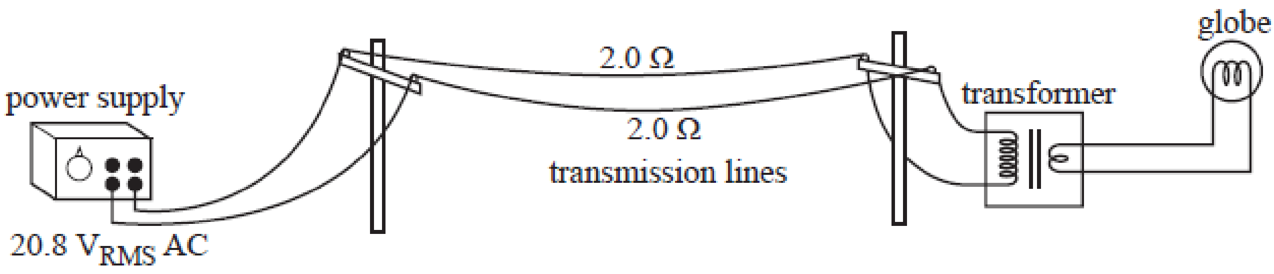
Transformers and Transmission

Multiple choice questions

To model an AC transmission system students set up their experiment as shown below.
They set the output of the power supply to 20.8 V_{RMS} AC. They use a 10:1 step-down transformer at the other end. The output of the transformer is connected to the globe. The globe is operating at 2.0 V and 4.0 W.



Before connecting the circuit, the students test the power supply by connecting it to an oscilloscope as shown below.

Example 1 2010 Question 18, 2 marks

What signal will they observe on the oscilloscope?

A. 20.8 V peak

B. 20.8 V peak to peak

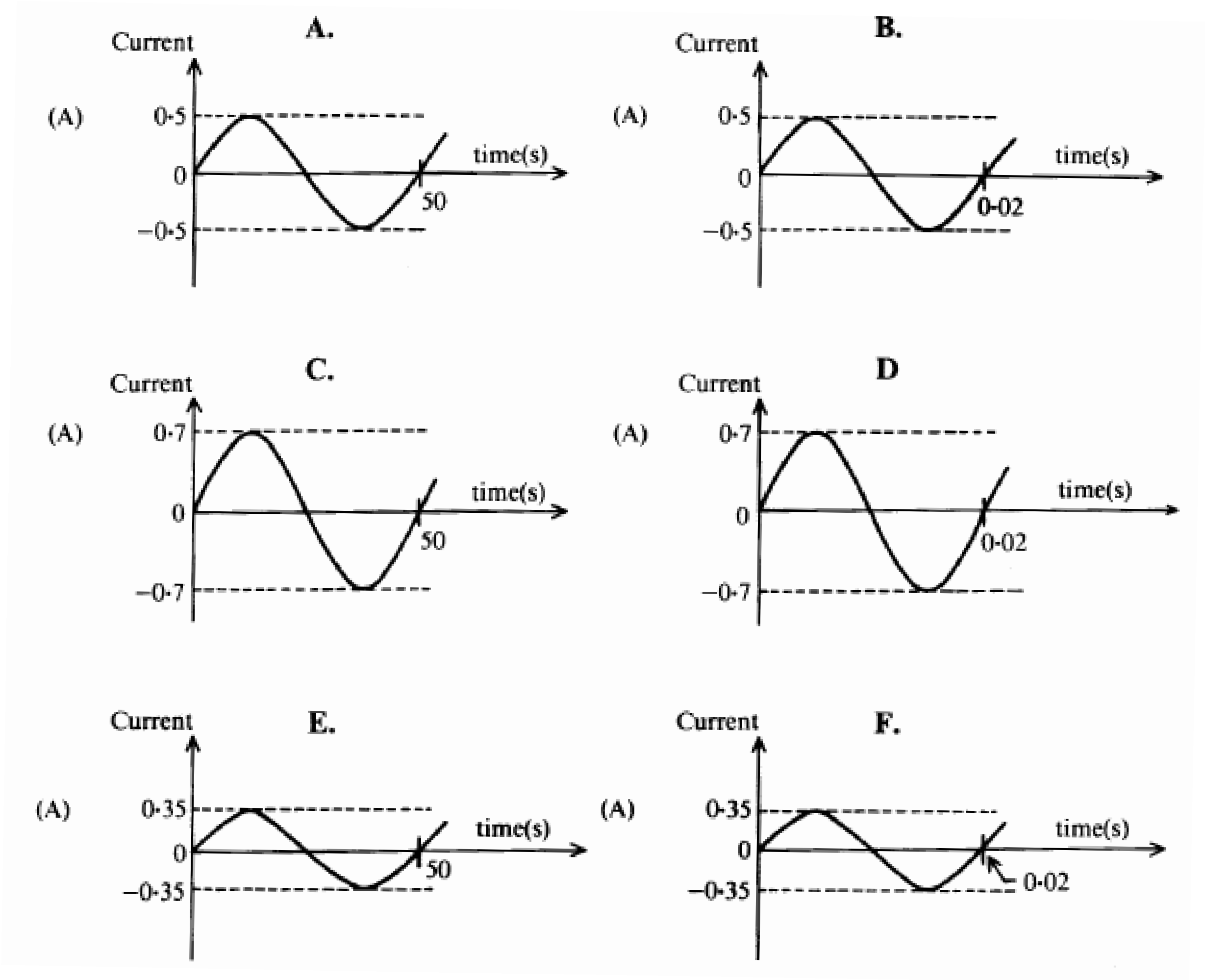
C. 29.4 V peak to peak

D. 58.8 V peak to peak

A 50 Hz AC supply is connected to a circuit and a rms current of 0.5 A is observed to flow.

Example 2 1984 Question 65, 1 mark

Which graph (**A - F**) below best represents the variation of current with time for the circuit?



Example 3 1978 Question 68, 1 mark

It has been found that for a transformer the ratio of the power output to the power input is

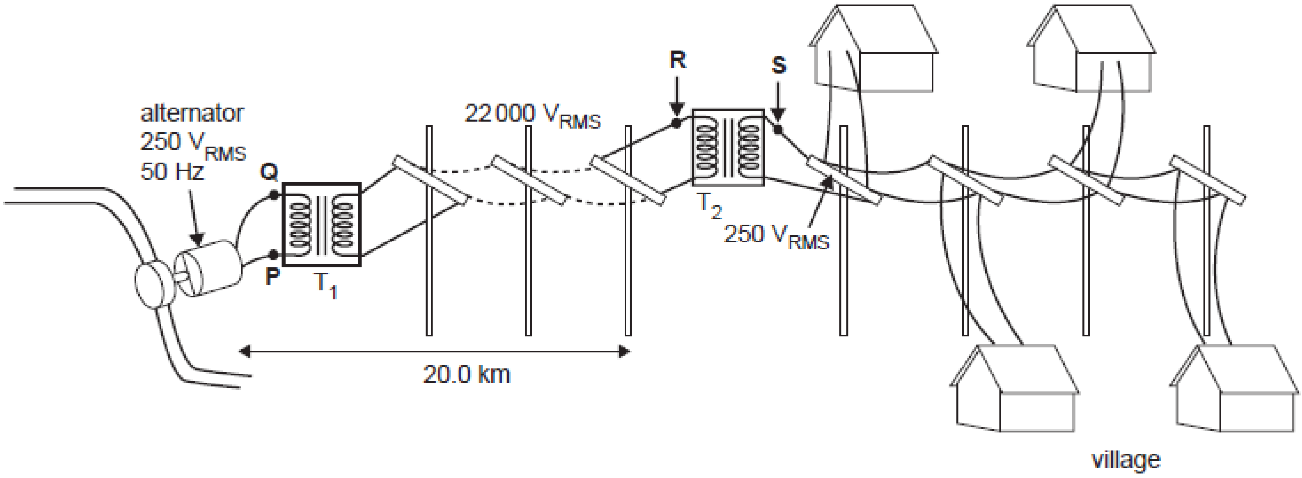
A. less than one in all cases because of heat losses.

B. less than one only if it is a step-down transformer.

C. more than one only if it is a step-up transformer.

D. more than one if an iron core replaces an air core.

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 (T1) 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 (T2) near the village. A diagram of the system is shown below.



A number of different transformers, (**A – D)**, are available for use as transformer T_1 in the system. Their characteristics are shown below.

Transformer	Number of turns in primary (input)	Number of turns in secondary (output)
A	62 200	500
B	44 000	500
C	500	44 000
D	500	62 200

Example 4 2006 Question 13, 2 marks

Which one of the transformers, **A - D**, would be suitable for use as transformer T_1?

Example 5 2011 QLD Question 13, 1 mark

A step-down transformer runs off 200.0 V with 400.0 turns on the primary side. If the output voltage is 25.0 V, how many turns are in the secondary coil?

A 25

B 50

C 100

D 200

Example 6 2001 NSW Question 11, 1 mark

A transformer has a primary coil with 60 turns and a secondary coil with 2300 turns.
If the primary voltage to the transformer is 110 V, what is the secondary voltage?

A. 2.4×10^{-4} V

B. 2.4×10^{2} V

C. 1.3×10^{3} V

D. 4.2×10^{3} V

Example 7 2003 NSW Question 8, 1 mark

A neon sign requires a 6000 V supply for its operation. A transformer allows the neon sign to operate from a 240 V supply.
What is the ratio of the number of secondary turns to the number of primary turns for the transformer?

A. 1 : 40

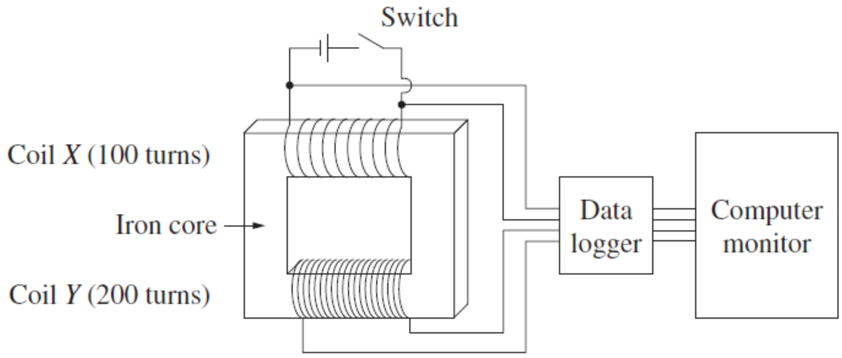
B. 1 : 25

C. 25 : 1

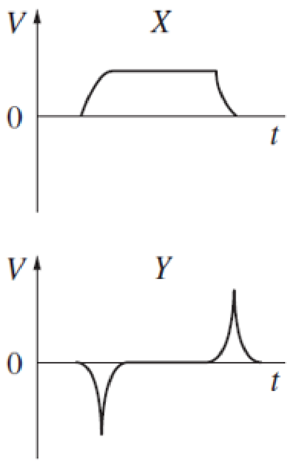
D. 40 : 1

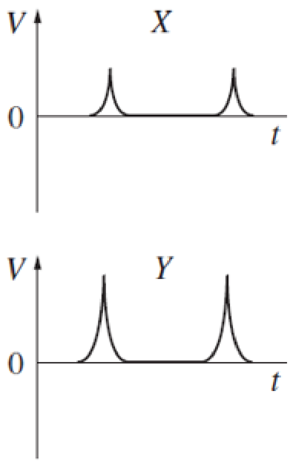
Example 8 2006 NSW Question 10, 1 mark

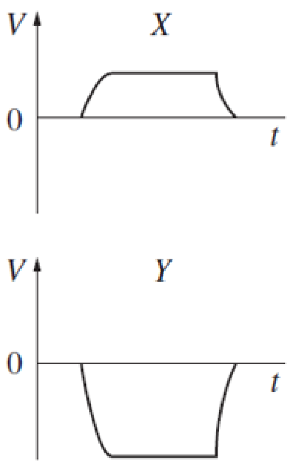
The apparatus shown is designed to investigate the operation of a transformer.

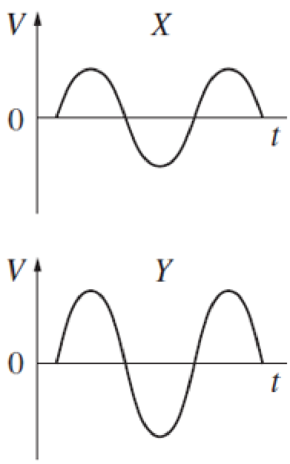


A student closes the switch for a short time, then opens it. The data logger records values of voltage for both coils for the duration of the investigation. The data logger software displays the results as a pair of voltage–time graphs on a computer monitor.
Which pair of graphs best depicts the student's results?

A.


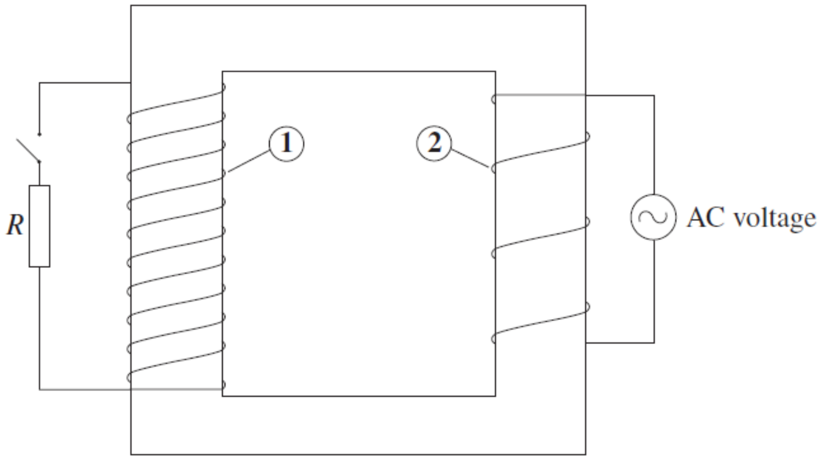
B.


C.


D.


Example 9 2010 NSW Question 10, 1 mark

The diagram shows a model of a transformer in a circuit.



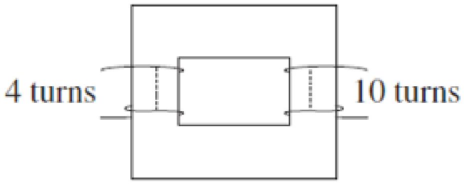
Which of the following correctly identifies Part 1 and Part 2 and the function of this transformer?

	Part 1	Part 2	Function of transformer
A.	Primary coil	Secondary coil	Step-up
B.	Secondary coil	Primary coil	Step-down
C.	Primary coil	Secondary coil	Step-down
D.	Secondary coil	Primary coil	Step-up

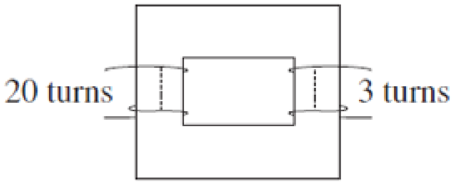
Example 10 2012 NSW Question 10, 1 mark

Which of the following ideal transformers could be used to convert an input voltage of 20 volts AC to an output voltage of 2 volts AC?

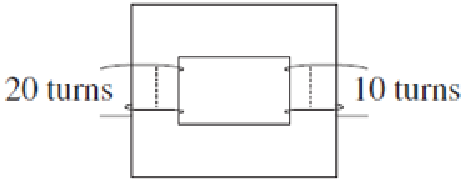
A.



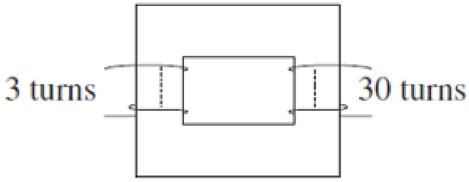
B.



C.



D.



Example 11 2016 NSW Question 1, 1 mark

Some mobile phones are recharged at a power point using a charger that contains a transformer. What is the purpose of the transformer?

A. To convert AC at the power point to DC

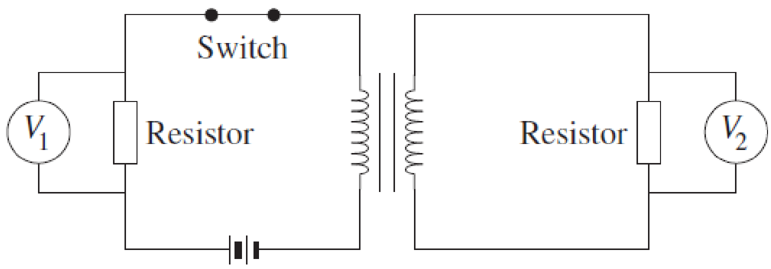
B. To convert DC at the power point to AC

C. To increase the AC voltage at the power point

D. To decrease the AC voltage at the power point

Example 12 2017 NSW Question 14, 1 mark

The diagram shows a DC circuit containing a transformer.

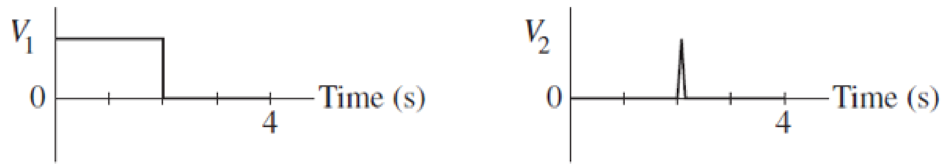


The potential differences V_1 and V_2 are measured continuously for 4 s. The switch is initially closed.

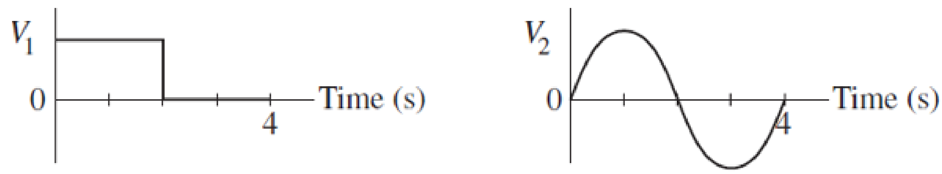
At t = 2 s, the switch is opened.

Which pair of graphs shows how the potential differences V_1 and V_2 vary with time over the 4-second interval?

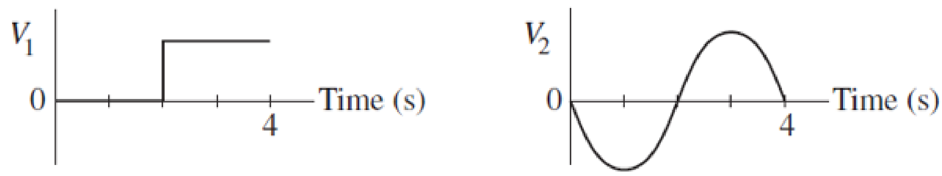
A.



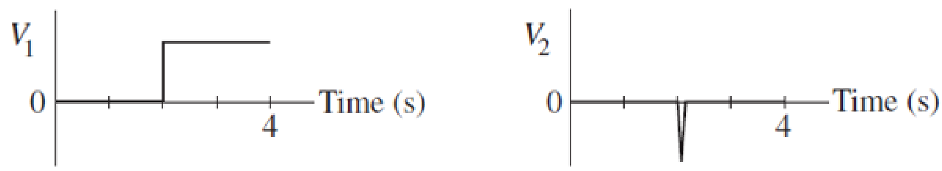
B.



C.



D.



Example 13 2002 NSW Question 6, 1 mark

What is the role of a transformer at an electrical power station?

A. To reduce heating in the transmission lines by stepping up the voltage

B. To reduce heating in the transmission lines by stepping up the current

C. To increase heating in the transmission lines by stepping up the voltage

D. To increase heating in the transmission lines by stepping up the current

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The power dissipated in an ohmic resistor can be written as either $P = \frac{V^2}{R}$ or $P = i^2R$, where V is the potential difference across the resistor, I is the current through the resistor and R is the resistance of the resistor.
In AC power transmission the power authority wishes to minimise power losses in the transmission lines while still providing sufficient power for the consumers at the end of the transmission lines.

Example 14 1984 Question 54, 1 mark

Which one or more of the following statements best describes how this might be achieved?

A. Transmit at low voltage and high line current. The formula $P = \frac{V^2}{R}$ means that low voltage gives low power loss.

B. Transmit at high voltage and low line current. The formula P: i^2R means that low current gives low power loss.

C. Make the line resistance as large as possible. The formula $P = \frac{V^2}{R}$ means that large resistance gives low power loss.

D. Make the line resistance as low as possible. The formula $P = i^2R$ means that low resistance gives low power loss.

(one or more answers)

Example 15 2010 NSW Question 9, 1 mark

Why is high voltage used to transmit electrical energy from power stations to users?

A. It helps to protect the system from lightning strikes.

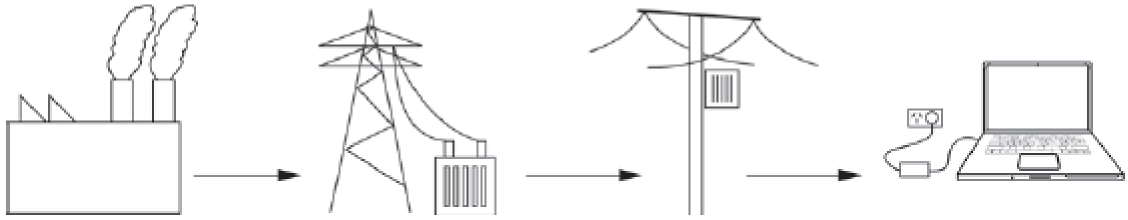
B. It allows the supporting structures to have smaller insulators.

C. It minimises the effects of the electrical resistance of the wires.

D. It ensures that, even with voltage losses, 240 V will still reach the user.

Example 16 2013 NSW Question 10, 1 mark

The diagram represents the transfer of electrical energy from a power station to a laptop computer.



Which flow diagram shows the correct use of transformers in this transfer?

A. Step-down → Step-up → Step-up → Step-down

B. Step-down → Step-down → Step-up → Step-up

C. Step-up → Step-down → Step-down → Step-down

D. Step-up → Step-up → Step-down → Step-up

Example 17 2014 NSW Question 5, 1 mark

Electricity is transported over long distances by transmission lines that are supported by pylons.
How are these transmission lines protected from lightning strikes?

A. The pylons are insulated from the ground.

B. There is a grounded wire on top of each pylon.

C. The transmission lines carry voltages similar to that of lightning.

D. Large ceramic insulators separate the transmission lines from the pylons.

Example 18 1982 Question 71, 1 mark

A length L of copper wire has a resistance R and a resistivity ρ.
A length 2L of the same copper wire would have

A. a resistance 2R and a resistivity 2ρ.

B. a resistance 2R and a resistivity ρ.

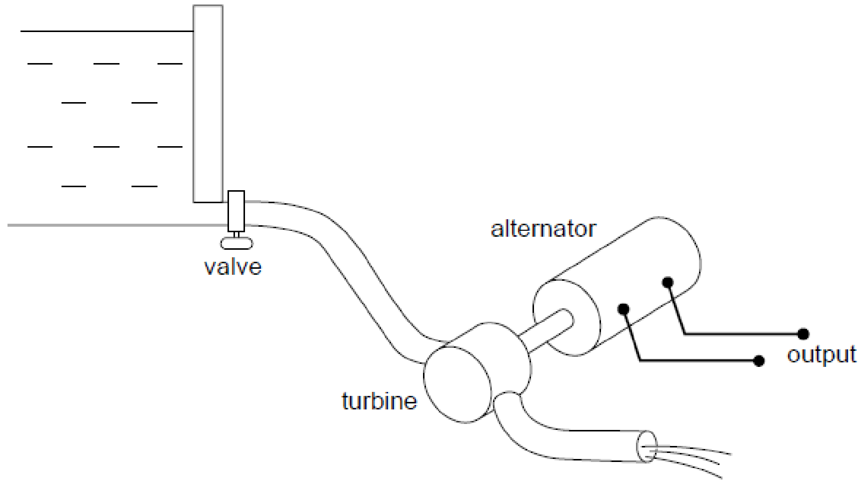
C. a resistance 2R and a resistivity ρ/2.

D. a resistance R and a resistivity 2ρ.

E. a resistance R and a resistivity ρ.

F. a resistance R and a resistivity ρ/2.

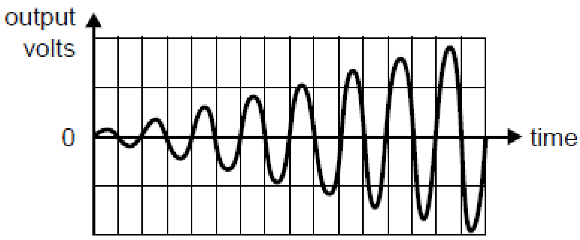
Another alternator is driven by a water turbine, as shown below.



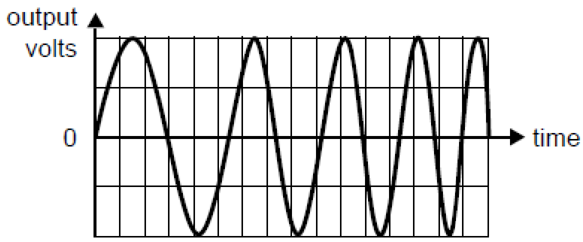
Question 19 2007 Question 10, 2 marks

When the valve is opened, water begins to flow and the alternator gradually speeds up from stationary.
Which one of the following graphs **(A. – D.)** best represents the shape of the output voltage as the alternator speeds up from rest?

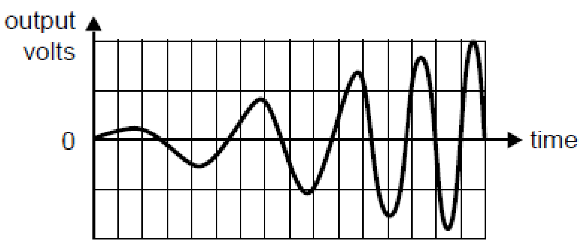
A.



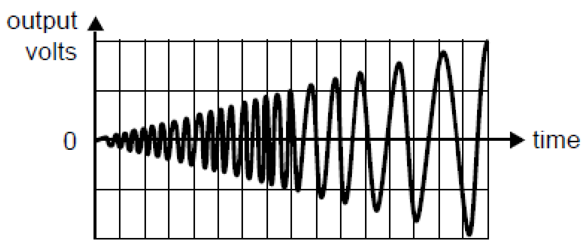
B.



C.



D.



Extended questions

A 24 watt globe is operated from a 6.0 Volt RMS alternating current supply.

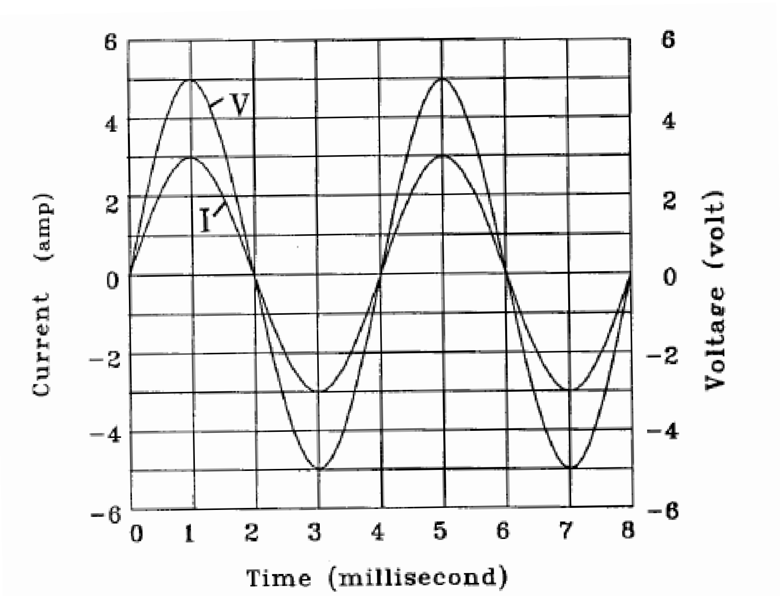
Example 20 1985 Question 49, 1 mark

What is the resistance of the globe when it is in operation?

Example 21 1985 Question 50, 1 mark

What is the peak value of the supply voltage?

To test the power output of an amplifier, Susan, an electronics technician, uses a cathode-ray oscilloscope to display the alternating current (I) through, and the voltage (V) across, the terminals of the loud speaker to which it is connected. The signals are shown in the diagram below.



Example 22 1990 Question 57, 1 mark

What is the RMS voltage across the speaker terminals?

Example 23 1990 Question 59, 1 mark

What is the resistance of the speaker?

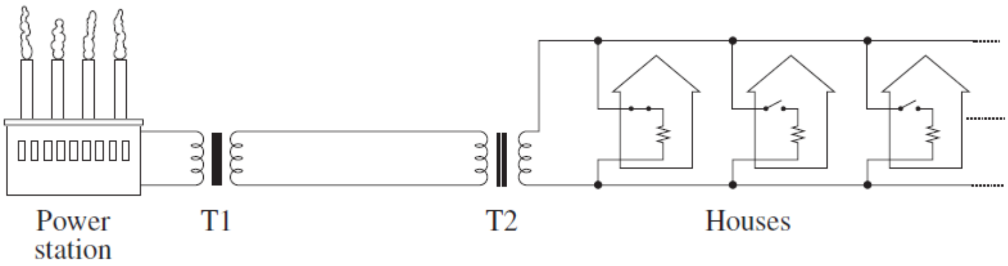
A conductor of length 10 cm and uniform diameter 1 mm has a resistance of 100 Ω.

Example 24 1985 Question 52, 1 mark

Calculate the resistance of a conductor of the same material with length 20 cm and uniform diameter 2 mm.

Example 25 2018 NSW Question 30, 6 marks

The diagram shows a model of a system used to distribute energy from a power station through transmission lines and transformers to houses.



During the evening peak period there is an increase in the number of electrical appliances being turned on in houses.
Explain the effects of this increased demand on the components of the system, with reference to voltage, current and energy.

A generator is capable of producing 3.00×10^2 kW of electricity at 415 V AC. Its output is stepped up to 11.0 kV for transmission.

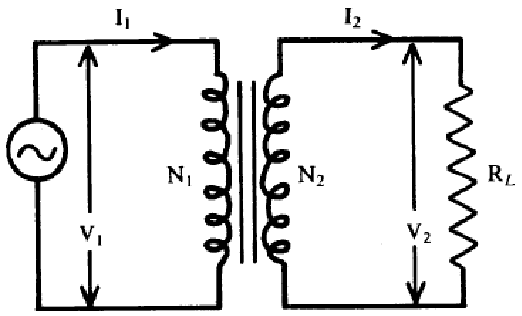
Example 26 2018 WA Question 1a, 1 mark

Determine the primary to secondary turns ratio of the step-up transformer used at the power station.

Example 27 2018 WA Question 1b, 2 marks

Determine the current available at the output of the step-up transformer.

The figure below shows an ideal transformer with a load resistance R_1 connected across the secondary coil. The primary current and voltage are marked as I_1 and V_1 and the secondary current and voltage as I_2 and V_2.
The primary coil has N_1 turns and the secondary coil has N_2 turns.



Assume that power transfer through the transformer is 100 per cent efficient.

Example 28 1984 Question 70, 1 mark

Write an expression for the secondary current I_2, in terms of I_1, N_1 and N_2.

Jamie has a study lamp that uses a 40 W globe that operates at 18 V_{RMS}. The lamp plugs into the 240 V_{RMS} supply, and a transformer (assumed ideal) in the base of the lamp provides the 18 V_{RMS} for the globe. The secondary coil of this small transformer has 30 turns.

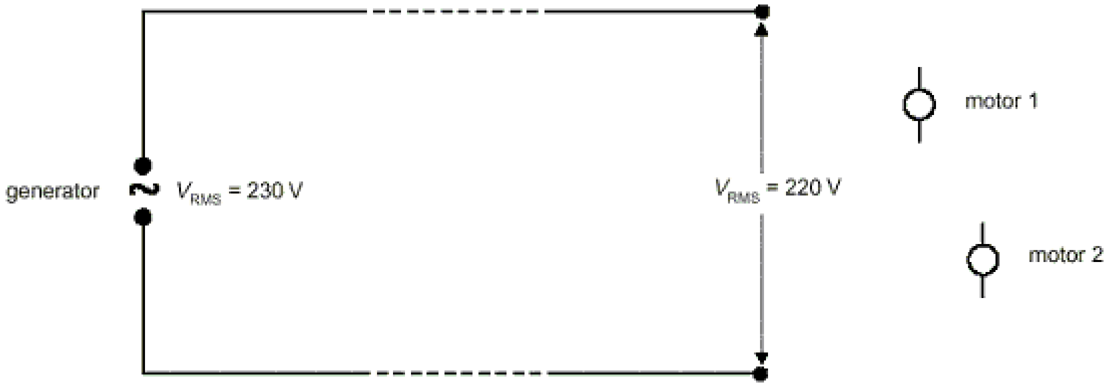
Example 29 2008 Question 14, 2 marks

How many turns are on the primary coil? Show working.

Example 30 2008 Question 15, 3 marks

When operating, what is the current flowing in the **primary** coil? Show working.

A generator at a farmhouse supplies electricity to two motors in a workshop, which is several kilometres from the house. The RMS voltage at the generator is 230 V. When the two motors are operating, the RMS voltage at the workshop is 220 V. When operating, the RMS current in motor 1 is 13 A and that in motor 2 is 10 A.
The figure below shows the generator connected to the workshop, but the wiring to the motors has been omitted.



Example 31 1997 Question 4, 1 mark

Show the wiring to the two motors.

Example 32 1997 Question 5, 1 mark

How much power is supplied by the generator when the two motors are running?

Example 33 1997 Question 6, 2 marks

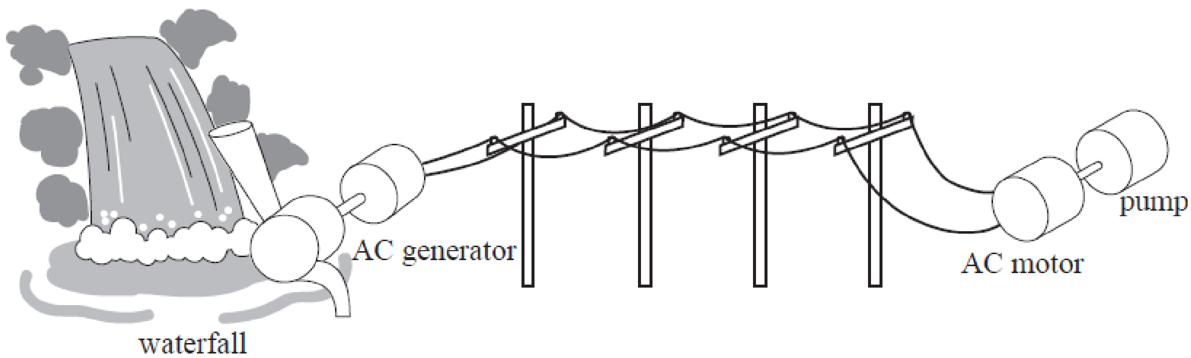
How much electric power is lost in the cables which connect the generator and the workshop? Show your working.

A farmer uses an AC motor to power an irrigation pump. The motor needs 900 V RMS AC input for the pump to operate correctly. When the motor is running with 900 V RMS AC, the motor draws 50 A RMS AC current.

Question 34 2012 Question 4a, 2 marks

a. Calculate the power input to the motor when the pump is operating correctly. You may assume that the motor uses power just like a resistor. Give your answer in kilowatt.

To supply electricity to the AC motor that drives the pump, a water-driven AC generator is installed at a waterfall some distance away from the pump. The generator provides current at a voltage of 1000 V RMS AC.
The farmer uses two aluminium wires to link the generator to the pump, as shown below. The wires have a total resistance of 7.0 Ω.



Question 35 2012 Question 4b, 2 marks

The motor has a constant resistance of 18 Ω.
Calculate the current flowing in the aluminium connecting wires.

Question 36 2012 Question 4c, 3 marks

Determine whether the pump will operate correctly. Support your conclusion with calculations.

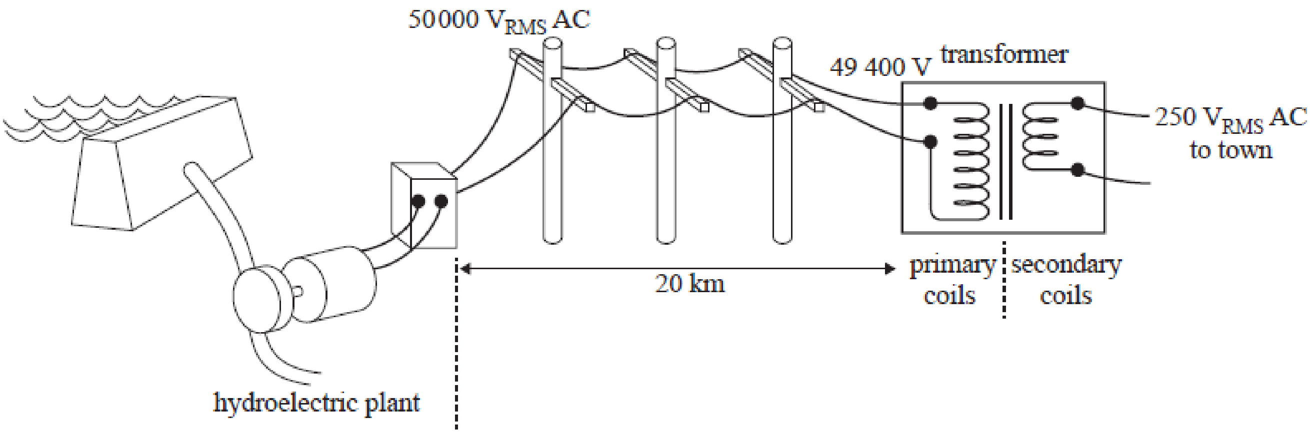
Question 37 2012 Question 4d, 4 marks

The farmer wishes to reduce the power losses in the electrical connections between the AC generator at the waterfall and the AC motor powering the irrigation pump. It is not possible to move the position of either the AC generator or the AC motor.
Identify and describe two different changes that would reduce the power losses between the AC generator and the AC motor. In your answer, you must also explain how each of the two changes you identified would reduce power losses.
first change

second change

Use the following information to answer Questions 13–16.

A small town is supplied with electricity from a small hydroelectric generation plant about 20 km from the town. Electricity is transmitted to the town through a two-wire high-voltage transmission line.
The input voltage to the transmission lines at the generator end is 50 000 V_{RMS} AC.
The current in the lines is 15 A_{RMS}. At the edge of town, a transformer converts this into 250 V_{RMS} AC for use in the town.
The system is shown below



Example 38 2011 Question 13, 2 marks

Calculate the power supplied to the transmission lines. Show your working.

Example 39 2011 Question 14, 3 marks

Some townspeople are concerned about the high voltages, and propose that the same power could be transmitted more safely at a lower transmission voltage. Explain clearly why this proposal would increase power losses in the transmission process.

The proposal is not accepted, and the transmission lines operate as originally designed.
With a current of 15 A_{RMS} the total power loss in the transmission lines is 9000 W

Example 40 2011 Question 15, 2 marks

Calculate the total resistance of the transmission lines

At the edge of town, a transformer is used to reduce the voltage to 250 V_{RMS} AC for use in the town. The voltage at the input to the substation is 49 400 V_{RMS}.

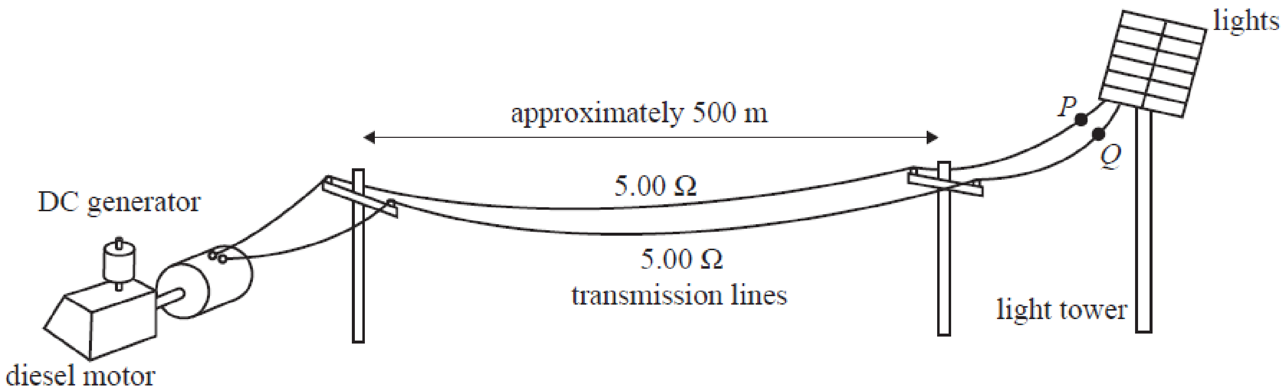
Example 41 2011 Question 16, 2 marks

Assuming that the transformer is ideal, calculate the value of $\frac{\text{current in the secondary coils}}{\text{current in the primary coils}}$

The following information relates to Questions 9 – 11.

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.

Question 42 2009 Question 9, 2 marks

What is the power output of the generator?

Question 43 2009 Question 10, 2 marks

What is the **total** power loss in the transmission lines?

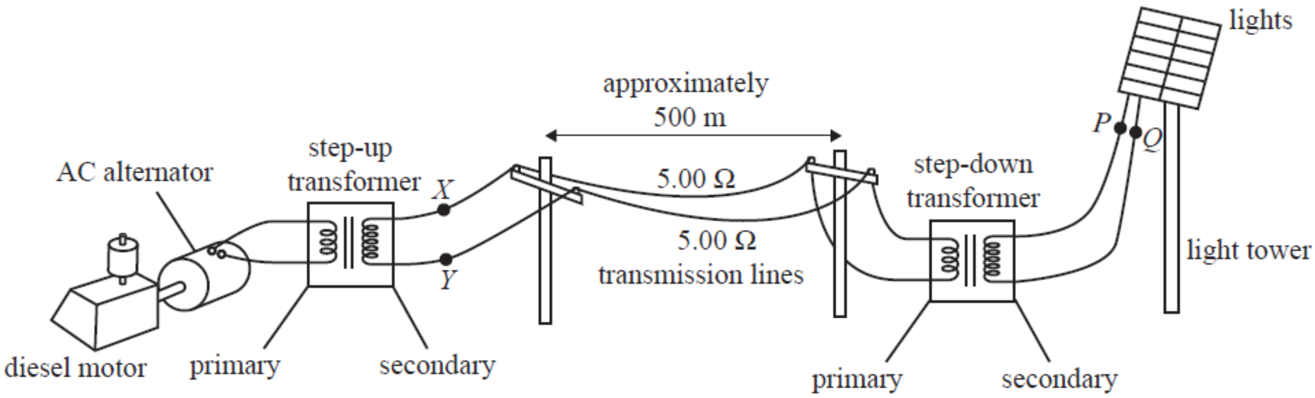
Question 44 2009 Question 11, 2 marks

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 VRMS
- 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.)

Question 45 2009 Question 12, 2 marks

What will the RMS voltage (potential difference) now be at the input to the transmission lines (at point *XY*) at the alternator end?

Question 46 2009 Question 13, 1 mark

The primary of the step-down transformer has 4800 turns. How many turns are in the secondary winding?

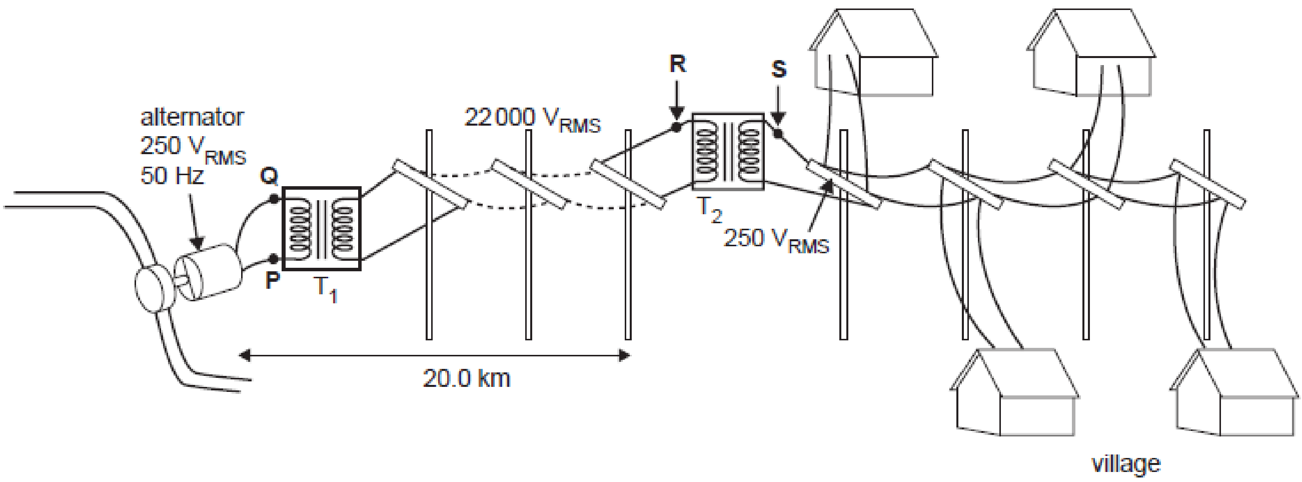
Question 47 2009 Question 14, 2 marks

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

Question 48 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.

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 (T1) 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 (T2) near the village. A diagram of the system is shown below.



Example 49 2006 Question 9, 2 marks

What would be the current in the wires at the point marked S when 100 kW of power is being used?

Example 50 2006 Question 10, 2 marks

Show that the current at point R is approximately 4.55 A when 100 kW of power is being used.

Example 51 2006 Question 11, 3 marks

Estimate the power loss in the high voltage transmission lines supplying transformer T2 when 100 kW of power is being used in the village. Show your working. Include the unit.

Example 52 2006 Question 12, 2 marks

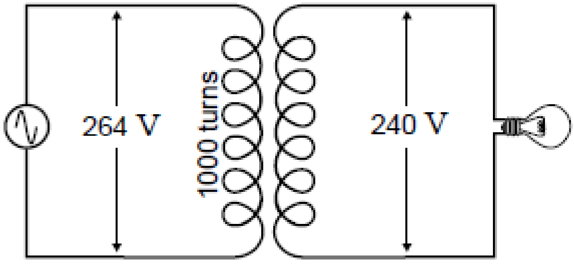
Briefly explain how high-voltage transmission leads to lower power losses in the system.

Andreas is having trouble with the reading lamp on his desk. Globes **rated at 60 W** and designed for an **RMS voltage of 240 V** keep burning out. He seeks help from his friend Emma who is a qualified electrician. They measure the RMS supply voltage and find it to be 264 V.

Example 53 1999 Question 1, 2 marks

What would the RMS current in one of these 60 W globes be if it was connected to an RMS voltage of **240 V**?

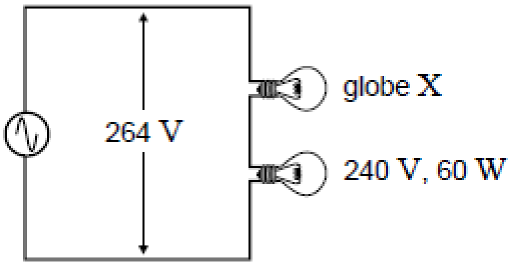
Emma and Andreas have different solutions to the problem of the globes burning out. Emma suggests to solve the problem by stepping down the supply voltage from 264 V to 240 V, using a transformer with 1000 turns in the primary coil as shown below.



Example 54 1999 Question 2, 2 marks

How many turns would there be in the secondary coil, assuming the transformer is ideal?

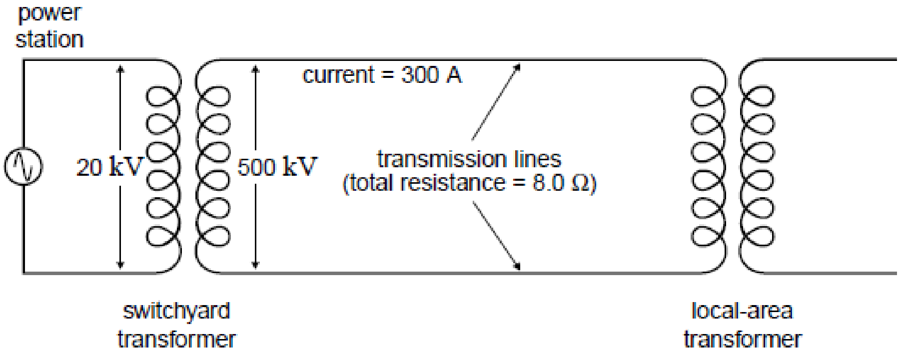
Andreas suggests the problem could be solved by connecting an appropriate second globe (globe X shown below) in series with the 60 W globe.



Example 55 1999 Question 3, 4 marks

What would be the power used in globe X?

A power station in the Latrobe Valley generates electric power at an RMS voltage of 20 kV 20 000V). The **switchyard transformer** steps up the voltage to an RMS value of 500 kV (500 000 V) for transmission to other parts of Victoria. On the outskirts of large towns a **local-area transformer** steps down the voltage for local transmission. The circuit below shows how the power station and the two transformers are connected.



The RMS current in the secondary of the switchyard transformer is 300 A. Assume the two transformers are ideal.

Example 56 1999 Question 10, 2 marks

What is the RMS current in the primary of the **switchyard transformer**?

The **total resistance** of the transmission lines is 8.0 Ω.

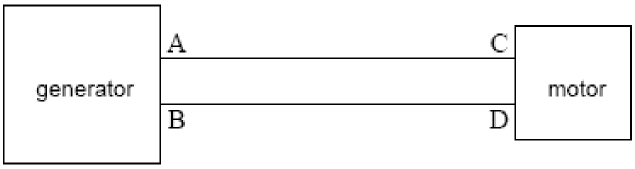
Example 57 1999 Question 11, 2 marks

How much power is lost in the transmission lines?

Example 58 1999 Question 12, 4 marks

What is the RMS voltage across the primary of the **local-area transformer**? Give your answer to three significant figures and make sure you show your working clearly.

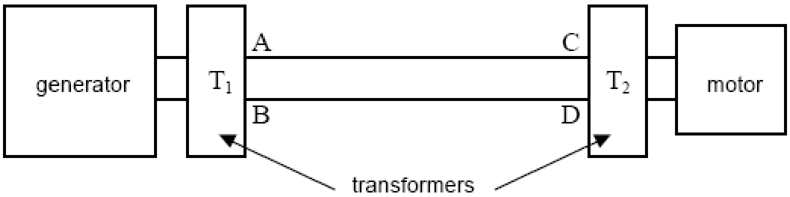
A 4.0 kW electric generator is used to supply power to an electric motor which is located some distance away. The RMS voltage at the output of the generator is 400 V, and the RMS current supplied to the motor is 10 A. The **total** resistance of the two cables, AC and BD, is 3.0 Ω. The situation is shown below.



Example 59 1998 Question 2, 2 marks

How much electric power is dissipated in the cables?

An engineer suggests that by connecting a transformer (T_1) at the generator output, and another (T_2) at the motor input, a larger fraction of the generated power could be transferred to the motor. The plan is shown below.



Example 60 1998 Question 3, 4 mark

Explain why this procedure increases the power transferred to the motor. Your answer should clearly show the physics involved. Indicate what type of transformer (step-up or step-down) should be used in each location.

After installation of the transformers, the RMS current in the transmission wires is 0.5 A. Assume the transformers are ideal.

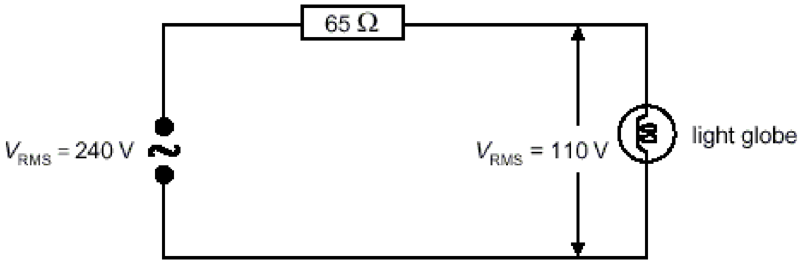
Example 61 1998 Question 4, 2 marks

What is the RMS voltage between the terminals A and B now?

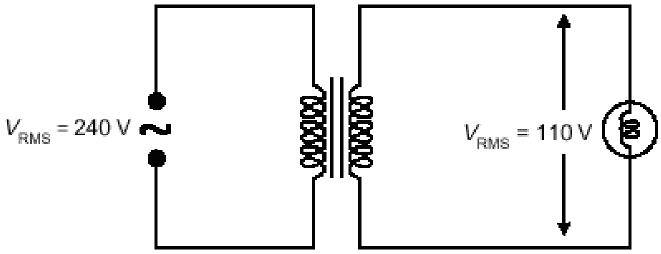
Example 62 1998 Question 5, 2 marks

How many turns of wire are in the **primary** of transformer T_1 if the secondary consists of 5000 turns? Show your working.

An electrician has imported an electric light globe that is designed to operate with an RMS voltage of 110 V. When operating at this voltage it has a resistance of 55 ohm. The globe has a power rating of 220 W. Two methods are considered that will allow the light globe to be used with a mains supply with an RMS voltage of 240 V.
In **method 1** a resistor of 65 ohm is placed as shown below, so that when used with an RMS supply voltage of 240 V, the RMS voltage across the light globe is 110 V.



In **method 2** a transformer is used to convert the RMS voltage of 240 V to an RMS voltage of 110 V, as shown below. Assume the transformer is ideal.



There are 1440 turns on the primary coil of the transformer.

Example 63 1997 Question 1, 1 mark

How many turns are on the secondary coil of the transformer?

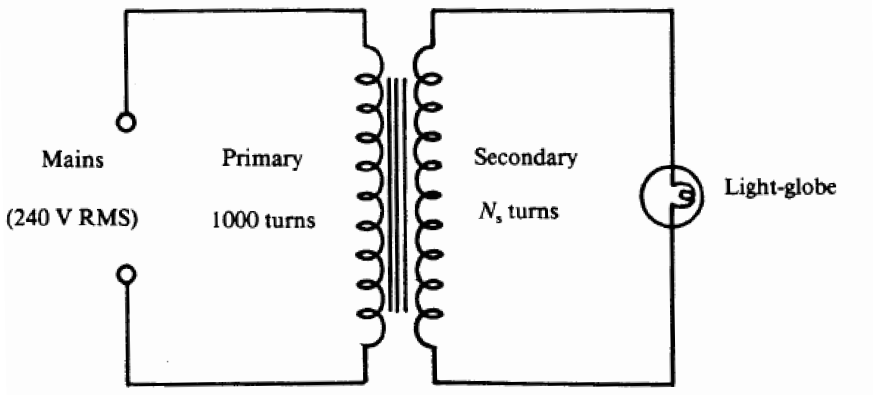
Example 64 1997 Question 2, 1 mark

What is the RMS current in the primary coil of the transformer?

Example 65 1997 Question 3, 1 mark

What is the power supplied from the mains for the two different methods?

A swimming pool has a light globe under water. For safety purposes the globe operates at 24 V. A step-down transformer is required to reduce the mains alternating voltage (240 V RMS). The primary coil of the transformer has 1000 turns. This information is shown below.



Assume that there are no losses in the transformer.

Example 66 1987 Question 66, 1 mark

Calculate the number of turns in the secondary coil necessary to produce a secondary voltage of 24 V RMS.

Under normal operation, the current in the pool light-globe is 10 A RMS.

Example 67 1987 Question 67, 1 mark

Calculate the value of the peak current in the secondary coil.

Example 68 1987 Question 68, 1 mark

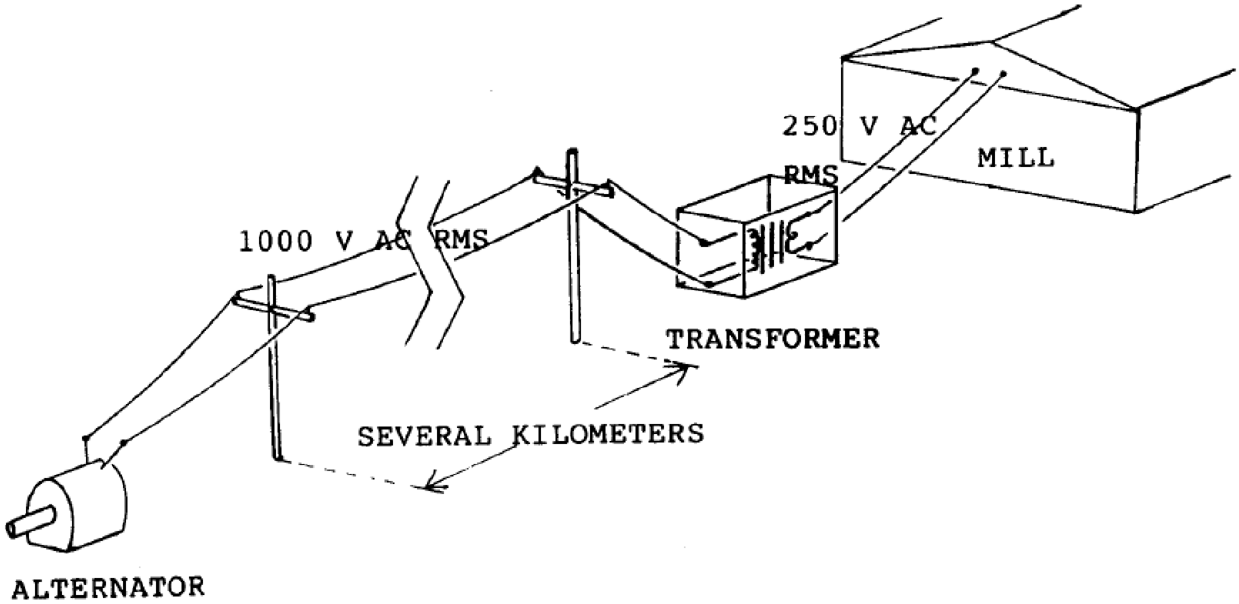
Calculate the electric power supplied to the primary coil of the transformer.

The primary coil is unplugged from the AC mains and connected by mistake to a DC power supply of 240 V.

Example 69 1987 Question 69, 1 mark

What is the electric current in the secondary coil in this case?

Electricity from a water driven alternator of output 1000 V AC RMS is transmitted by several km of transmission lines to a step-down transformer which provides 250 V AC RMS for a mill.



Question 70 1988 Question 56, 1 mark

What is the peak voltage across the terminals of the alternator?

Question 71 1988 Question 57, 1 mark

The primary (high voltage) winding of the transformer consists of 2000 turns. How many turns are there on the secondary winding?

The alternator produces 200 kW of electrical power when the mill is working. The total resistance of the high voltage transmission lines is 0.20 ohm.

Question 72 1988 Question 58, 1 mark

What is the RMS current flowing in the transmission lines when the mill is working?

Question 73 1988 Question 59, 1 mark

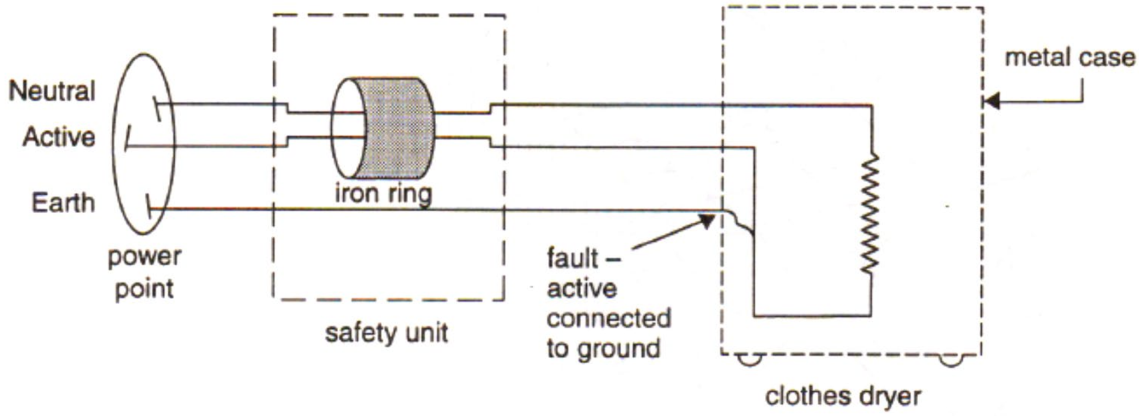
What is the power loss in the high voltage transmission lines when the mill is working?

Question 74 1988 Question 60, (This is an extended answer question) 5 marks

The mill engineer is concerned about the power loss in the transmission lines from the alternator to the mill. Explain briefly what steps he could take to reduce this loss. Your answer should include consideration of the transmission voltage and the power lines.

General instructions for extend answer questions
In your answer use a graph or diagram if you think it is appropriate. This question is worth 5 marks. Spend approximately 10 minutes on it. More marks will be given for a brief, well thought out answer than for a longer, less careful answer.

It is now possible to buy an electrical safety unit that turns off the electrical current in an appliance if a current flows in the earth wire. The power lead of the appliance plugs into a box containing the unit. The box in turn plugs into a power point.



The figure above shows a clothes dryer connected to the mains supply via a safety unit. The iron ring is an essential part of the safety unit. The active and neutral wires run through the ring.
The clothes dryer has an electrical fault, a connection between the active wire and the earthed metal case of the dryer.

Example 75 1993 Question 6, 1 mark

The magnitude of the current in the earth wire is 2 A, and the magnitude of the current in the neutral wire is 5 A. What is the magnitude of the current in the active wire?