How are fields used to move electricity?

Generation of electricity

- **calculate magnetic flux when the magnetic field is perpendicular to the area, and describe the qualitative effect of differing angles between the area and the field:**

  $\boldsymbol{\Phi_B = B_\perp A}$.

- **investigate and analyse theoretically and practically the generation of electromotive force (emf) including AC voltage and calculations using induced emf, $\varepsilon = -N\frac{\Delta\phi_B}{\Delta t}$, with reference to:**

  – rate of change of magnetic flux

  – number of loops through which the flux passes

  – direction of the induced emf in a coil.

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
4, 5, 6, 7, 8	6, 7, 8, 9, 14, 15	4, 8, 9, 10	2, 3, 16	2, 3, 8, 9, 10, 11	6, 7 8, 9, 10, 11,12	8a, b, c	17a, b, c, d	13a, b, c 17d	12b, c 13a, b, c	15a, b

Magnetic flux

Magnetic flux (Φ_B) is a measure of the amount of magnetic field passing through an area.
$\Phi_B = B_\perp \times A$
$\therefore B_\perp = \frac{\Phi_B}{A}$ where $B_\perp$ is the magnetic field strength (T) perpendicular to the given area A and Φ_B is the magnetic flux (Wb - Weber) and A the area (m^2).

Electromagnetic Induction is the creation of an electric current in a conductor moving across a magnetic field. This current can cause an EMF to be produced between the ends of the conductor. Induced current is achieved by either moving the conductor relative to the magnetic field or changing the strength of the magnetic field surrounding the conductor.

Faraday's law of electromagnetic induction

The **magnitude** of the induced EMF is directly proportional to the rate of change of magnetic flux or the rate at which magnetic flux is cut for a wire moving across magnetic field lines.

The induced EMF is $\xi = \frac{\Delta\Phi_B}{\Delta t}$

EMF induced by changing flux in a loop

Wire can be used to produce a loop, and there is always an EMF generated in a conducting loop in which there is a changing magnetic flux. If the coil has 'n' turns then the total EMF is $\xi = -n\frac{\Delta\Phi_B}{\Delta t}$

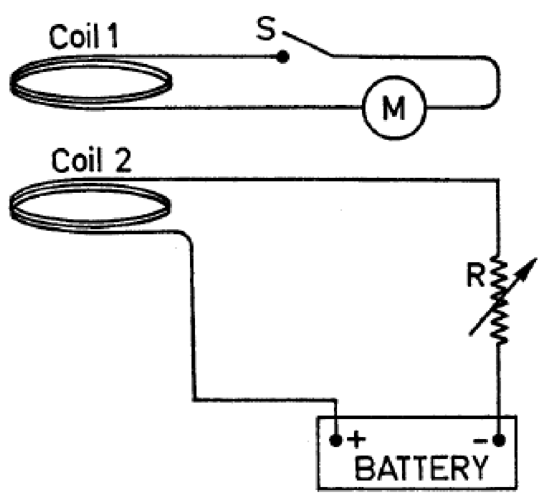
Lenz's Law.

The **direction** of the induced EMF is the same as that of a current whose magnetic action would oppose the flux change. $\xi = -n\frac{\Delta\Phi_B}{\Delta t}$ ξ: = EMF (volts)

n: number of turns, ϕ magnetic flux (Weber), -ve means that the EMF opposes the change in flux.

Induced EMF in a rotating coil

The EMF generated by the rotating coil, $\xi = -n\frac{\Delta\Phi_B}{\Delta t}$ the result obtained from this differentiation is the negative of the gradient of the flux v time graph.



Example 3.1: 1970 Question 90 (1 mark)

Two flat, horizontal coils are mounted as shown. Which one or more of the following actions will cause the sensitive current meter M to register?

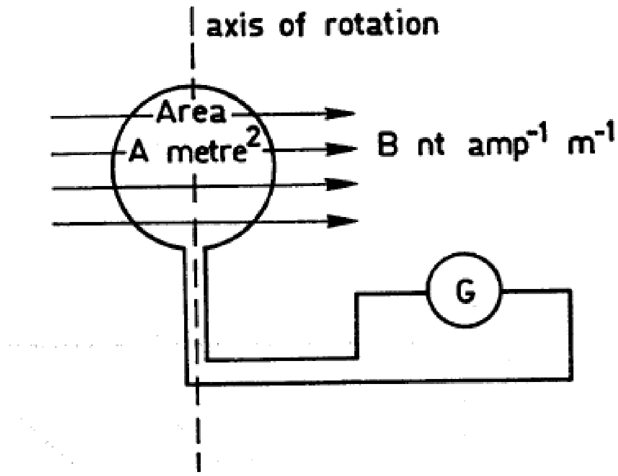
A. Coil 2 stationary and coil 1 moving upwards with S kept closed.

B. Both coils stationary and S switched on and off.

C. Coil 1 stationary with S closed and Coil 2 moving to the right.

D. With S closed, a variable resistance R is increased and decreased

(One or more answers)



A loop of wire is in a region of uniform magnetic field.

The loop originally has its face parallel to the direction of the magnetic field, as shown in the diagram.

Example 3.2: 1972 Question 91 (1 mark)

What is the magnetic flux through the loop in this position?

The loop is now rotated 90^0 about the axis shown.

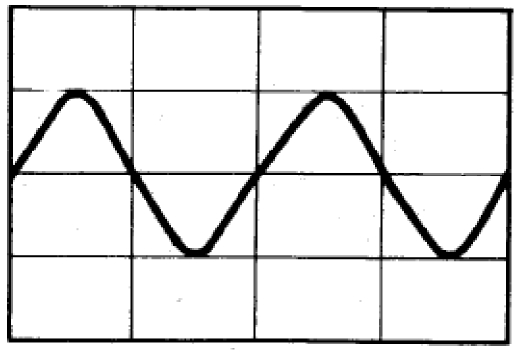
Example 3.3: 1972 Question 92 (1 mark)

What is the flux through the coil in this new position?

Example 3.4: 1972 Question 93 (1 mark)

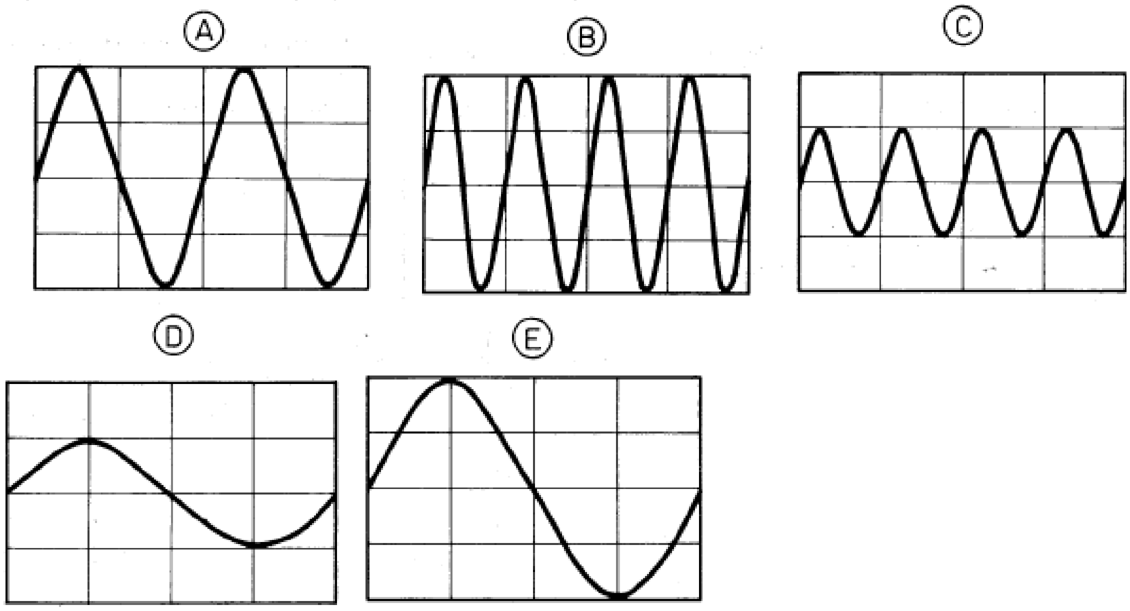
The total resistance of coil and external circuit is R ohm. The 90^0 rotation took t sec. What is the average current in the circuit during this time interval?

The output of a simple alternator can be fed into an oscilloscope; the visual display represents a graph of the output-EMF against time. The figure represents the display for an alternator rotating at a rate of ‘f’ rotations per second.

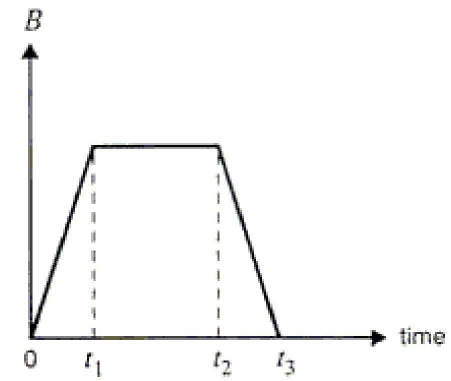


Example 3.5: 1981 Question 70 (1 mark)

The alternator is now made to rotate at ‘2f’ revolutions per second. Which of the following best represents the new display on the oscilloscope?



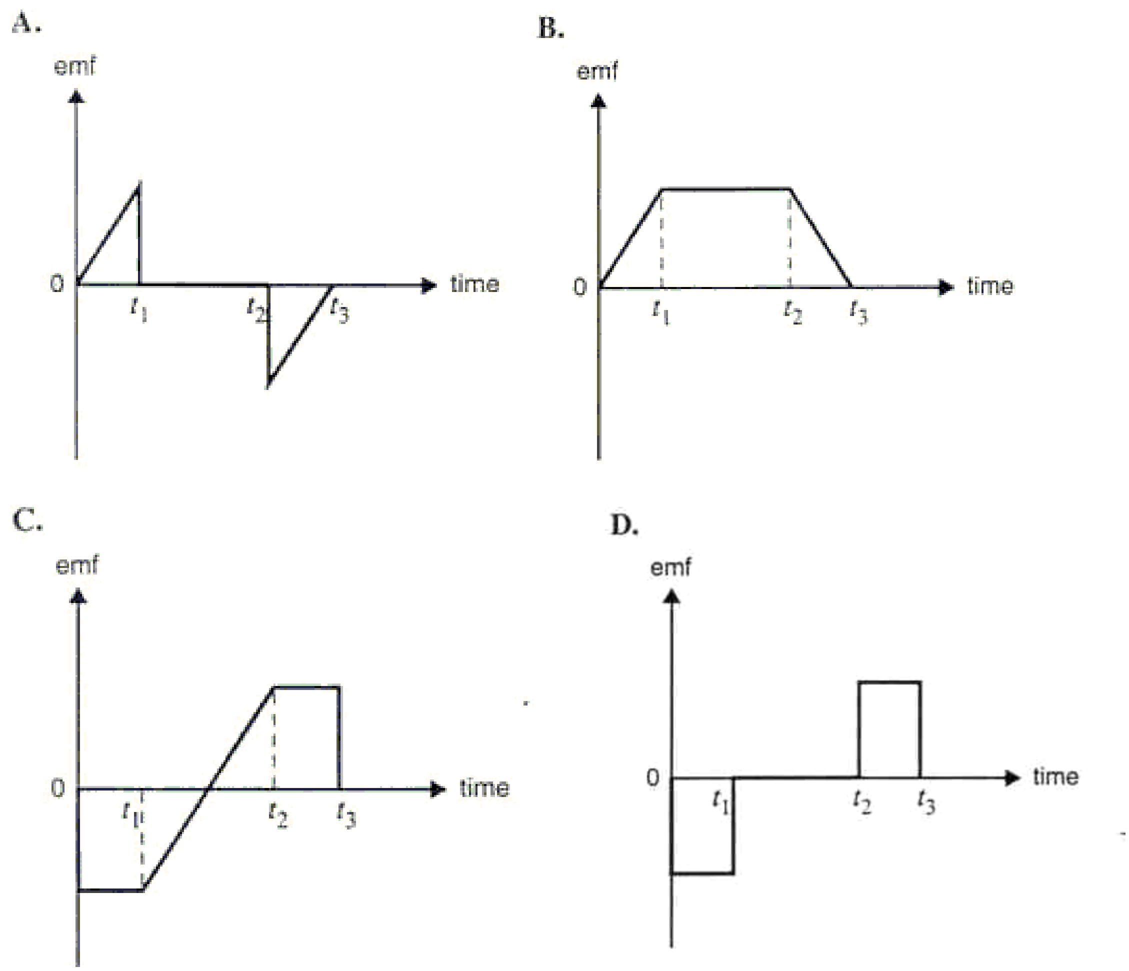
The on-off action of a lightning stroke produces an electromagnetic field surrounding the stroke. It is this field that causes the crackling in your radio or TV during a thunderstorm.
The magnetic field, ***B,*** produced by a lightning stroke varies with time as shown.



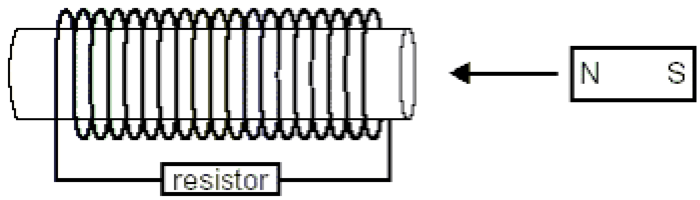
A small coil is placed perpendicular to the magnetic field, and the induced emf is monitored on an oscilloscope.

Example 3.6: 2000 Question 3 (2 marks)

Which **one** of the graphs **(A - D)** best shows the variation of the emf with time?



Jackie and Jim are studying electromagnetic induction. They have a small permanent magnet and a coil of wire wound around a hollow cylinder as shown below.



Jackie moves the magnet through the coil in the direction shown at constant speed.

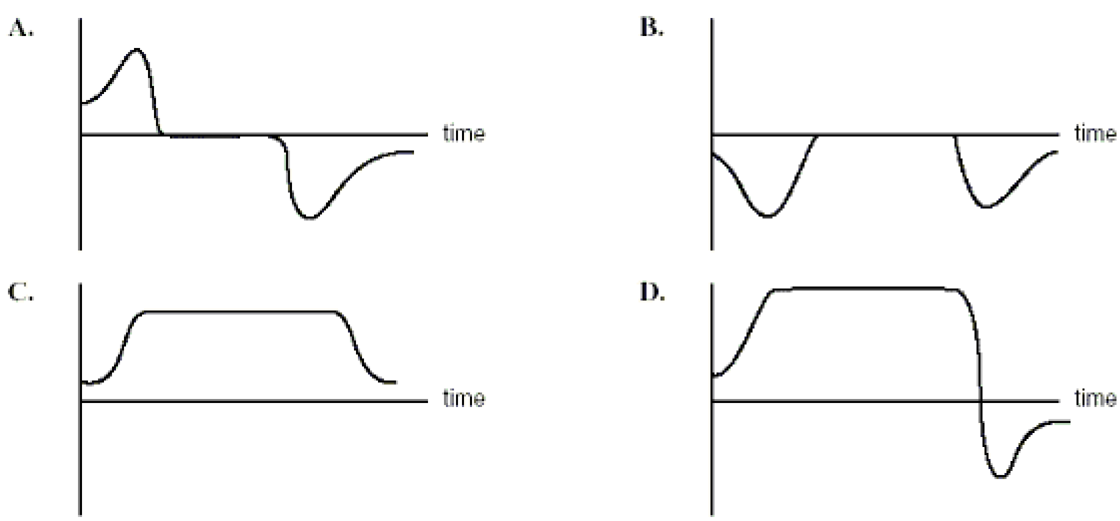
Example 3.7: 2002 Question 9 (2 marks)

Indicate on the diagram the direction of the induced current that flows in the resistor. Explain the physics reason for your choice.

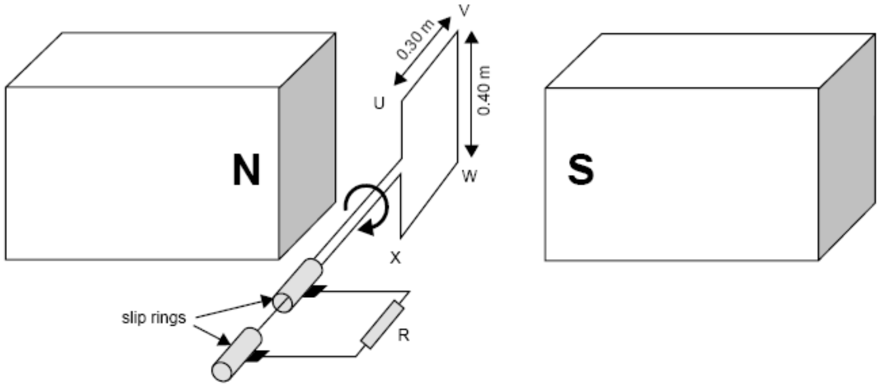
They next decide to move the magnet, at a constant speed, all the way through the coil and out the other side.

Example 3.8: 2002 Question 10 (2 marks)

Which **one** of the diagrams (**A – D**) below best shows how the current through the coil varies with time?



The figure below is a diagram of a simple alternator. A coil (UVWX) 0.30 m by 0.40 m, **consists of 20 turns of wire**. It is in a uniform magnetic field of strength 0.25 T, and can rotate as shown.



Example 3.9: 2003 Question 8 (2 marks)

With the coil oriented as above, what is the magnitude of the magnetic flux through each turn of the coil?

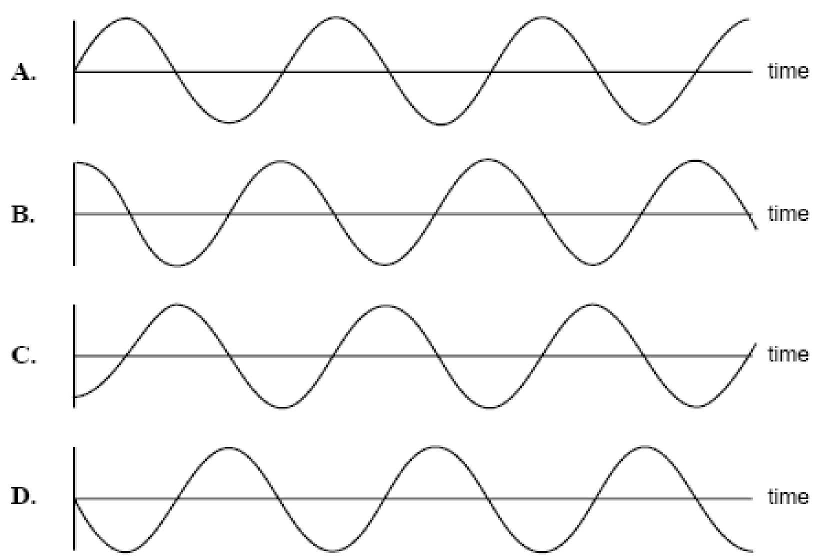
Example 3.10: 2003 Question 9 (3 marks)

The coil is rotated at **a constant rate of 50 revolutions per second** in the direction shown.
What is the **average voltage** developed across the resistor R when the coil rotates through 90^0 from the orientation shown in the figure above?

The graphs below show possible variations of **the magnetic flux** through the coil as a function of time as it rotates. They all begin at time t = 0, when the coil is oriented as in the diagram above.

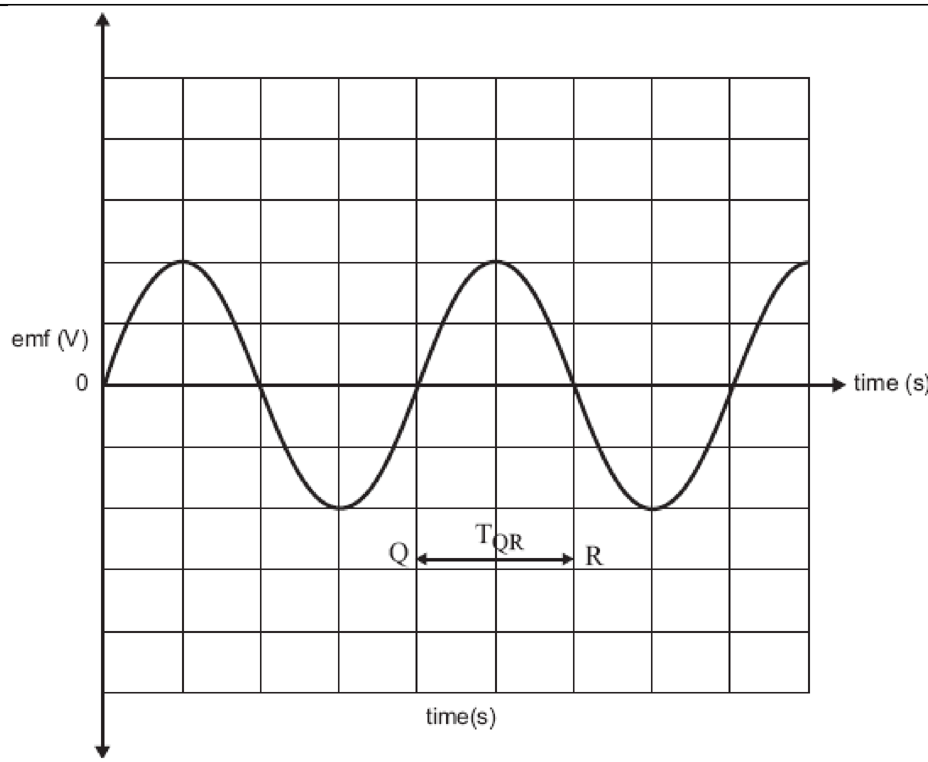
Example 3.11: 2003 Question 10 (2 marks)

Which of these graphs (**A – D**) best shows the variation of **the magnetic flux** through the coil as a function of time? Take the direction from N to S in the figure as positive.



Example 3.12: 2003 Question 11 (3 marks)

Assuming the same conditions as in the question above, which of the graphs (**A – D**) best shows the variation of the current flowing **from U to V in the coil**, as a function of time? Explain the logic of your choice.



The coil is rotated at a rate of 10 revolutions per second, and the output is observed on an oscilloscope (CRO), as shown above.

The rotation speed of the coil is increased to 20 revolutions per second.

Example 3.13: 2005 Question 5 (3 marks)

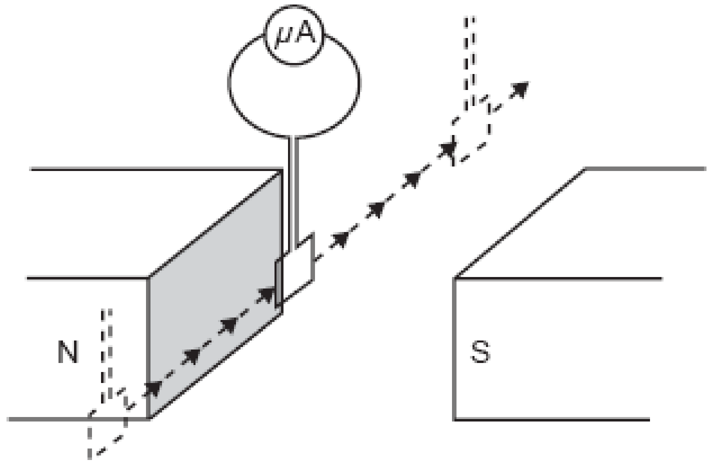
On the figure above, sketch the output from the oscilloscope that would be observed now.

Joan and her grandfather were discussing how a transformer works and this led to a discussion about Faraday's and Lenz's laws. Joan's grandfather stated that the two laws were essentially the same, but Joan disagreed.

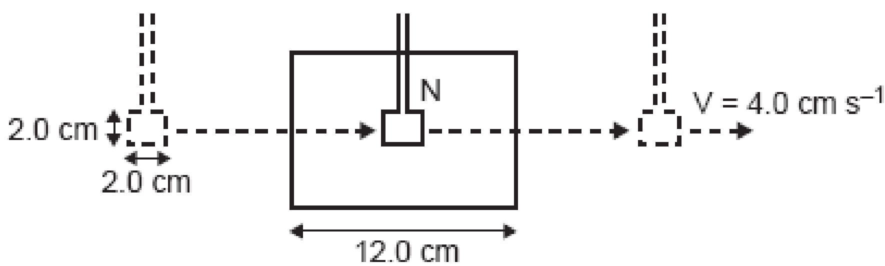
Example 3.14: 2005 Question 15 (3 marks)

Compare and contrast Faraday's law and Lenz's law.

A loop of wire in the form of a 2.0 cm square is moved through a uniform magnetic field at a constant speed of 4.0 cm s^{-1}. This is shown below.



The figure below shows an end-on view of the loop as it passes across the face of the north pole of the magnet. Current flowing through the loop is measured by a micro-ammeter (*μ*A).
You may assume the magnetic field exists **only** in the region between the north and south poles.

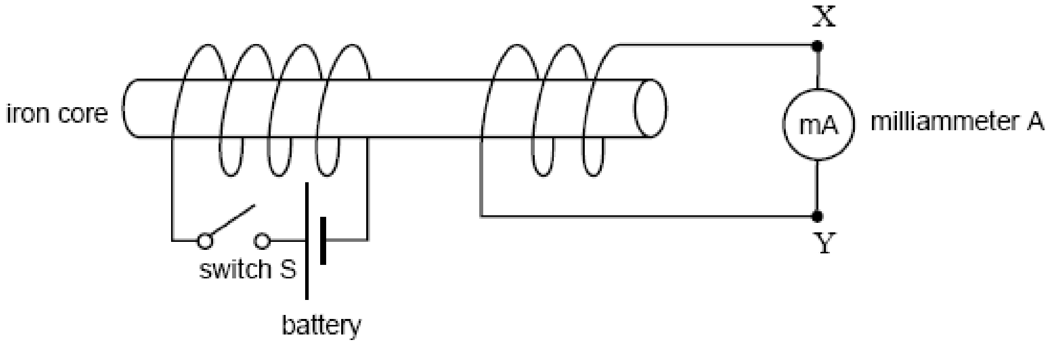


The field strength between the poles is 3.7×10^{-3} T (Wb m^{-2}).

Example 3.15: 2006 Question 8 (4 marks)

Calculate the maximum induced voltage in the loop.

To study Lenz's law, students set up the following experiment using the circuit shown below.



Initially switch S is open.

Example 3.16: 2007 Question 14 (2 marks)

Which one of the following **(A - D)** will best describe the current through the milli-ammeter A, when the switch S is closed?

A. current flows momentarily in the direction X to Y

B. current flows momentarily in the direction Y to X

C. current flows continuously in the direction X to Y

D. current flows continuously in the direction Y to X

Example 3.17: 2007 Question 15 (3 marks)

Explain how Lenz's law enables you to determine the direction of the current flow in this experiment.

A group of students is studying electromagnetic induction. The apparatus the students use is shown in Figure A.

The apparatus consists of a square magnet and a square loop that can move. The magnet, of sides 8.0 cm, has a uniform magnetic field strength of 4.0×10^{-3} T between the poles. The field can be considered zero outside the poles. The loop is square of side 2.0 cm. The loop moves through the magnet at a constant speed of 2.0 cm s^{-1}. Figure B below shows the situation as seen from above.

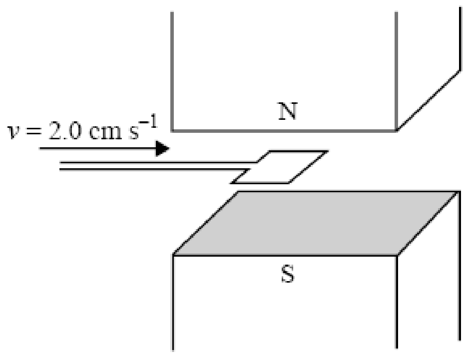


Figure A

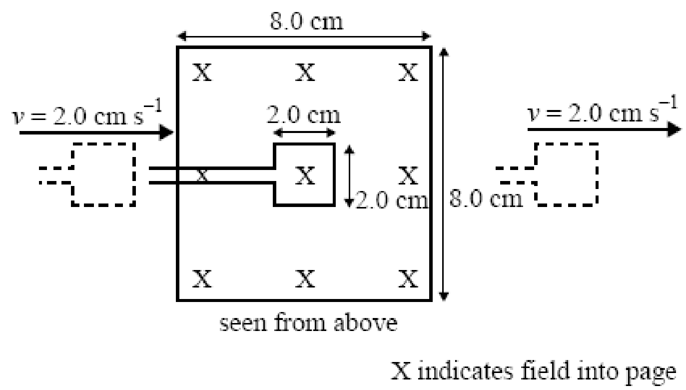
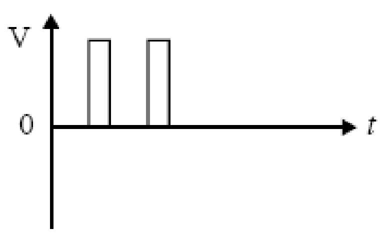


Figure B

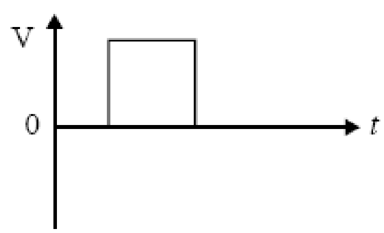
Example 3.18: 2008 Question 8 (2 marks)

Which of the following diagrams (**A – F**) best shows the shape of the output emf (voltage) induced in the loop as a function of time as the loop moves from outside the field at left to outside the field at right as shown in Figure B?

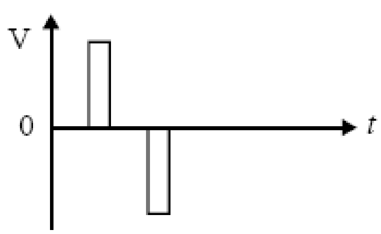
A.



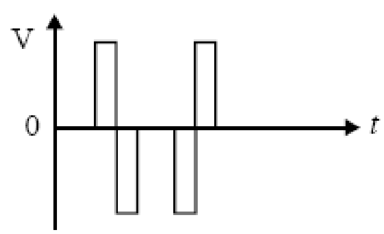
B.



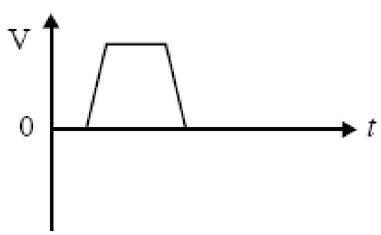
C.



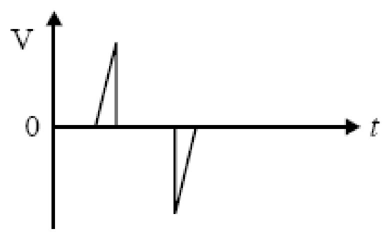
D.



E.

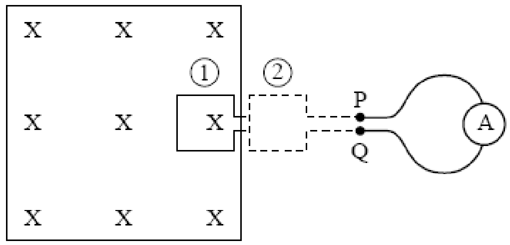


F.



Example 3.19: 2008 Question 9 (3 marks)

The square loop moves from position 1 (just inside the magnetic field) to position 2 (just outside the magnetic field) as shown below (seen from above). What is the average emf (voltage) induced? Show working.

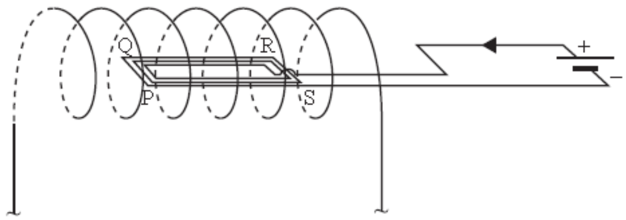


Example 3.20: 2008 Question 10 (4 marks)

Will the current due to the induced voltage flow from P to Q **or** Q to P **through the square loop** as it moves from position 1 to position 2?

Explain your answer in terms of Lenz's law.

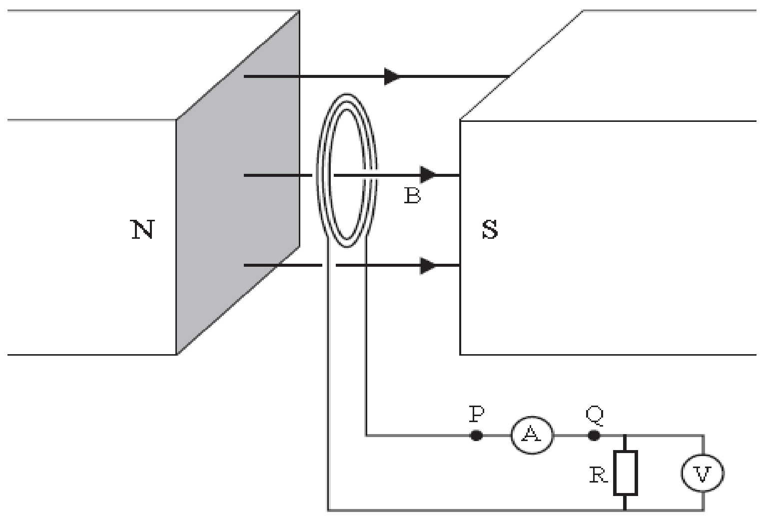
A rectangular loop of wire, PQRS, of sides PQ = 4.0 cm and QR = 8.0 cm, is placed inside the solenoid as shown below. The loop has 3 turns of wire. A current of 4.0 amps flows in the loop, in the direction indicated by the arrow. The uniform magnetic field strength inside the solenoid is 5.0×10^{-2} T.



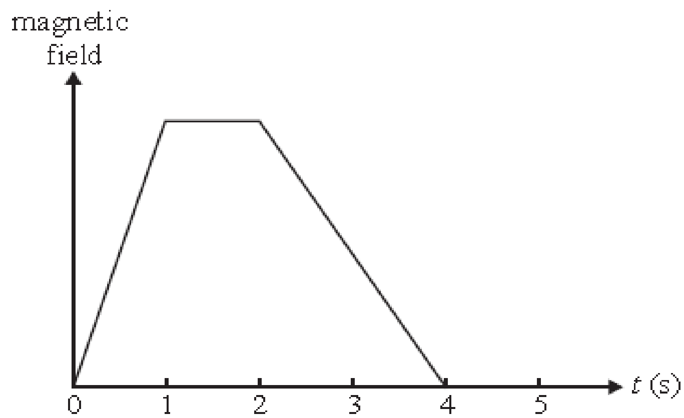
Example 3.21: 2010 Question 2 (2 marks)

What is the magnetic flux threading the loop? Explain your answer.

The figure below shows an experiment where the voltage induced in a coil by a time-dependent magnetic field is measured. The voltmeter measures the voltage induced in the coil as a function of time. The coil has 120 turns.

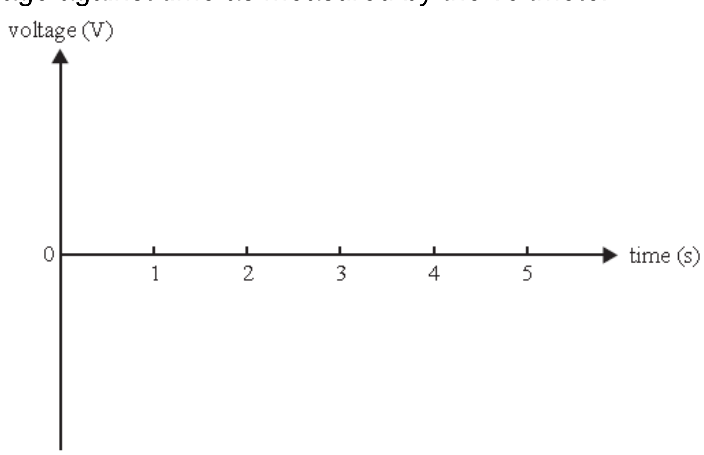


The magnetic field varies with time as shown below.



Example 3.22: 2010 Question 8 (2 marks)

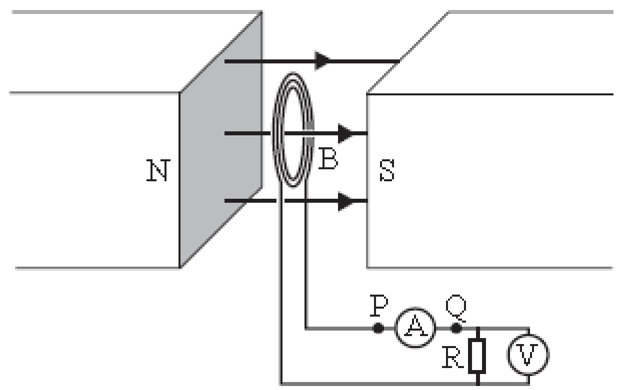
Sketch a graph of voltage against time as measured by the voltmeter.



Example 3.23: 2010 Question 9 (1 mark)

Identify the physical law you used for constructing your graph.

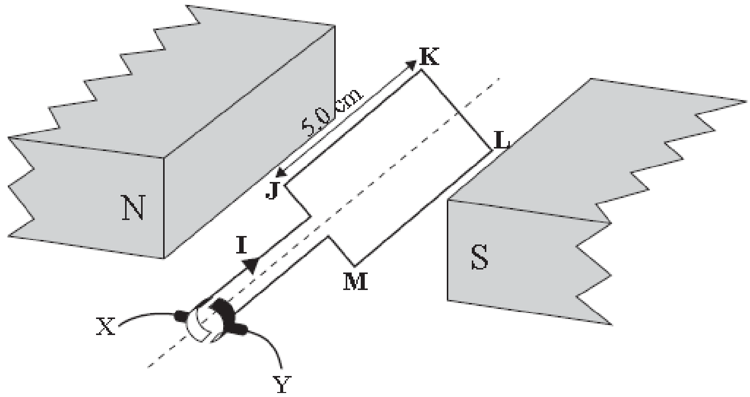
At another time, the magnetic flux through the 120 turns coil is a constant 3.0×10^{-4} Wb. The magnetic field is now reduced to zero over a period of 0.012 s.



Example 3.24: 2010 Question 11 (2 marks)

As the field is being reduced, in what direction (P → Q or Q → P) will the current flow through the ammeter A in the figure above? Explain your answer.

The figure below shows a schematic diagram of a DC electric motor. The motor has a rectangular coil, JKLM, of 50 turns. The permanent magnets provide a uniform magnetic field of 0.30 T in the region of coil JKLM.

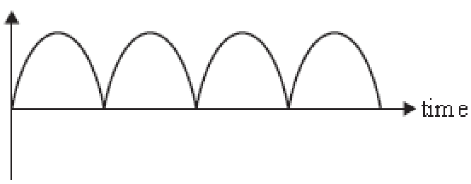


Coil JKLM is now disconnected from the source of steady current, and the coil is turned by hand at a constant speed. Points X and Y are now connected to an oscilloscope.

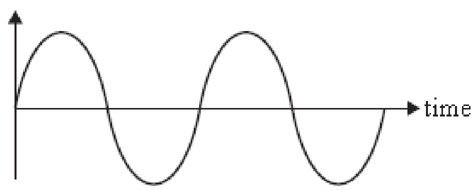
Example 3.25: 2011 Question 6 (1 mark)

Which of the following graphs best shows the shape of the voltage-time display on the oscilloscope?

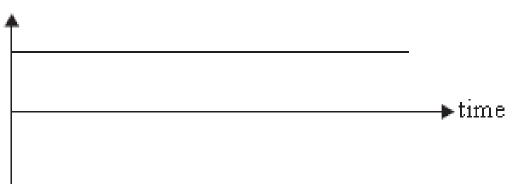
A.



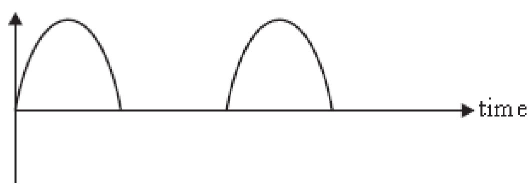
B.



C.



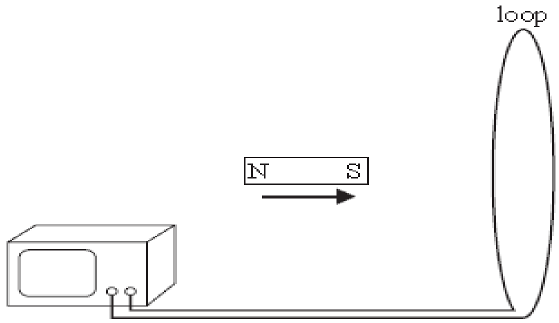
D.



Example 3.26: 2011 Question 7 (2 marks)

Explain your answer to Question 6.

A small bar magnet is moved through a circular wire loop, as shown below. The magnet moves with **constant** speed through the centre of the loop, in the direction shown by the arrow. An emf is generated in the wire loop. The wire loop is connected to an oscilloscope, as shown below.



Example 3.27: 2011 Question 11 (2 marks)

On the graph axes below, sketch the variation of the emf with time, from when the magnet is a long way to the left of the loop, through the loop, to when it is a long way to the right of the loop. Note that you can take either upwards or downwards as positive.

After the magnet has passed through the wire loop, and is moving away from the loop, current flows around the loop in an **anticlockwise** direction as viewed from the left in the figure above.

Example 3.28: 2011 Question 12 (3 marks)

Use Lenz's law to explain why the current flows in an **anticlockwise** direction.

Figures 7a and 7b show a square loop being moved between the poles of a magnet. In the space between the poles there is a uniform magnetic field.
The loop moves at a steady speed from position 1 to position 3.
The loop is connected to a sensitive micro ammeter. The area of the loop is much less than the area of the magnetic field.
You may assume that the only magnetic field present is located directly between the north and south poles.

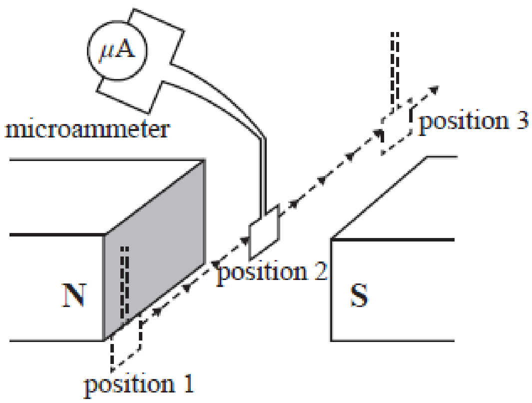


Figure 7a

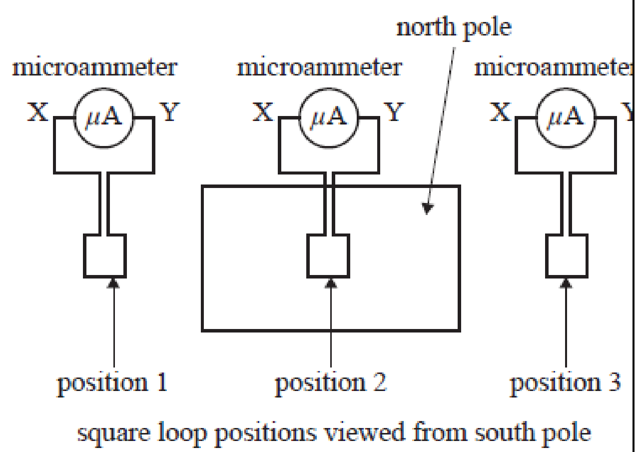
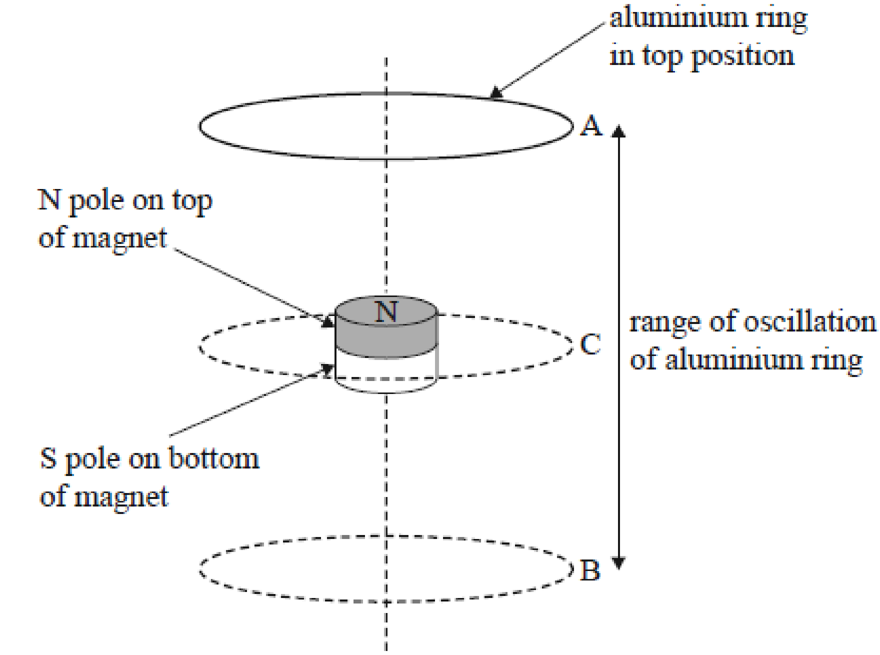


Figure 7b

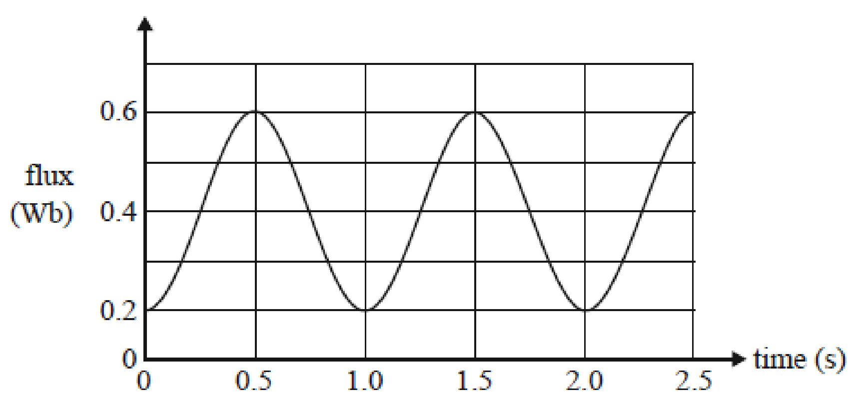
Example 3.29: 2012 Question 8c (3 marks)

Describe the direction of the current in the square loop as it moves from position 2 to position 3, as viewed from the south pole (see Figure 7b). You may use a sketch in your answer. Explain the reasons for your answer.

Students conduct an experiment that is shown below. An aluminium ring is made to oscillate vertically between point A and point B. Point C is the midpoint between A and B. A strong, small bar magnet is fixed at the centre of the oscillation, as shown.



The vertical dashed line goes through the centre of the aluminium ring and also through the centre of the bar magnet in the diagram.
The magnetic flux through the aluminium ring is graphed as a function of time in the graph shown below.



Example 3.30: 2013 Question 17b (2 marks)

Use information from the graph to specify the time(s) after t = 0 s and before t = 2.0 s when the emf around the ring will be zero.

Example 3.31: 2013 Question 17c (4 marks)

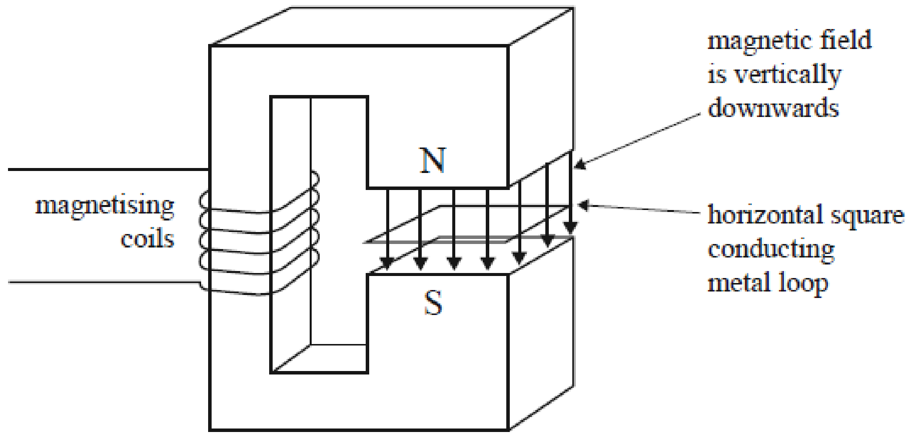
When the ring is moving downwards towards the N pole of the magnet, a current flows around the ring. Use a sketch or words to describe the direction of this current when viewed from above. Explain your answer carefully.

Example 3.32: 2013 Question 17d (2 marks)

Use information from the graph to complete the table below, showing the times (between $t = 0$ s and $t = 2.5$ s) when the aluminium ring is located at point A, point B and point C, as shown.
At $t = 0$ s, the ring is at point A.

Position of ring	Time(s)
at point A	0
at point C	
at point B	

A horizontal square conducting metal loop of one turn is placed in a uniform, steady magnetic field between two poles of an electromagnet, as shown below. The plane of the loop is perpendicular to the magnetic field.



Example 3.33: 2014 Question 13a (1 mark)

Students discuss different methods of causing a current to flow in the loop.
Choose **one or more** of the following options that would cause a current to flow in the loop.

A. moving the loop directly upwards in the field towards the N pole

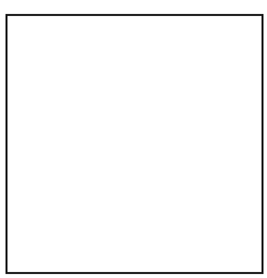
B. moving the loop sideways (to the left) but keeping it completely inside the field

C. moving the loop sideways (to the right) so that it moves out of the magnetic field

D. rotating the loop about a horizontal axis

Example 3.34: 2014 Question 13c (3 marks)

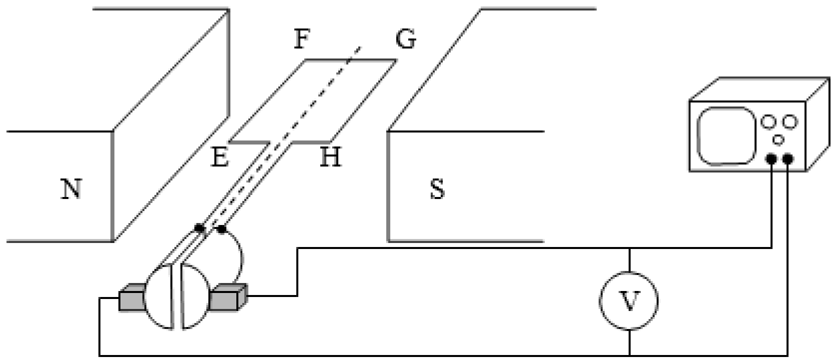
The magnetic field is reduced to zero.
On the figure below, indicate the direction of the resulting induced current in the loop. Explain your reasoning.



loop as viewed from above

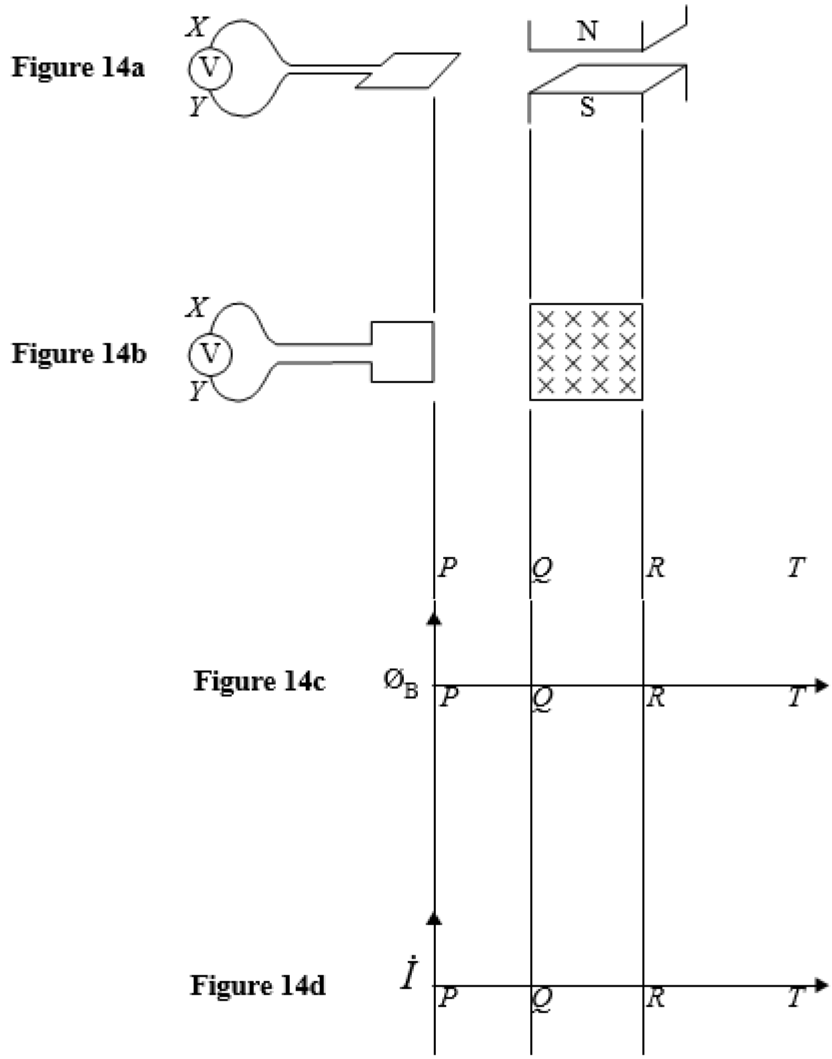
Example 3.35: 2015 Question 12c (3 marks)

The model is now set up as a DC generator, with the output connected to a voltmeter and oscilloscope via a commutator, as shown below, with the same coil of side length 4.0 cm and 10 turns, and a uniform magnetic field of 2.0×10^{-3} tesla.
The shaft is rotated by hand.



The shaft and coil make two complete revolutions per second.
Calculate the magnitude of the average voltage as shown on the voltmeter during one-quarter revolution. Show your working.

To study electromagnetic induction, students pass a square loop at constant speed through the pole pieces of a magnet, as shown in Figure 14a. Figure 14b shows the experimental set-up as viewed from above. The axes below indicate the same distances as shown in Figure 14b.
In answering Question 13, you do not have to include any calculations or values on the axes.



Example 3.36: 2015 Question 13a (2 marks)

On the axes in Figure 14c, sketch the magnetic flux as the front edge of the loop passes from *P* to *T*.

Example 3.37: 2015 Question 13b (2 marks)

On the axes in Figure 14d, sketch the emf, as measured by the voltmeter, as the front edge of the loop passes from *P* to *T*.

Example 3.38: 2015 Question 13c (4 marks)

Determine the direction of the current through the voltmeter as the loop enters the magnetic field. Write *X* to *Y* or *Y* to *X* in the answer box below. Explain how you determined this in terms of Lenz's Law.

Generation of electricity

- **explain the production of DC voltage in DC generators and AC voltage in alternators, including the use of split ring commutators and slip rings respectively.**

Transmission of electricity

- **compare sinusoidal AC voltages produced as a result of the uniform rotation of a loop in a constant magnetic field with reference to frequency, period, amplitude, peak-to-peak voltage (V_{p-p}) and peak-to-peak current (I_{p-p})**

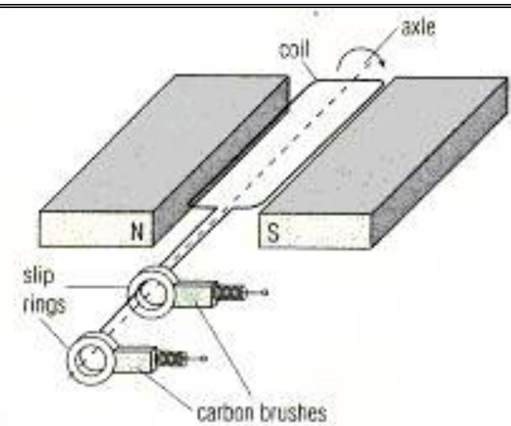
2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
	10	5, 6, 7	2, 3	6, 7		7a, b, c		18a, b, c	12d, 14a	17a, b, c, d

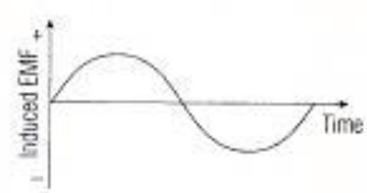
AC Generators (Alternators)

An AC generator has a rotating coil in a magnetic field, or a rotating magnetic field positioned inside a coil. Instead of a commutator, slip rings are used to keep contact with the brushes and the direction of the induced EMF changes every half cycle and an AC output is produced.

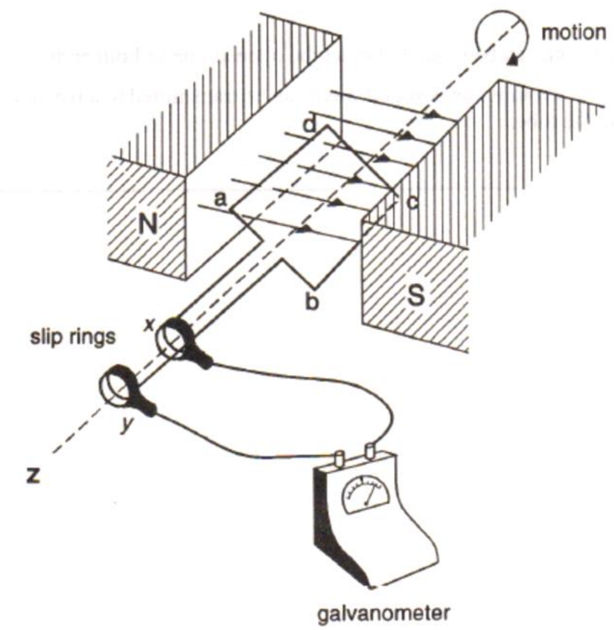
Slip rings are used, where one end of the loop is always attached to the same ring, so that the output varies sinusoidally, ie AC output.

If a split ring commutator is used the output is DC.

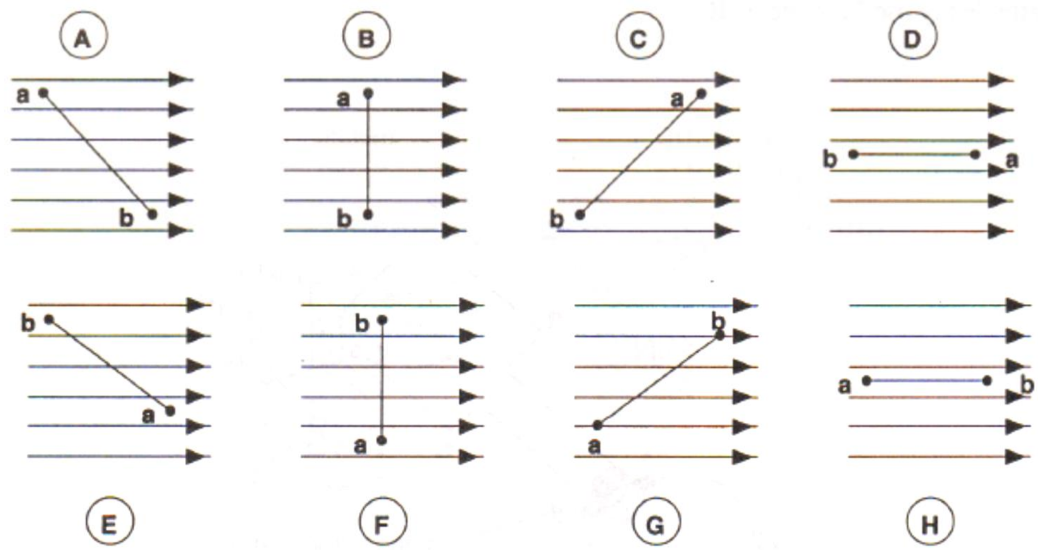




The figure shows a model generator which a student used to investigate electromagnetic induction. The student turned the coil at a slow constant speed and observed the current using a galvanometer as shown. The galvanometer has a central zero setting.



The figure below shows one complete cycle for the coil, viewed from position Z.

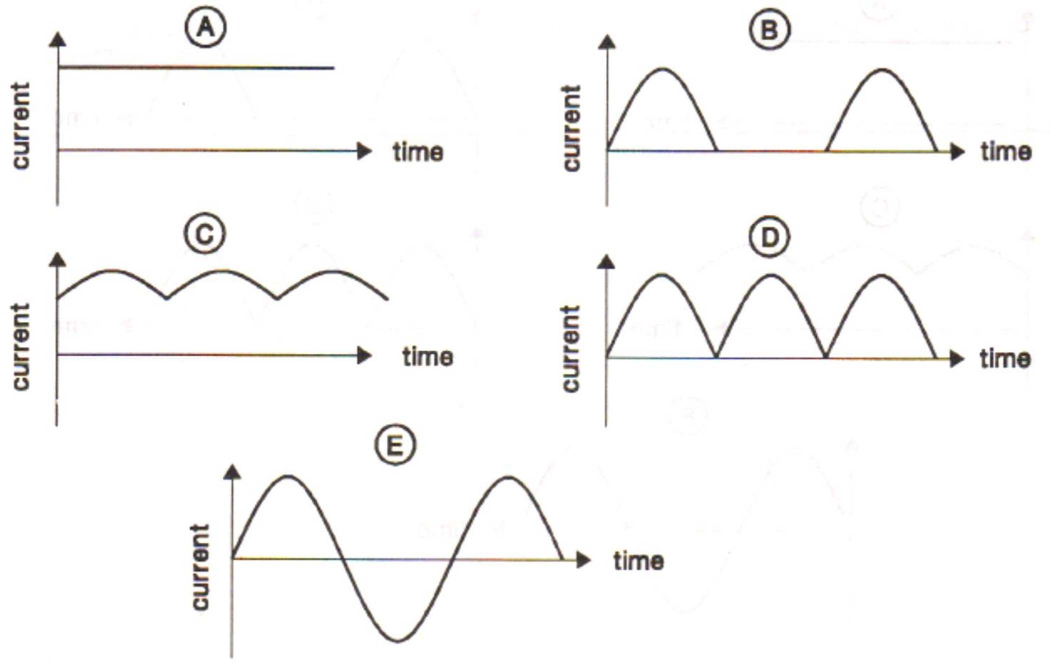


Example 3.39: 1993 Question 1 (1 mark)

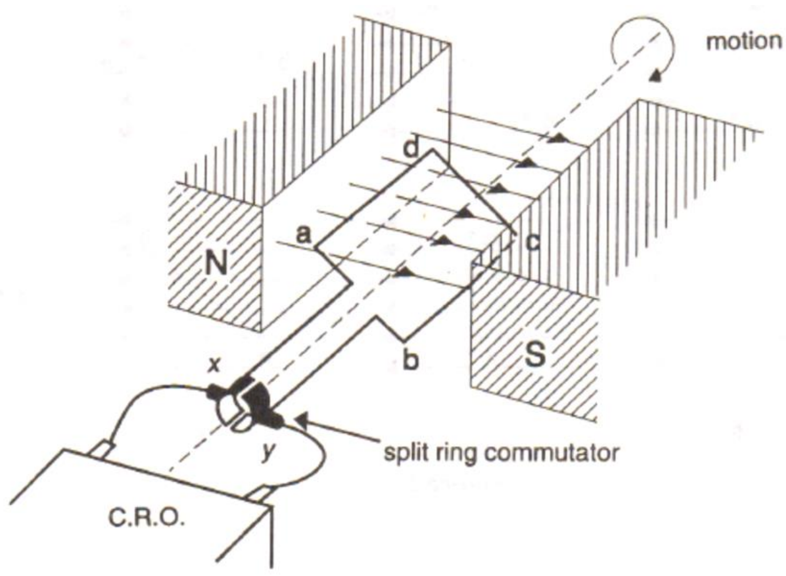
In the figure above, at which one or more positions would the magnitude of the magnetic flux through the coil have been a maximum?
(one or more answers)

Example 3.40: 1993 Question 2 (1 mark)

Which one of the following diagrams **(A – E)** best shows how the current through the galvanometer varied with time?



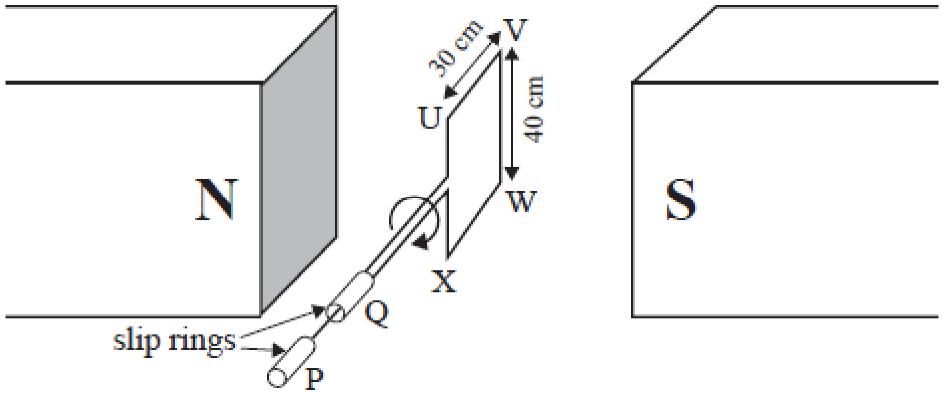
The student then modified the generator by removing the galvanometer and slip rings, and including a split-ring commutator instead, as shown below. The way the voltage across the brushes varied with time was observed using a cathode ray oscilloscope (C.R.O.).



Example 3.41: 1993 Question 3 (1 mark)

Which one of the waveforms **(A – E)** above, best shows what the student observed on the C.R.O., when the coil was rotated as before?

Students are experimenting with a simple AC generator, as shown below. It consists of a rectangular coil of *n* turns that rotates at a constant speed in a uniform magnetic field.



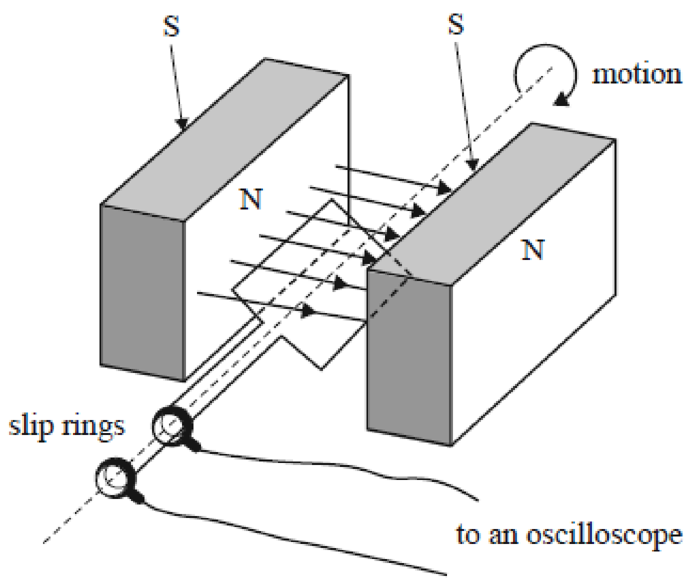
The uniform magnetic field in the region between the magnets is 0.030 T. The dimensions of the rectangular coil are 30 cm × 40 cm.

The coil is located completely within the uniform magnetic field of the two magnets.
The coil is rotating at a steady rate of 2 rotations per second.

Example 3.42: 2012 Question 7a (2 marks)

Describe how the magnetic flux through the rotating coil changes as the coil makes a complete rotation. Take the starting point of the rotation to be the position shown above. You do not need to include any calculations or numbers in your answer. You may use a sketch in your answer.

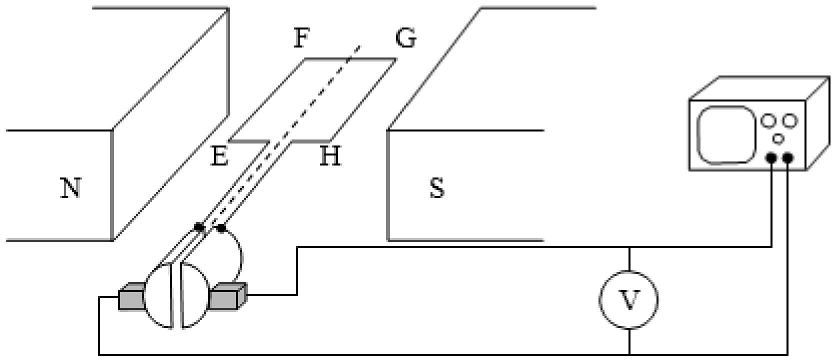
A sketch of a small model generator is shown below. The magnetic field is supplied by two permanent magnets. The output of the generator is fitted with slip rings and is connected to an oscilloscope.



Example 3.43: 2014 Question 18a (3 marks)

The display on the oscilloscope shows an AC signal.
Explain why the signal is AC rather than DC.

The model is set up as a DC generator, with the output connected to a voltmeter and oscilloscope via a commutator, as shown below, with the coil of side length 4.0 cm and 10 turns, and a uniform magnetic field of 2.0×10^{-3} tesla.
The shaft is rotated by hand.



Example 3.44: 2015 Question 12d (3 marks)

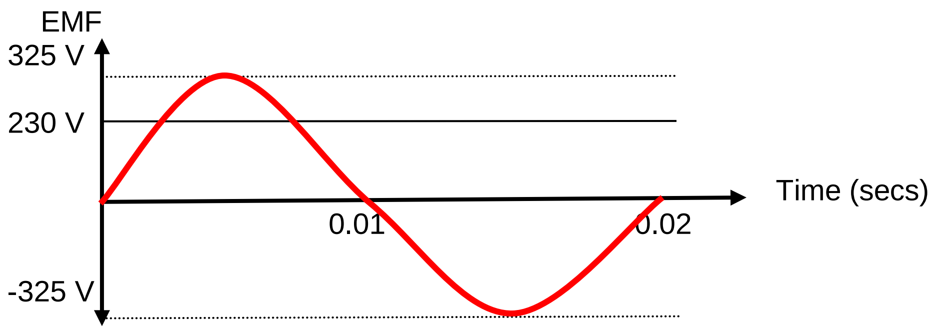
The students wish to convert this DC generator into an AC generator.
Describe the change or changes the student would have to make to achieve this. Explain your answer.

Transmission of electricity

- **compare alternating voltage expressed as the root-mean-square (rms) to a constant DC voltage developing the same power in a resistive component**
- **convert between rms, peak and peak-to-peak values of voltage and current**

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
				17		5a, b, c		14b	14b	

RMS Voltage – Peak to Peak.



The peak to peak voltage is from +325 to – 325. The peak voltage is 325 V. The Root Mean Square (RMS) voltage is the square root of the mean of the square of the potential difference.

The DC potential difference that transfers the same energy is given by $\sqrt{\frac{V_o^2}{2}}$ where V_0 is 325 V.

In Australia the RMS is equal to 230 V. An AC current can be given an RMS equivalent value in exactly the same manner. When doing calculations involving power etc. always use the RMS values, unless otherwise stated.

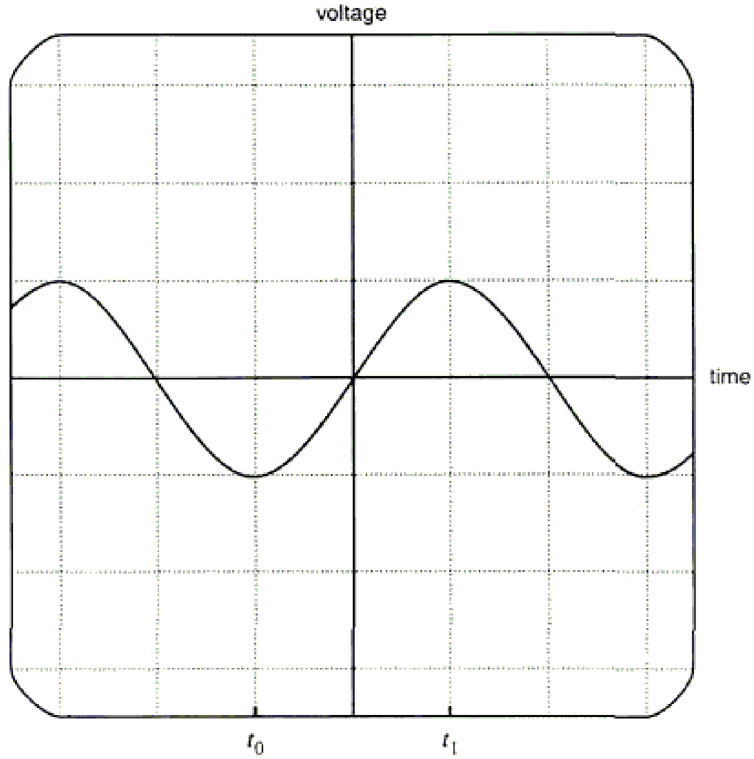
Household electricity supply

Two wires come from the power pole to the house. The ACTIVE wire is 230 V_{RMS}. The NEUTRAL wire is 0 V and is connected to the ground.

The cable from the pole goes first to a mains connection which contains a fuse in the active wire. Then it is connected to the switchboard or fuse box.

A main switch is placed in the active wire so that the power can be easily cut in case of emergency. Several lighting and power circuits originate at the switchboard and each has a fuse or circuit breaker (again in the active wire) so that individual circuits can be isolated and cut.

An oscilloscope is used to examine the waveform of the mains voltage from a domestic power outlet. The mains voltage is 240 V (RMS), at a frequency of 50 Hz. The **waveform** as seen on the oscilloscope screen is shown below.



Example 3.45: 2000 Question 6 (2 marks)

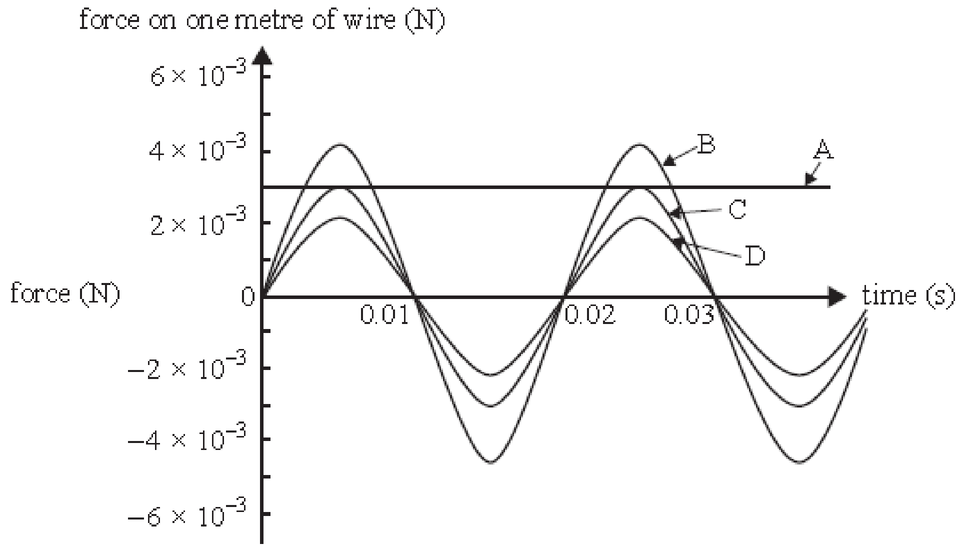
What is the time difference, in millisecond, between t_0 and t_1?

Example 3.46: 2000 Question 7 (2 marks)

What voltage does one vertical division of the oscilloscope screen correspond to?

Example 3.47: 2011 Question 17 (2 marks)

In a part of Victoria, a section of one wire of a transmission line is running horizontally from west to east. The current in the transmission line is 30 A_{RMS}. Earth's magnetic field there is pointing directly north, parallel to the ground, of strength 1.0 x 10^{-4} T. Which one of the following graphs **(A – D)** below best illustrates how the magnetic force acting on each metre of the wire varies as a function of time? Show a numerical calculation to justify your answer.



Transmission of electricity

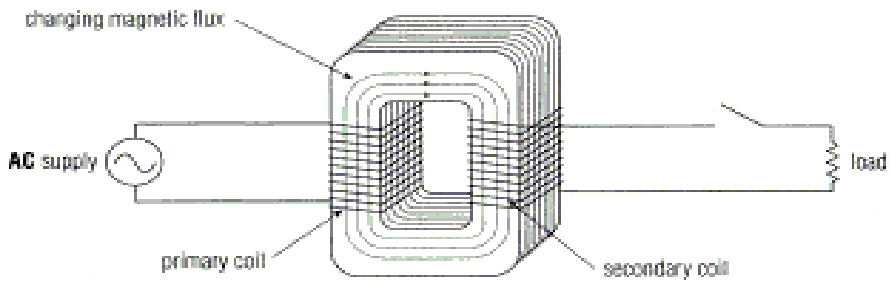
- **analyse transformer action with reference to electromagnetic induction for an ideal transformer:** $\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_S}{I_P}$

2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
9, 10, 14,15, 16, 17	11, 13	14, 15		19	16	6a, b	15a, b, c d	14a	16d, e, f	16a, b, c, d, e

c

Transformers

Transformers are a major component of the electrical distribution system, because they enable energy losses in transmission lines to be reduced. The changing (alternating) current in the primary coil generates a changing (alternating) magnetic field in the iron core. This changing field passes through the secondary coil and induces an EMF in the secondary.



In an ideal transformer the total transfer of magnetic flux is assumed, ∴ energy (power) is conserved.

Input power = Output power

$P_{in} = P_{out}$ $V_pI_p = V_sI_s$

In the **ideal** case: $\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{I_S}{I_P}$

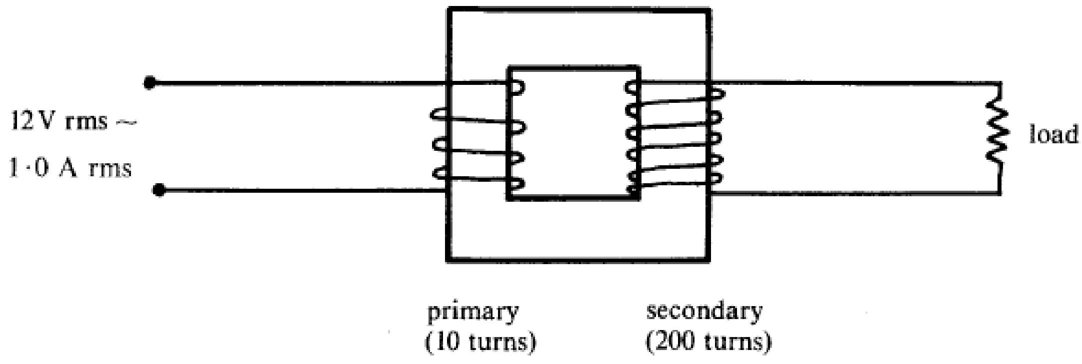
I_P = current in primary coil I_S = current in secondary coil.
V_P = voltage in primary coil V_S = voltage in secondary coil.
N_P = number of turns in primary coil N_S = number of turns in secondary coil.

In a step-up transformer, the number of secondary turns exceeds that in the primary coil, and therefore the output voltage is greater than the input voltage. In a step up transformer the current is stepped down by the same factor by which the potential difference is stepped up.

Step up transformer $V_{OUT} > V_{IN} \Rightarrow N_{OUT} > N_{IN}$ **Step down transformer** $V_{IN} > V_{OUT} \Rightarrow N_{IN} > N_{OUT}$

In a transformer using a DC battery as a supply, it is possible to induce a current in the secondary coil in only two circumstances: if the initial current in the primary coil is zero, and then a switch is used to allow the current to flow, and induced current will flow in the secondary coil as the current (primary) is changing from zero to a constant value.

An ideal transformer is supplied with an alternating voltage of 12 V rms and current of 1.0 A rms as shown.



Example 3.48: 1983 Question 70 (1 mark)

What is the peak voltage across the primary of the transformer?

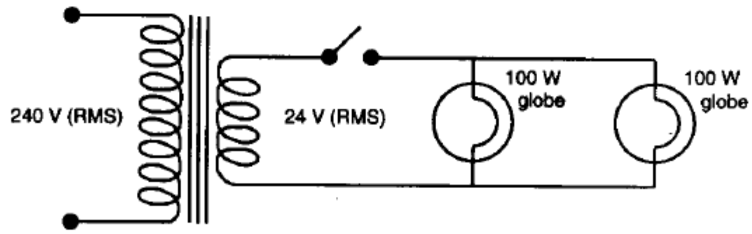
Example 3.49: 1983 Question 71 (1 mark)

What is the rms potential difference across the load in the secondary circuit?

Example 3.50: 1983 Question 72 (1 mark)

What is the power being supplied to the load?

For safety reasons it is necessary for the voltage supplied to the lights around a home swimming pool to be much lower than the voltage supplied to the house.
A transformer, which can be assumed to be 100 percent efficient, converts the 240 V (RMS) supplied to a house to 24 V (RMS). It supplies energy to two 24 V, 100 W light globes as shown below.

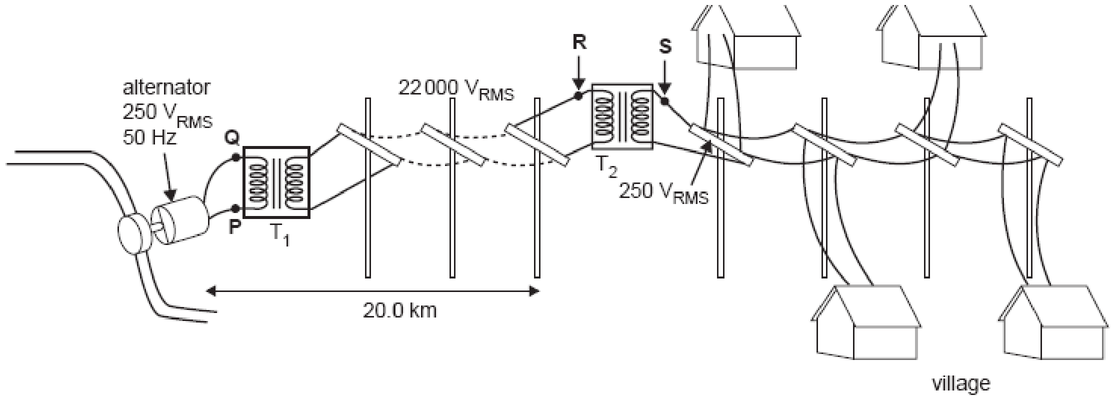


One pool owner decided to connect the input of the transformer to a 240 V DC supply instead of the 240 V AC mains supply.

Example 3.51: 1994 Question 10 (1 mark)

When the switch was closed the light globes did not light. In terms of the principles of operation of a transformer, explain why this was so.

A village has a maximum electrical power requirement of 100 kW. The power is supplied by an alternator, approximately 20.0 km from the village, which generates electricity at 250 V_{RMS} at a frequency of 50 Hz. This is converted by a step-up transformer (T_1) to 22 000 V_{RMS}, transmitted to the edge of the village by power lines with a total resistance of 2.0 Ω, and converted back to 250 V_{RMS} by a step-down transformer (T_2) near the village. A diagram of the system is below.



Example 3.52: 2006 Question 14 (3 marks)

Explain the operation of a transformer in terms of electromagnetic induction.

The alternator fails and the village is without power. One possibility is to replace the alternator with a DC generator but an electrician says this should not be used.

Example 3.53: 2006 Question 15 (2 marks)

Explain why an alternator rather than a DC generator should be used in this system.

Normally, the power being used in the village is 40 kW. However, as people come home, the power use increases to 80 kW. The alternator continues to provide 250 V_{RMS} at point P.

Example 3.54: 2006 Question 16 (2 marks)

Which one of the following (**A - D**) is the most likely effect on the voltage at point S?

A. The voltage would increase slightly.

B. The voltage would decrease slightly.

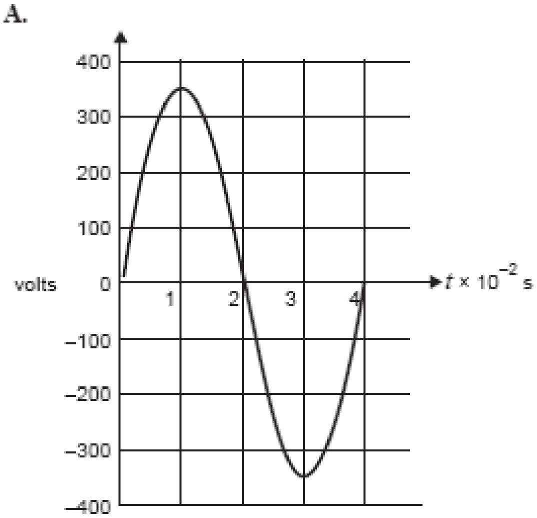
C. The voltage would remain the same.

D. The voltage would halve.

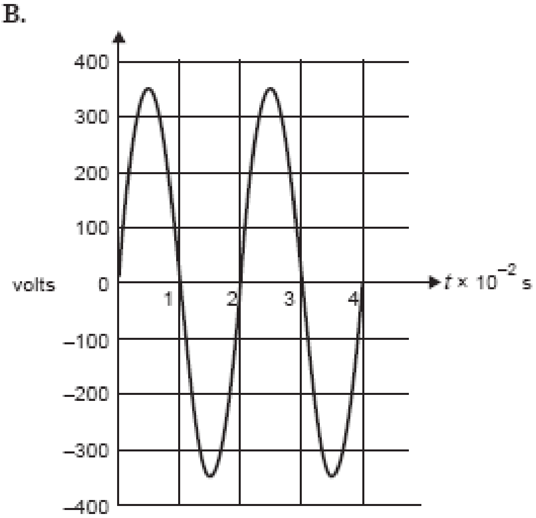
Example 3.55: 2006 Question 17 (2 marks)

Which one of the following graphs, (**A – D**), best represents the output (voltage against time) at the alternator output terminals (P and Q).

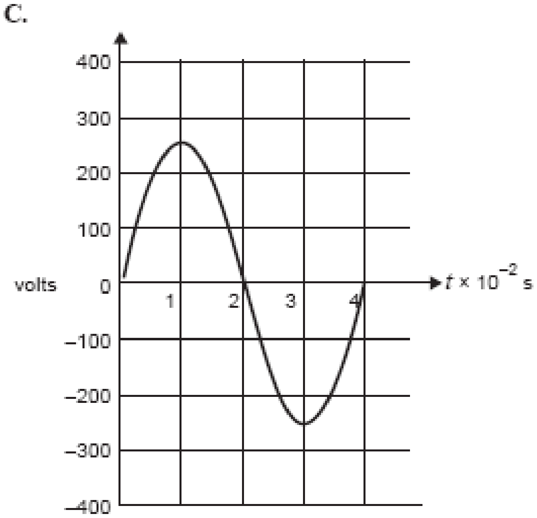
A.



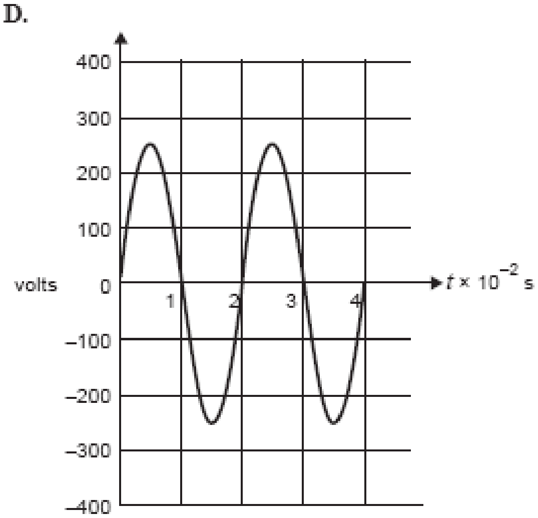
B.



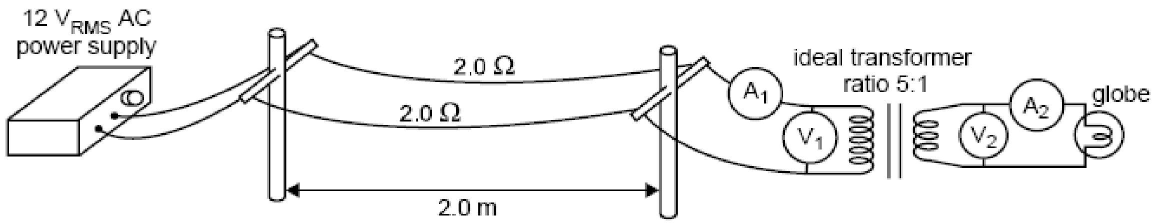
C.



D.



A class of physics students builds a model of an electricity distribution system. The circuit diagram of the model is shown below. Ignore the resistance of wires connecting the power supply, transformer and globe to the transmission lines.



Assume that the transformer acts as an ideal transformer (no energy losses in transformer) of ratio primary to secondary windings of 5:1. The current through ammeter A_1 is 0.50 A.

Example 3.56: 2007 Question 11 (3 marks)

What would be the reading on each of the meters A_2, V_1 and V_2?

Students are testing a transformer. The transformer is working correctly. The transformer has 600 turns in the primary coil and 150 turns in the secondary coil.

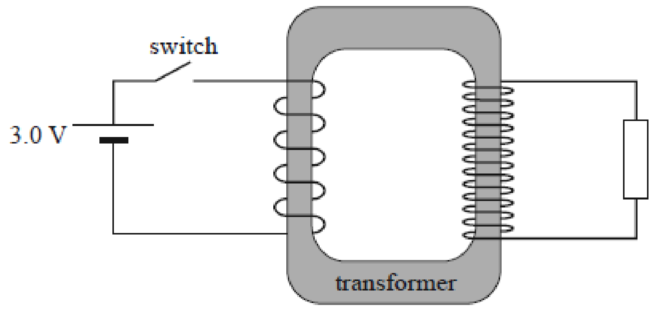
Example 3.57: 2012 Question 6a (1 mark)

The students attach the primary coil to a 20 V RMS AC power supply.
Calculate the RMS voltage across the secondary coil

Example 3.58: 2012 Question 6b (2 marks)

The students now connect the primary coil of the transformer to a 20 V battery and find, after a short time, that there is no voltage across the secondary coil.
Explain why there is no voltage produced across the secondary coil. In your explanation, include a reference to the relevant physics principle.

Students are experimenting with an ideal transformer. The students now modify the circuit, and connect a 3.0 V DC battery and a switch in the primary circuit. The circuit is shown below.



Example 3.59: 2013 Question 15d (3 marks)

The students have been asked to observe the current in the resistor as the switch is closed. Before the switch is closed, there is no current in the resistor. This does not surprise them. When the switch is closed, there is a very short pulse of current in the resistor. When the switch remains closed, there is no current in the resistor.
Explain why there is a short pulse of current as the switch is closed and why there is no current in the resistor as the switch remains closed. No numbers are required in your answer, but you should refer to the relevant law of physics.

An ideal transformer has 130 turns in the primary coil and 5 200 turns in the secondary coil.

Example 3.60: 2014 Question 14a (1 mark)

A DC voltage signal of 12 V is connected to the primary coil.
State the value of the steady voltage at the output of the secondary coil.

Transmission of electricity

- **analyse the supply of power by considering transmission losses across transmission lines**
- **identify the advantage of the use of AC power as a domestic power supply.**

2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
9, 10, 11, 12	11, 12	12,	11,12, 13	10,11, 12,13, 14, 15	14, 15 16, 17 20	13, 14, 15, 16	4a, b, c, d	18a, b, c, d	15a, b, c, d 16	16a, b, c,

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Power loss in transmission lines

Resistance of power lines is proportional to the length of the lines.

$P_{loss} = V_{loss} \times I_{transmission}$ but, $V_{loss} = I_{transmission} \times R$ $\Rightarrow P_{loss} = I^2_{transmission} \times R$

Transmitting at high voltages and relatively low current reduces power losses. This requires stepping up the voltage at the power station and stepping it down for industrial and domestic use. Typically, the power is sent from the generating station at voltages as high as 500 kV. As it arrives at a terminal station it is stepped down to 66 kV and then down to 11 kV at a substation. Pole transformers further step it down to 415 and 230 volts for domestic use. Power losses in transmission lines need to be considered in some questions. The power is not actually lost, it is degraded into heat, which becomes unusable. The power supplied to the consumer is equal to the power supplied at the start minus the power lost in transmission.

The power is transmitted in AC because it is able to be transformed either up or down. In contrast DC current is unable to be transformed necessitating transmission of large amounts of power, which would increase the energy loss resulting from large voltage drops.

Joe and Jan are installing two low-voltage lights in their garden. The lights are supplied from a transformer that has an output RMS voltage of 12 V, and is connected to the 240 V household supply.

Example 3.61: 2000 Question 4 (2 marks)

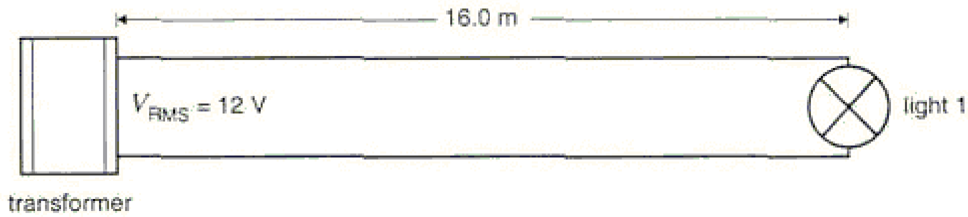
What is the value of the ratio $\dfrac{\text{number of turns on the primary coil}}{\text{number of turns on the secondary coil}}$

Each light is designed to operate at an RMS voltage of 12 V, and has a resistance **of 18 ohm, which does not** depend on temperature.

Example 3.62: 2000 Question 5 (2 marks)

What is the power dissipated in such a light when operated at an RMS voltage of 12 V?

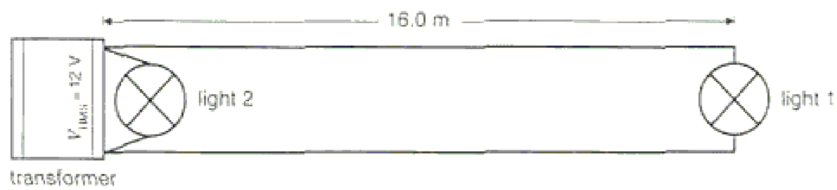
Joe and Jan now connect light 1 to the transformer using two wires, each 16.0 m long, as shown below. Each wire has a resistance of 0.050 ohm per metre.



Example 3.63: 2000 Question 6 (4 marks)

What is the RMS voltage across light 1? Show your working.

They now connect light 2 directly across the secondary of the transformer as shown below.



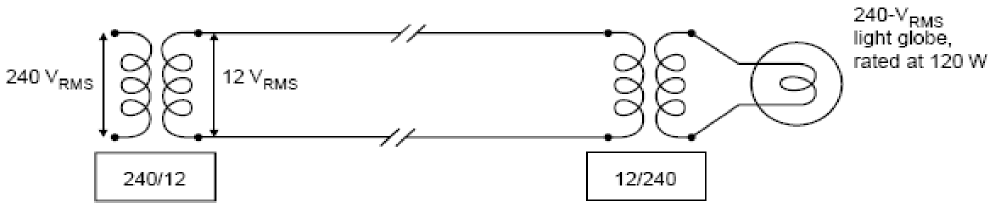
Joe and Jan thought that the two lights would be equally bright. In fact light 2 is brighter than light 1.

Example 3.64: 2000 Question 7 (4 marks)

Explain why this is so. Your answer should also include

- the **value** of the current flowing through light 2
- the **value** of the current flowing through light 1.

It is common practice for the wires in the cables associated with garden lights to carry only low-voltages (often 12 V_{RMS}). However it is more efficient to use 240 volt globes in the lights. In order to achieve this, the circuit shown below is used. At the 240 V supply, the voltage is stepped down using a 240 V to 12 V transformer, and at the light it is stepped up using a 12 V to 240 V transformer. The wires joining the two transformers are each many metres long. The transformers are ideal.



Example 3.65: 2001 Question 3 (2 marks)

The light globe is rated at 120 W when connected to a 240-V_{RMS} supply. What current should flow through it under this condition?

Example 3.66: 2001 Question 4 (3 marks)

When the system was tested, it was clear that the globe was not operating at the rated 120 W. Explain the reason for this.

Example 3.67: 2001 Question 5 (2 marks)

When the garden light is operating, the voltage across the input to the transformer that supplies the globe is 10 V_{RMS}. What is the voltage across the globe?

Under these conditions the current flowing through the long wires is 8.3 A.

Example 3.68: 2001 Question 6 (2 marks)

What current is flowing through the globe?

Example 292: 2001 Question 7 (2 marks)

What is the total resistance of the two wires? Remember that the transformers are ideal.

Example 3.69: 2001 Question 8 (2 marks)

Which **one or more** of the following changes would increase the voltage across the globe?

A. use wires of higher resistance

B. use wires of lower resistance

C. use transformers with ratios of 240:24 and 24:240

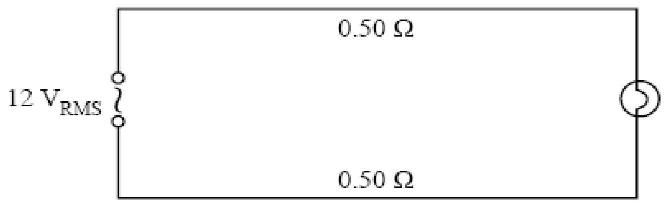
D. use transformers with ratios of 240:6 and 6:240

Bruce's garden has a pond with a fountain in it. Bruce buys a floodlight to illuminate the fountain. The resistance of the floodlight filament is 3.0 Ω when operating.

Example 3.70: 2008 Question 11 (3 marks)

First Bruce tests the floodlight before he installs it. He tests it by applying 12 V_{RMS} across the floodlight. What is the power used in the floodlight when supplied with a voltage of 12 V_{RMS}? Show working.

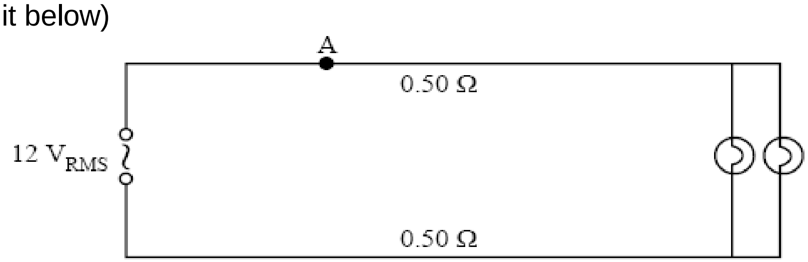
Bruce now installs the floodlight.
The electricity supply for the floodlight is supplied from the house using two wires (as shown below). Each of the two wires that connect the supply has a resistance of 0.50 Ω.



Example 3.71: 2008 Question 12 (3 marks)

When operating, what is the voltage across the floodlight? Show working.

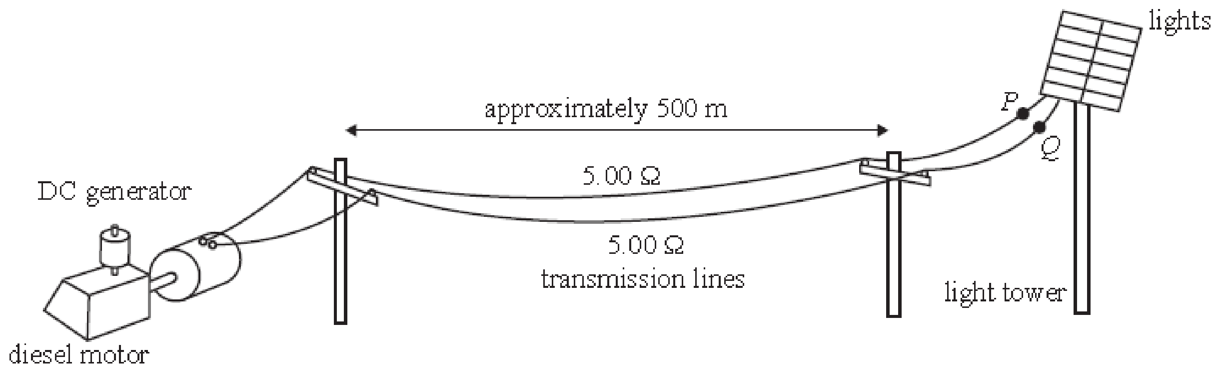
Bruce decides that the light is not bright enough and installs a second identical floodlight (as shown in the circuit below)



Example 3.72: 2008 Question 13 (3 marks)

What is the current now flowing through the wire at point A? Show working.

A diesel-powered portable DC generator is used to power lights on a light tower at an isolated football ground. The generator produces a constant 500 V DC. The generator is approximately 500 m from the light tower, and a two wire transmission line connects the generator to the lights. **Each** of the wires in the transmission lines has a resistance of 5.00 Ω. Ignore the resistance of the other connecting wires. The system is shown below.

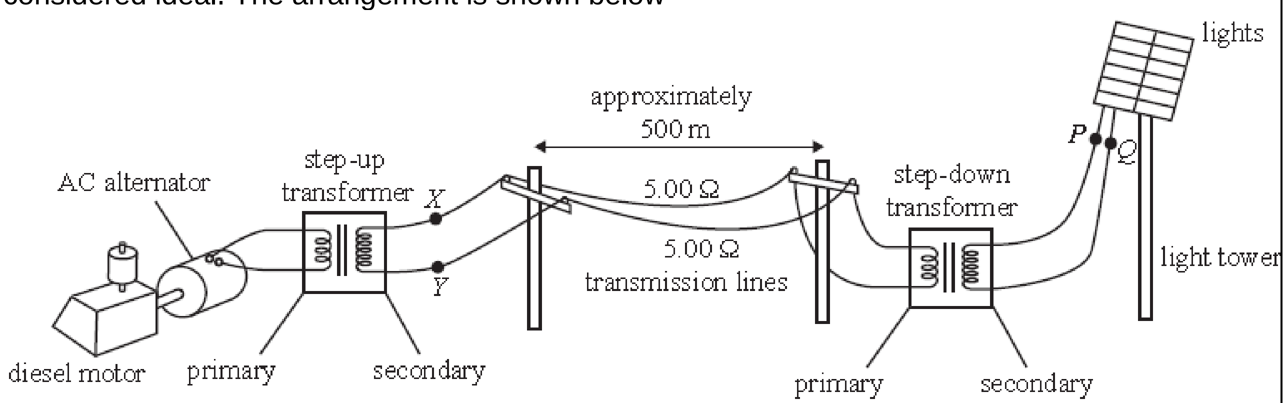


With the lights on, the generator has an output of 20.0 A.

Example 3.73: 2009 Question 11 (3 marks)

What is the voltage (potential difference) across the terminals (*PQ*) of the light tower?

The players find the lights too dim. They call in an electrician. She suggests the following.
• retain the diesel motor • replace the DC generator with an AC alternator producing 500 V_{RMS}
• insert a 1:10 step-up transformer between the alternator and the power lines, and a 10:1 step-down transformer between the power lines and the light tower. The transformers can be considered ideal. The arrangement is shown below



The lights are on. The resistance of each wire in the transmission lines is still 5.00 Ω. Ignore the resistance of the other connecting wires. The output of the alternator is 20.0 A_{RMS}. (The generator output was 20.0 A DC.) The primary of the step-down transformer has 4800 turns.

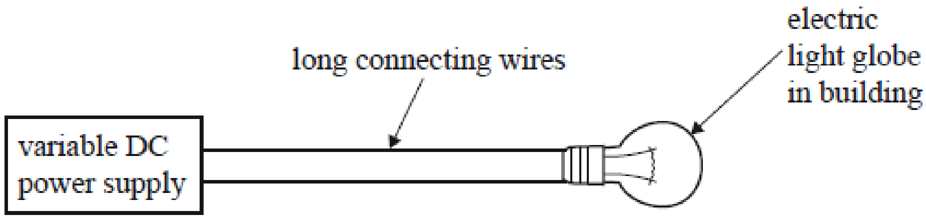
Example 3.74: 2009 Question 14 (2 marks)

What will be the power loss in the transmission lines now?

Example 3.75: 2009 Question 15 (3 marks)

What will be the voltage at the output of the step-down transformer? Give your answer correct to three significant figures.

Jemima is planning to operate an electric light globe in a building some distance from her house. To do this, she connects two long wires from a variable voltage DC power supply in the house to an electric light globe in the building.



The wires have a total resistance of 5.0 Ω. The DC power supply produces a constant output voltage of 13 V. The light globe in the building is designed to operate at 6.0 V. Assume that its resistance is a constant 1.5 Ω.
When Jemima switches on the circuit, she measures the voltage at the light globe to be only 3.0 V.

Example 3.76: 2014 Question 15d (3 marks)

Jemima knows that more brightness can be achieved if she sets the DC power supply to a higher constant voltage. However, she also knows that it is unwise to run the light globe at greater than 6.0 V as it will probably fail.
Calculate the greatest voltage that Jemima can set the DC power supply at, without exceeding 6.0 V across the light globe in the building. Show your working.

Example 3.77: 2014 Question 16 (4 marks)

Efficient transmission of electric power over long distances often involves the use of step-up and step-down transformers.
Outline how the use of these transformers reduces transmission losses. Include relevant physics formulas.