice versa.

$5^2 - 4^2 = 3^2$

Now you need to do something to remove the squared sign on the 3.

Note: remember that by moving a term from one side of the formula to the other, you reverse the operation so divide becomes multiply.

The reverse operation of ‘squared’ is to take the square root. Don’t forget whatever you do to one side you must also do to the other.

$$\sqrt{5^2 - 4^2} = \sqrt{3^2}$$

$$\sqrt{5^2 - 4^2} = 3$$

Note: the square root of a number squared is *that* number. For example, $9^2 = 81$ and $\sqrt{81} = 9$

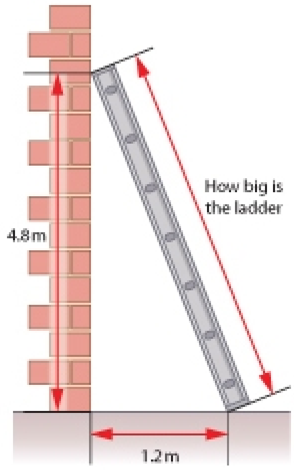
Worked example 2

You need to find the hypotenuse.

$A^2 = B^2 + C^2$

(A is the hypotenuse or the ladder size, B is the height of the lamp from the ground and B is the base distance of the ladder from the wall.)

You need to make A the subject of the formula so the squared sign needs to go. The opposite operation of squared is square root. Don’t forget that you have to take the square root of both sides of the formula.



$$\sqrt{A^2} = \sqrt{B^2 + C^2}$$

$$A = \sqrt{B^2 + C^2}$$

$$\text{Ladder} = \sqrt{4.8^2 + 1.2^2}$$

$$\text{Ladder} = 4.95\,\text{m}$$

Activity

The ladder in the worked example above is extendable. With the next section extended it reaches 5.4 m up the wall and is out from the wall by 1.35 m at the base. How tall is the actual ladder?

The ladder has a third section added to reach its maximum position on the wall of 6 m and is 1.5 m away from the wall at its base. How long is the ladder now?

If there was one more section that could be added to the ladder to take it to a height of 6.4 m up the wall, how far would the ladder be from the wall at its base and how long is the actual ladder?

Sine, cosine and tangent, page 14

Worked example 1

The hypotenuse is 134 mm and the angle is 38° – how long is the adjacent?

$$\text{Cosine } \theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\text{Cos } \theta = \frac{\text{Adjacent}}{134}$$

$$\text{Cos } 38 \times 134 = 105.6\,\text{mm}$$

Worked example 2

The adjacent is 13 cm and the angle is 18° – how long is the hypotenuse?

$$\text{Cosine } \theta = \frac{\text{Adjacent}}{\text{Hypotenuse}}$$

$$\text{Hypotenuse} = \frac{\text{Adjacent}}{\text{Cosine } \theta}$$

$$\text{Hypotenuse} = \frac{13}{\text{Cosine } 18}$$

$$\text{Hypotenuse} = 13.7\,\text{cm}$$

Resistance and resistivity, page 15

Worked example 1

Now use the same resistivity and cross sectional area as in example 1 but this time the cross sectional area has doubled. What is the new resistance?

$$R = \frac{(28.2 \times 10^{-9} \times 10 \times 10^{3})}{(6.284 \times 10^{-6})}$$

$$R = 44.875\,\Omega$$

Notice the resistance has halved.

Worked example 2

Use the same information as before but now the distance has doubled to 20 km. What is the new resistance?

$$R = \frac{(28.2 \times 10^{-9} \times 20 \times 10^{3})}{(6.284 \times 10^{-6})}$$

$$R = 89.75\,\Omega$$

Notice the resistance has gone back to what is was in the first example.

Worked example 3

What if the diameter of the conductor is doubled? What is the new resistance?

Firstly, work out the new cross sectional area:

$$A = \frac{1}{4}\pi(8 \times 10^{-3})^2$$

$$A = \frac{1}{4}\pi 8 \times 10^{-6} = 6.284 \times 10^{-6}$$

$$R = \frac{(28.2 \times 10^{-9} \times 20 \times 10^3)}{(6.284 \times 10^{-6})}$$

$$R = \frac{0.000564}{0.000006284}$$

$$R = 89.75\,\Omega$$

Power in a circuit, page 24

Worked example 1

A 3.3 kΩ resistor is put in series with an ammeter. The ammeter reads 2.56 A. What is the power being used by the resistor?

$P = I^2 \times R$

$P = 2.56^2 \times 3.3 \times 10^3$

P = 21.63 kW

Worked example 2

What is the power of a 3.3 kΩ resistor when a supply of 400 V is connected across it?

$$P = \frac{V^2}{R}$$

$$P = \frac{400^2}{3.3 \times 10^3}$$

$$P = 48.48\,\text{W}$$

Strength of a magnet, page 31

Worked example 1

Calculate the magnetic flux of a magnet with a flux density of 2 T and a CSA of 0.15 m².

$$B = \frac{\varphi}{A}$$

$$\varphi = B \times A$$

$$\varphi = 2 \times 0.15$$

$$\varphi = 300\,\text{mWb}$$

Worked example 2

Calculate the cross sectional area of a magnet with a flux density of 22 μWbm² and magnetic flux of 66 μWb.

$$B = \frac{\varphi}{A}$$

$$A = \frac{\varphi}{B}$$

$$A = \frac{66 \times 10^{-6}}{22 \times 10^{-6}}$$

$$A = 3\,m^2$$

Force on a conductor, page 35

Worked example 1

A force of 10 N is experienced by a 1.2 m conductor when placed into a magnetic field of 13.2 T. What current is flowing in the conductor?

$$F = B \times I \times L$$

$$I = \frac{F}{B \times L}$$

$$I = \frac{10}{13.2 \times 1.2}$$

$$I = 0.63\,A$$

Worked example 2

What is the length of a conductor that experiences a force of 6mN when placed into a magnetic field of 0.65 T and carrying a current of 20 mA?

$$F = B \times I \times L$$

$$L = \frac{F}{B \times I}$$

$$L = \frac{6 \times 10^{-3}}{0.65 \times 20 \times 10^{-3}}$$

$$L = 0.46\,m$$

Calculating magnitudes of a generated emf, page 36

Worked example 1

If a conductor with a length of 1.2 m is moving at right angles to a magnetic field with a velocity of 500 mm per second and an emf of 2.4 V is generated, what is the strength of the magnet?

$$\mathrm{E} = \mathrm{B} \times \mathrm{L} \times V$$

$$\mathrm{B} = \frac{\mathrm{E}}{\mathrm{L} \times V}$$

$$\mathrm{B} = \frac{2.4}{1.2 \times 0.5}$$

$$\mathrm{B} = 4\,\mathrm{T}$$

Worked example 2

If a conductor is moving at right angles to a magnetic field of flux density 5 T at a velocity of 5000 m per minute and an emf of 12 V is generated, what is the length of the conductor?

$$\mathrm{E} = \mathrm{B} \times \mathrm{L} \times V$$

$$\mathrm{L} = \frac{\mathrm{E}}{\mathrm{B} \times V}$$

$$\mathrm{L} = \frac{12}{5 \times 83.3}$$

$$\mathrm{L} = 0.0288\,\mathrm{m}$$

Sine wave – frequency and period, page 38

Worked example 1

What is the period for a 60 Hz supply?

$$\mathrm{T} = \frac{1}{\mathrm{f}}$$

$$\mathrm{T} = \frac{1}{60}$$

$$\mathrm{T} = 0.016 \text{ or } 16.7\,\mathrm{mS}$$

Worked example 2

What is the frequency if two complete cycles of a sine wave takes 10 mS?

$$\mathrm{f} = \frac{1}{\mathrm{T}}$$

$$\mathrm{f} = \frac{1}{5}$$

$$\mathrm{f} = 0.2 \text{ or } 200\,\mathrm{mS}$$

Transformer calculations, page 47

Worked example 1

A step down transformer has a turns ration of 7:1. The secondary voltage is 30 V. What is the primary voltage?

What do you know?

- It a voltage transformer.
- It is a step down transformer.
- It has a ratio of 7:1 so all we have to do is find the bigger primary voltage.

The primary voltage can be found by multiplying by 7 or going back and using the formula:

$$V_p = \frac{V_s \times N_p}{N_s}$$

or

$$V_p = \frac{30 \times 7}{1}$$

V_p = 210 V

Worked example 2

A current transformer has a primary current of 3 A and a turns ration of 9:1. What is the secondary current?

This time you will use the formula:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_s}{I_p}$$

No values for voltage are given so you can ignore that part of the formula leaving:

$$\frac{N_p}{N_s} = \frac{I_s}{I_p}$$

$$\frac{N_p \times I_p}{N_s} = I_s$$

Now simply put in the values you know to give:

$$I_s = \frac{9 \times 3}{1} = 27\,\text{A}$$

Don't forget a step down voltage transformer is a step up current transformer!

Mass and weight, page 49

Worked example 1

A large motor has a label on it indicating a weight force of 10 kN. What is the mass of the motor?

F = 10000 N

g = 9.81ms^{-2}

F = mg

So rearranging the formula to make m the subject (divide both sides by g):

m = F÷g, and substituting the values becomes:

m = 10000 ÷ 9.81

m = 1019.37 kg (just over 1 metric ton)

Worked example 2

An extractor fan in a large horticultural warehouse has a label on it indicating a weight force of 0.96 kN. What is the mass of the fan and, if you assumed a maximum of 25 kg per person, how many would it take to lift it?

F = 960 N

g = 9.81 ms^{-2}

F = mg

So rearranging the formula to make m the subject (divide both sides by g):

m = F ÷ g, and substituting the values becomes:

m = 960 ÷ 9.81

m = 97.86 kg

This would require a minimum of four staff.

Work and energy, page 50

Worked example 1

How far has a drum of SWA cable moved across the workshop floor if the work done is 150 J and the force used is 9.81 N?

F = 9.81 N

W = 150 J

W = Fd (rearrange formula to make ‘d’ the subject and then substitute the values)

d = W ÷ F

d = 150 ÷ 9.81

d = 15.29 m

Worked example 2

You have to clear a room in a retirement home before you can rewire it. There are 20 identical motorised lifting chairs that need moving 15 m and each one requires a force of 8 N. What energy have you used?

F = 20 × 8 N

d = 15 m

W = Fd

W = 160 × 15

W = 2.4 kJ

Potential energy (PE), page 51

Worked example 1

You have to lift your laser level to 3.5 m above fixed floor level (ffl) so that you can mark out a cable tray route in a false ceiling. What potential energy (PE) will there be if the 0.5 kg laser level is lifted from the floor to the fixing position?

PE = mgh

m = 0.5 kg

g = 9.81 ms^{-2}

h = 3.5 m

PE = 0.5 × 9.81 × 3.5

PE = 17.17 J

Worked example 2

A d.c. motor weighs 1000 kg and requires lifting 0.35 m in to its operating position. What potential energy will there be?

PE = mgh

m = 1000 kg

g = 9.81 ms^{-2}

h = 0.35 m

PE = 1000 × 9.81 × 0.35

PE = 3433.5 J

Energy and power, page 52

Worked example

Your electrical stores have been delivered to the wrong place and you need to push them into the storage lockup 10m away from where the wholesaler has left them. You are in the way of other trades but they have agreed to give you 1 hour to move everything while they have lunch. How much power will you use if there are nine pallets each weighing 55 kg?

Step 1 – write down what you know/have been given:

m = 55 kg each

d = 10 m

t = 60 mins = 3600 s (convert to base unit of time, s)

F = mg

W = Fd

P = W ÷ t

Step 2 – what can you work out from the facts you have?

F = mg

F = 55 × 9.81

F = 539.55 N

and:

W = Fd

W = 539.55 × 10

W = 5395.5 J (or 5.3955 KJ)

Don’t forget this has to be done for each pallet, so:

W = 5395.5 × 9 = 48.5595 KJ

so:

P = W ÷ t

P = 48559.5 ÷ 3600

P = 13.49 W

Third order lever, page 54

Worked example 1

Using the diagram on page 54 of the candidate handbook, in this scenario D_1=500mm, D_2=300mm, F_2=300N. Work out F_1.

$$F_1 = \frac{F_2 \times D_2}{D_1}$$

$$F_1 = \frac{300 \times 300}{500}$$

F_1 = 180 N (or 18.35 kg)

Worked example 2

Using the diagram on page 54 of the candidate handbook, in this scenario D1=230mm, D2=600mm, F2=120N. Work out F_1.

$$F_1 = \frac{F_2 \times D_2}{D_1}$$

$$F_1 = \frac{120 \times 600}{230}$$

F_1 = 313.04 N (or 31.91 kg)

Efficiency, page 55

Worked example 1

If the input power to a motor is 11 kW and the output power is 10.3 kW:

- what is the efficiency of the motor
- what are the losses?

$$\text{efficiency}, \eta = \frac{10300}{11000} \times 100\%$$

$$\text{efficiency}, \eta = 93.64\%$$

Losses = input power – output power

Losses = 11000 – 10300

Losses = 700 W

Worked example 2

If the output power of a machine is 20 kW and the loss is 1.3 kW:

- what is the efficiency of the machine
- what is the input power?

$$\text{efficiency}, \eta = \frac{20000}{20000 + 1300} \times 100\%$$

$$\text{efficiency}, \eta = 93.90\%$$

Input power = output power + losses

Losses = 1300 W

Input power = 21300 W or 21.3 kW