Electromagnetic Induction

PRINCIPLES OF ELECTROMAGNETIC INDUCTION
THE A.C. GENERATOR
THE TRANSFORMER

Principles of Electromagnetic Induction

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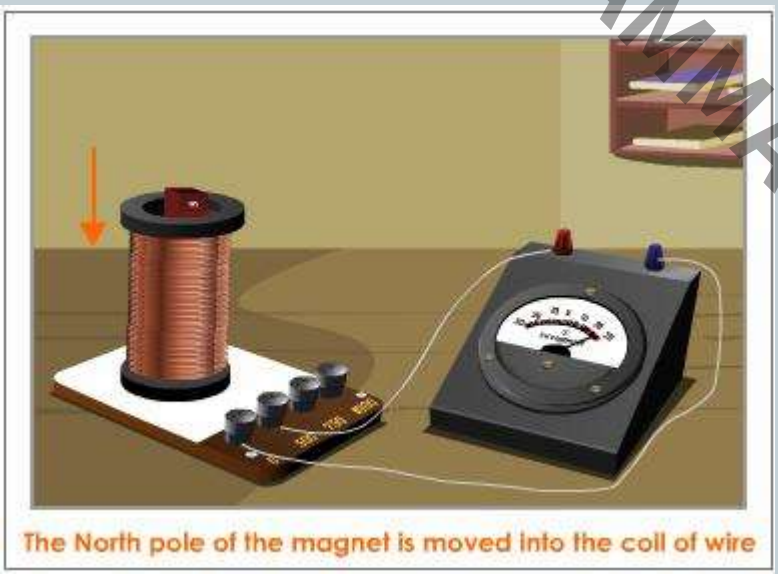
DESCRIBE AN EXPERIMENT WHICH SHOWS THAT A CHANGING MAGNETIC FIELD CAN INDUCE AN E.M.F. IN A CIRCUIT.

Faraday's Experiment

- Michael Faraday showed that electricity can be obtained from magnetism.
- The current produced in this way is called an induced current.
- The process by which the current is obtained is called electromagnetic induction.

To Demonstrate Electromagnetic Induction



- When a magnet is plunged into the coil, the galvanometer pointer gave a momentary deflection

- Moving out the magnet out form the coil, the galvanometer gave another deflection

- No current was induced if the magnet was allowed to remain at rest inside or outside the coil.

- Whenever there was a relative movement between magnet and coil, there was induced current.
- The current was induced in the circuit as a result of the wire being cut by magnetic flux lines when either the magnet or coil moved.
- An electromotive force is induced whenever there is a changing magnetic flux in a circuit.

Principles of Electromagnetic Induction

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STATE THE FACTORS AFFECTING THE MAGNITUDE OF THE INDUCED E.M.F.

- Faraday's law of electromagnetic induction states that the magnitude of the induced e.m.f. is proportional to the rate of change of the magnetic flux linked with the circuit or rate at which the magnetic flux are cut.
- Faraday also found that the magnitude of the induced current increases when
  - The magnet is move at a faster speed in and out of the coil;
  - A stronger magnet is used;
  - The number of turns in the coil is increased.

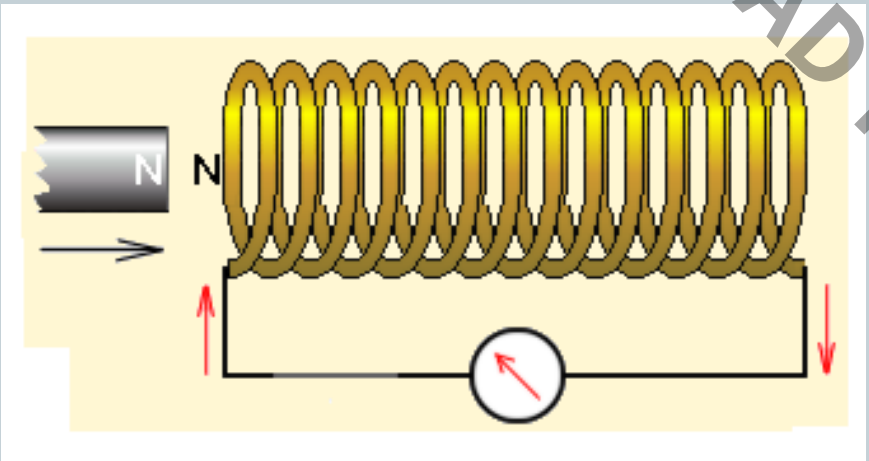
Principles of Electromagnetic Induction

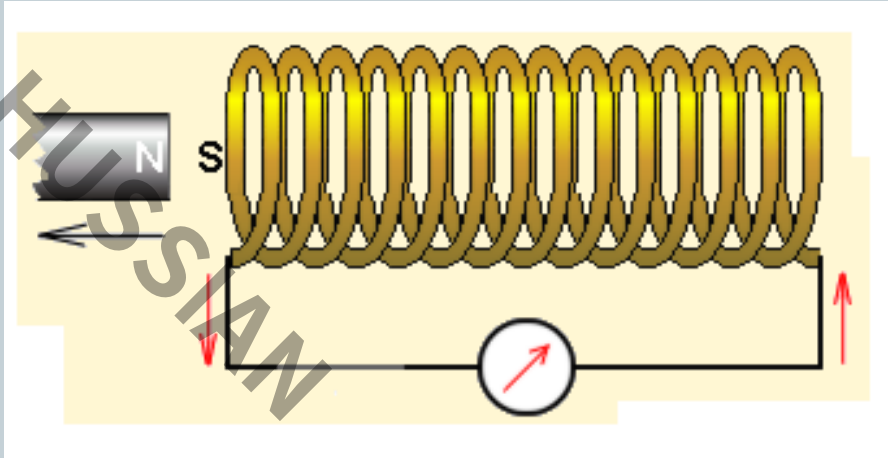
STATE THAT THE DIRECTION OF A CURRENT PRODUCED BY AN INDUCED E.M.F. OPPOSES THE CHANGE PRODUCING IT

(LENZ'S LAW) AND DESCRIBE HOW THIS LAW MAY BE DEMONSTRATED.

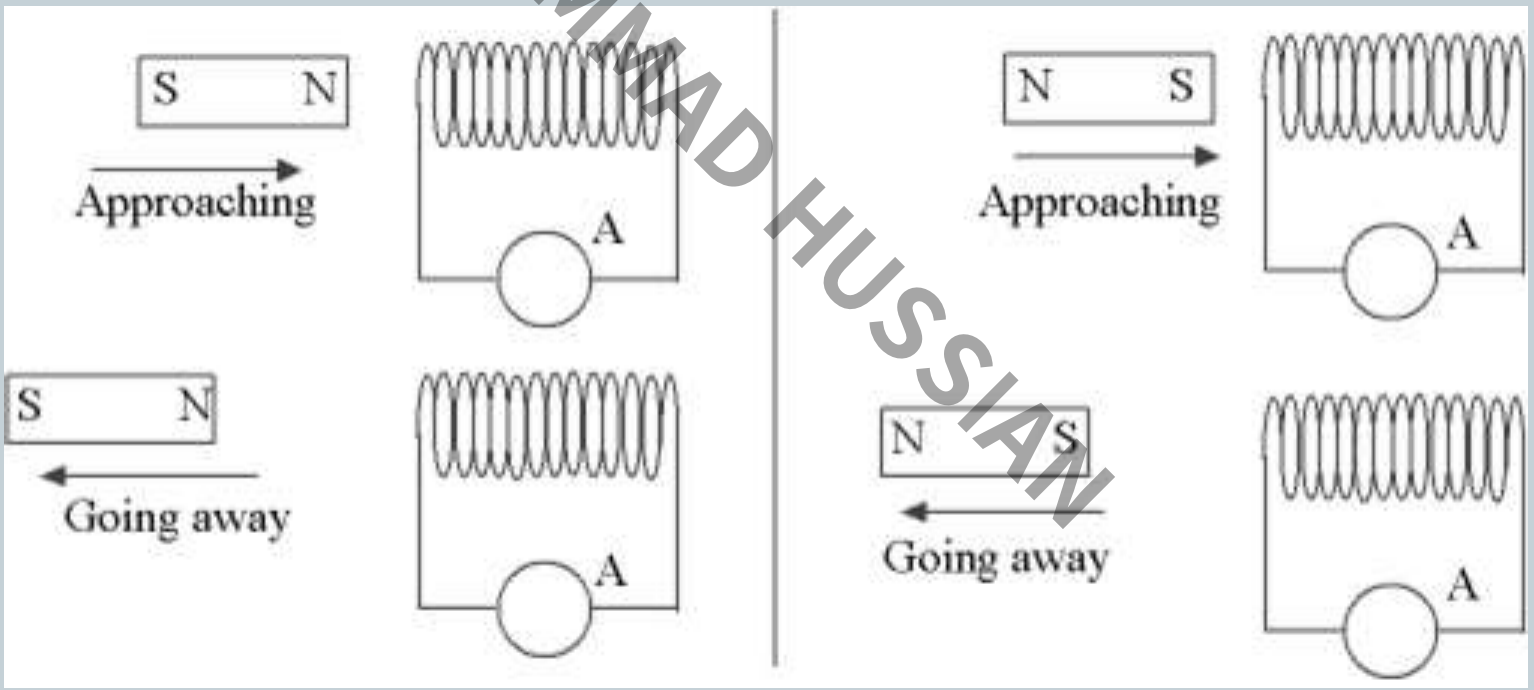
Direction of Induced E.m.f.

- Lenz's law of electromagnetic induction states that the induced current is always in a direction to oppose the change producing it.





- By Lenz's Law and the Right-Hand Grip Rule trace the direction of current through the load resistor:



The A.C. Generator

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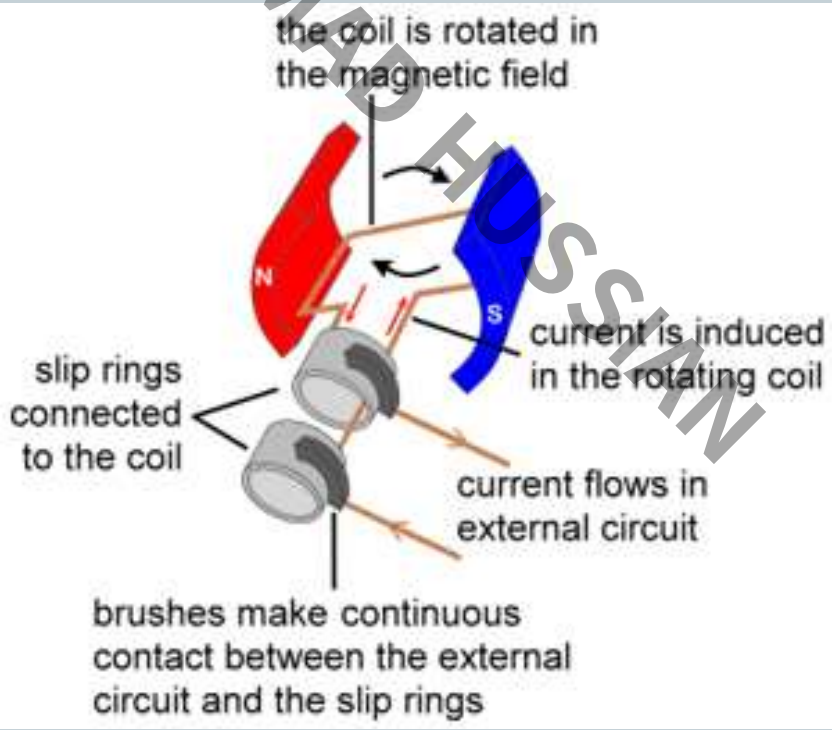
DESCRIBE A SIMPLE FORM OF A.C. GENERATOR (ROTATING COIL OR ROTATING MAGNET) AND THE USE OF SLIP RINGS WHERE NEEDED.

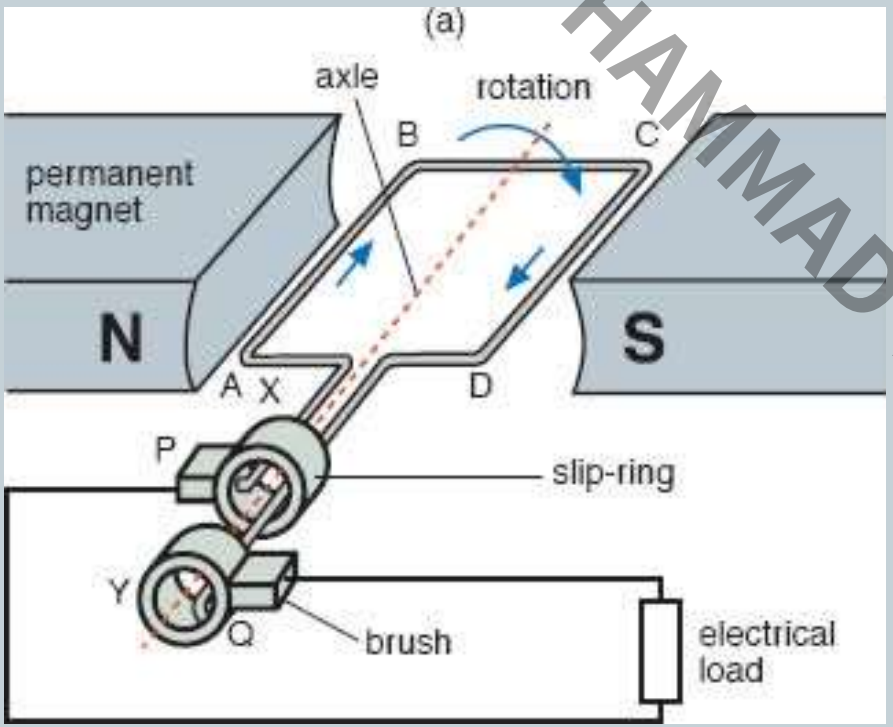
The A.C Generator

- In motor, electrical energy is used to rotate the coil to provide mechanical energy
- In generators, mechanical energy is used to rotate the coil to produce electrical energy
- Power stations use generators to supply the needed electrical energy
- A generator can be described as an electromagnetic device which converts mechanical energy to electrical energy

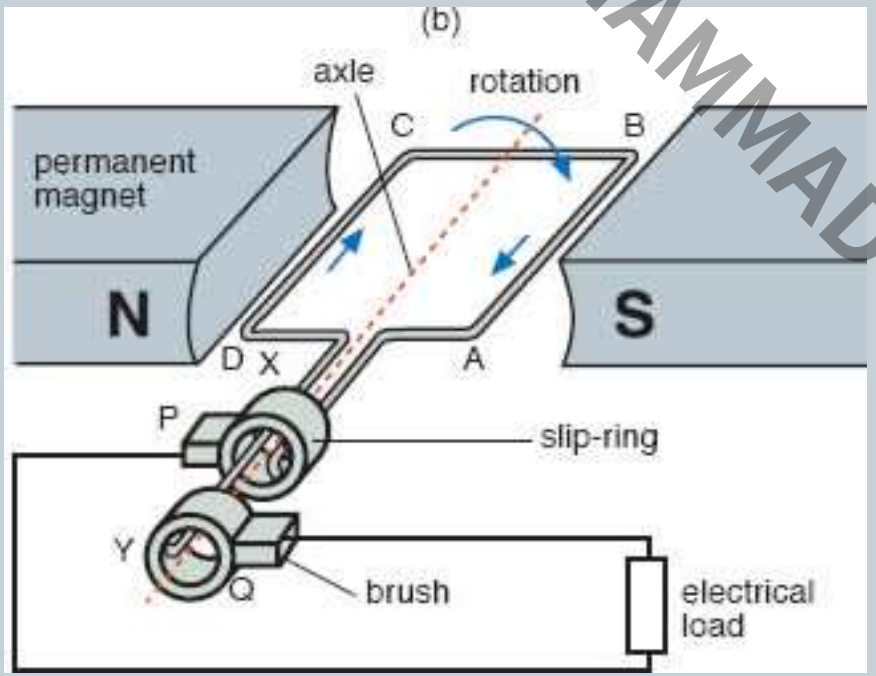
Principle of A.C. Generators

- A simple alternating current generator consists of a rectangular coil mounted on an axle which is fixed between the poles of a permanent magnet.

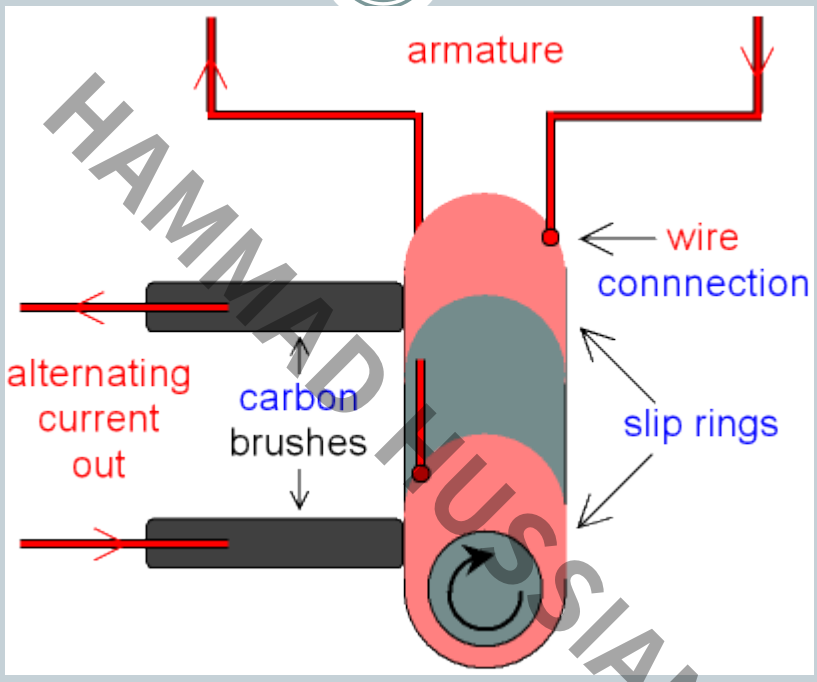




- Using Fleming's right-hand rule, the induced current flows form A to B and C to D
- The current then flows through the two *slip-rings* (X and Y) to an electrical load.
- The two slip-rings each make sliding contact with a fixed carbon brush (P and Q). The current flows from Y to Q and from P to X.



- When the coil has rotated at 180° (vertical position), the sides of the coil will changed places.
- The current flows from B to A and D to C in the coil, and from X to P and from Q to Y through the sliding contact.
- Every time the coil turns through 180°, the current reverse its direction through the electrical load.



- The generator produces alternating current because slip rings are used in place of a split - ring commutator.
- The slip rings keep a continuous connection with the wire around the armature.

The A.C. Generator

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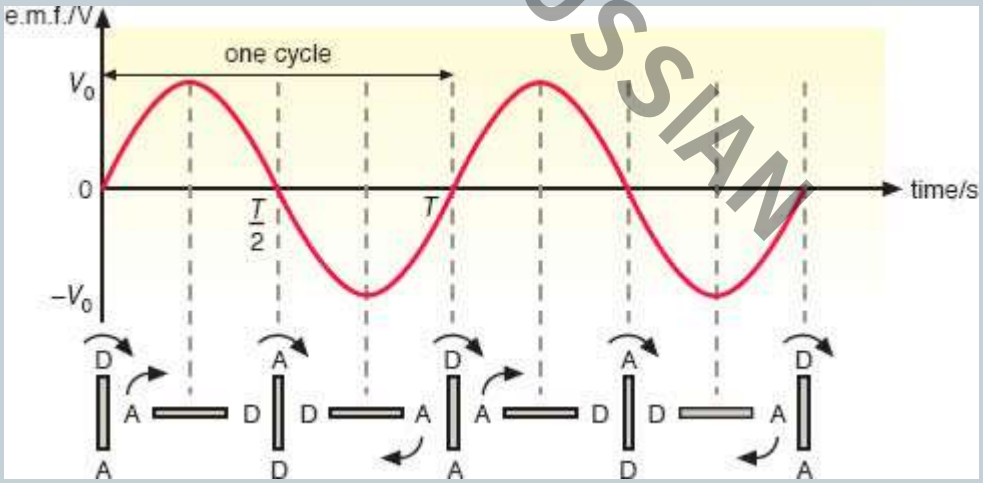
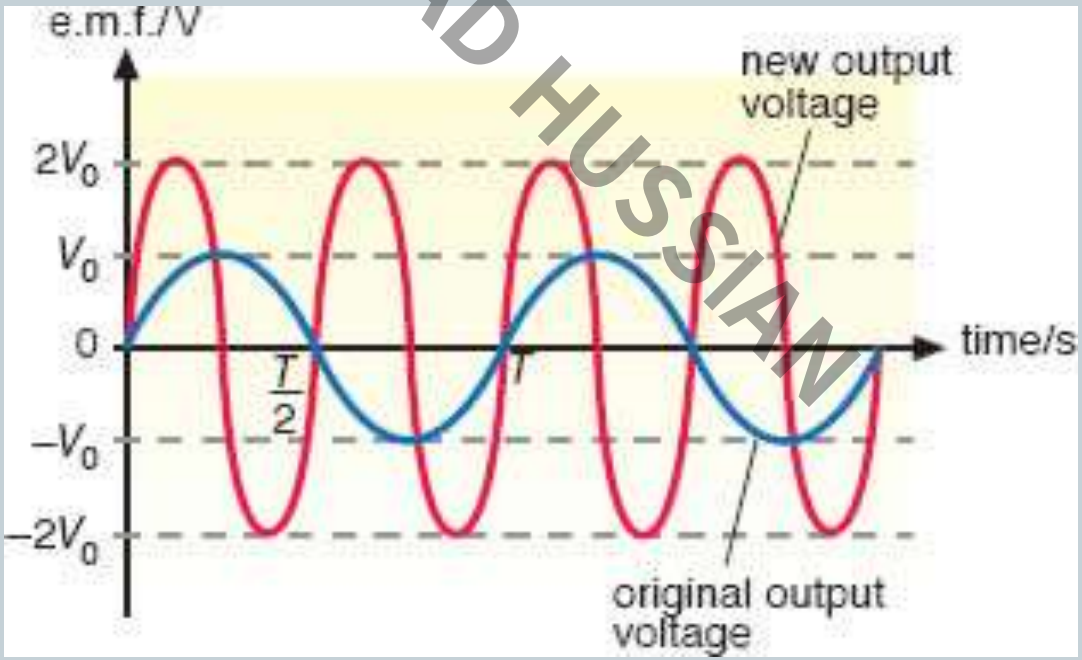
SKETCH A GRAPH OF VOLTAGE OUTPUT AGAINST TIME FOR A SIMPLE A.C. GENERATOR.

Voltage output of an A.C Generator

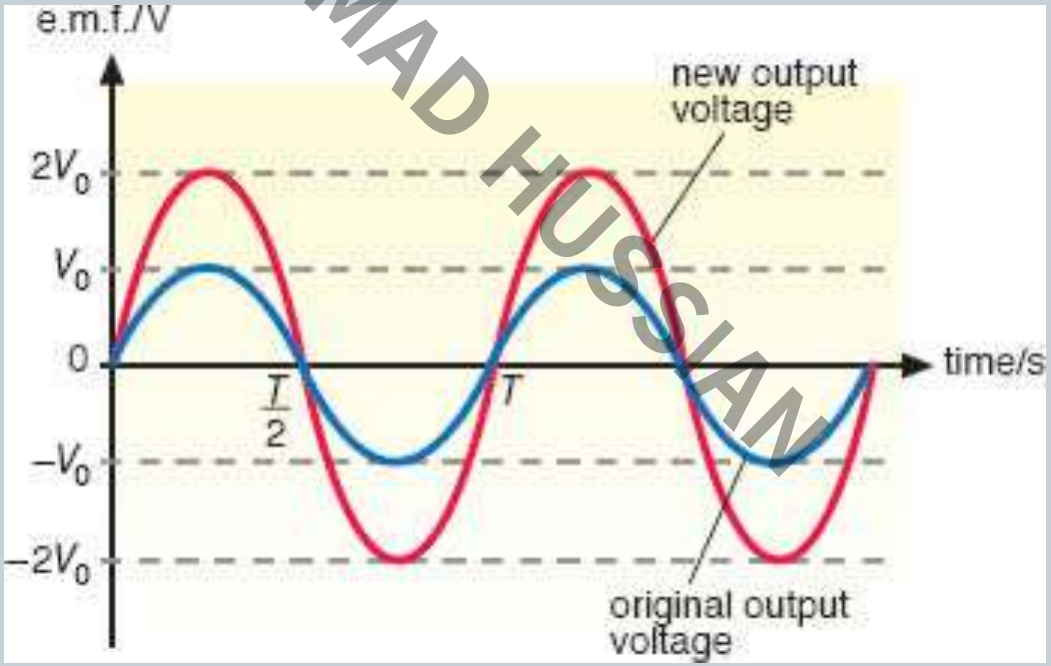
- When the coil is horizontal, the rate at which the coil cuts the magnetic lines of force is the greatest – the induced e.m.f is maximum
- When the coil is vertical, the rate at which the coil cuts the magnetic lines of force is the least – the induced e.m.f is minimum



- If the speed of rotation of the coil is doubled, both the frequency of the alternating current and the rate of cutting of the magnetic lines of force will be doubled.
- Hence the maximum output voltage is also doubled.



- When the number of turned of the coil is doubled, both the frequency of the output voltage is the same although its maximum output voltage is doubled.



- In conclusion, the induced electromotive force of a generator can be increased by
  - Increasing the speed of rotation of the coil,
  - Increasing the number of turns in the coil,
  - Winding the coil on a soft iron core so as to concentrate the magnetic lines of force through the coil,
  - Using stronger magnets

The Transformer

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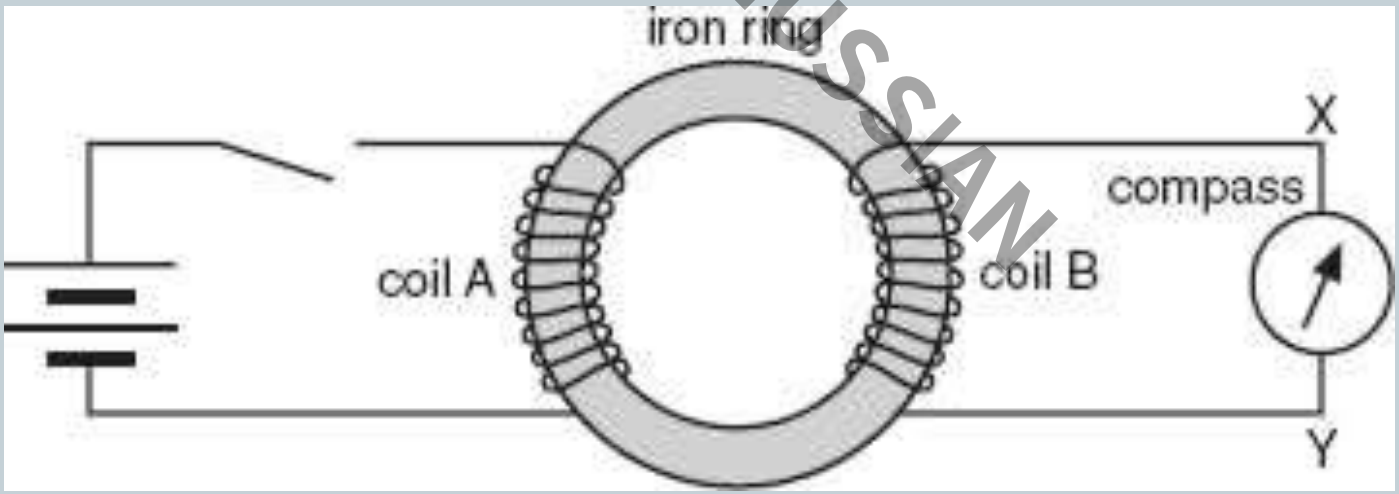
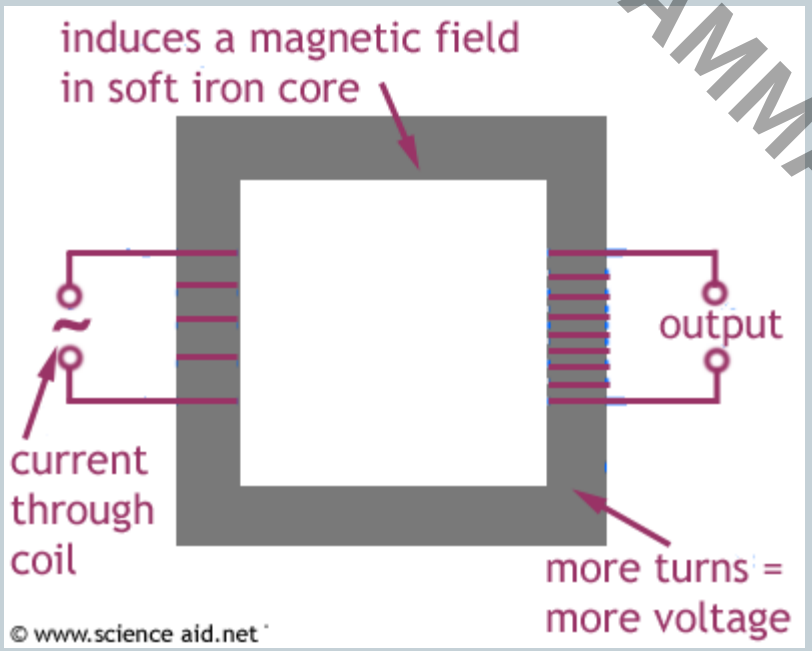
DESCRIBE THE STRUCTURE AND PRINCIPLE OF OPERATION OF A SIMPLE IRON-CORED TRANSFORMER.

The Transformer

- In 1831, Faraday performed an experiment by winding two coils round a soft iron ring
- When the switch was closed, the needle of the compass which was placed above wire XY had deflected
- The compass needle again deflected when the switch was opened
- No deflection occurred when a steady current was supplied in coil A





- A transformer needs an *alternating current* that will create a **changing magnetic field**.
  - The primary coil is connected to an AC supply.
  - An alternating current passes through a primary coil wrapped around a soft iron core.
  - The changing current produces a changing magnetic field.
  - This induces an alternating voltage in the secondary coil.
  - This induces an alternating current (AC) in the circuit connected to the secondary coil.

- A transformer is used to change the voltage of an alternating current.
- This is done by having different numbers of turns in the primary and secondary coils.
- A step-up transformer has more turns in the secondary coil than in the primary coil. This increases the output voltage.
- A step-down transformer decreases the voltage by having fewer turns in the secondary coil than in the primary coil.

- It may be shown that for an ideal transformer,

$$\frac{\text{secondary output voltage}}{\text{primary input voltage}} = \frac{\text{no. of turns in secondary coil}}{\text{no. of turns in primary coil}}$$

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

- From the principle of conservation of energy, the output power cannot be more than the input power
- Energy output cannot be more than energy input.
- For an ideal transformer,

$$\text{Output power} = \text{Input power}$$

$$V_S I_S = V_P I_P$$

Problem Solving

1. Calculate the output voltage from a transformer when the input voltage is 230 V and the number of turns on the primary coil is 2000 and the number of turns on the secondary is 100.
2. To step down the a.c. voltage of 240 V to 12 V, what must be the number of turns in the secondary coil, if the primary coil has 200 turns? In this step-down transformer, what will be the current in the secondary coil, if the input current in the primary coil is 5 A? Assume that the transformer is an ideal one.

3. A transformer has the ability to change an a.c. supply of 2 kW, 240 V to 60 V.
   a) What is the turns ratio of this transformer?
   b) How large is the output current if the transformer is 100% efficient?
   c) What will the output current be if there is a 10% power loss in the transformer?
4. A transformer has 500 turns in the primary and 3000 turns in the secondary. In the primary, the potential difference is 120 V a.c. and the current is 150 mA. Find (a) the secondary potential difference and (b) the secondary current.

5. A large power transformer converts 325 000 V to 7 500 V, at the rate of 2.5 million watts. Find (a) the primary current, (b) the secondary current.
6. A transformer has an input voltage of 2 V. There are 50 turns on the primary coil. The secondary coil has 600 turns.
   a) What is the output voltage
   b) The secondary coil has a resistance of 12 Ω. What is the secondary current?
   c) The transformer is perfectly efficient. What is the primary current.

7. The main supply of 240 V is stepped down to 6 V using a transformer.
   a) What is the ratio of the number of turns in the secondary coil to that in the primary coil?
   b) If the number of turns in the primary coil is 1000, how many turns are there in the secondary coil?
   c) The output from the secondary coil is used to light a 6 V lamp. If the current in the lamp is 1.5 A and the transformer is 100% efficient, what is the current in the primary coil?
8. A step-down transformer has 1000 turns in the primary coil and 500 turns in the secondary coil. The primary coil is connected to a 240 V a.c. supply. If the transformer is 100% efficient and primary current is 1.2 A, what will be the secondary current.

The Transformer

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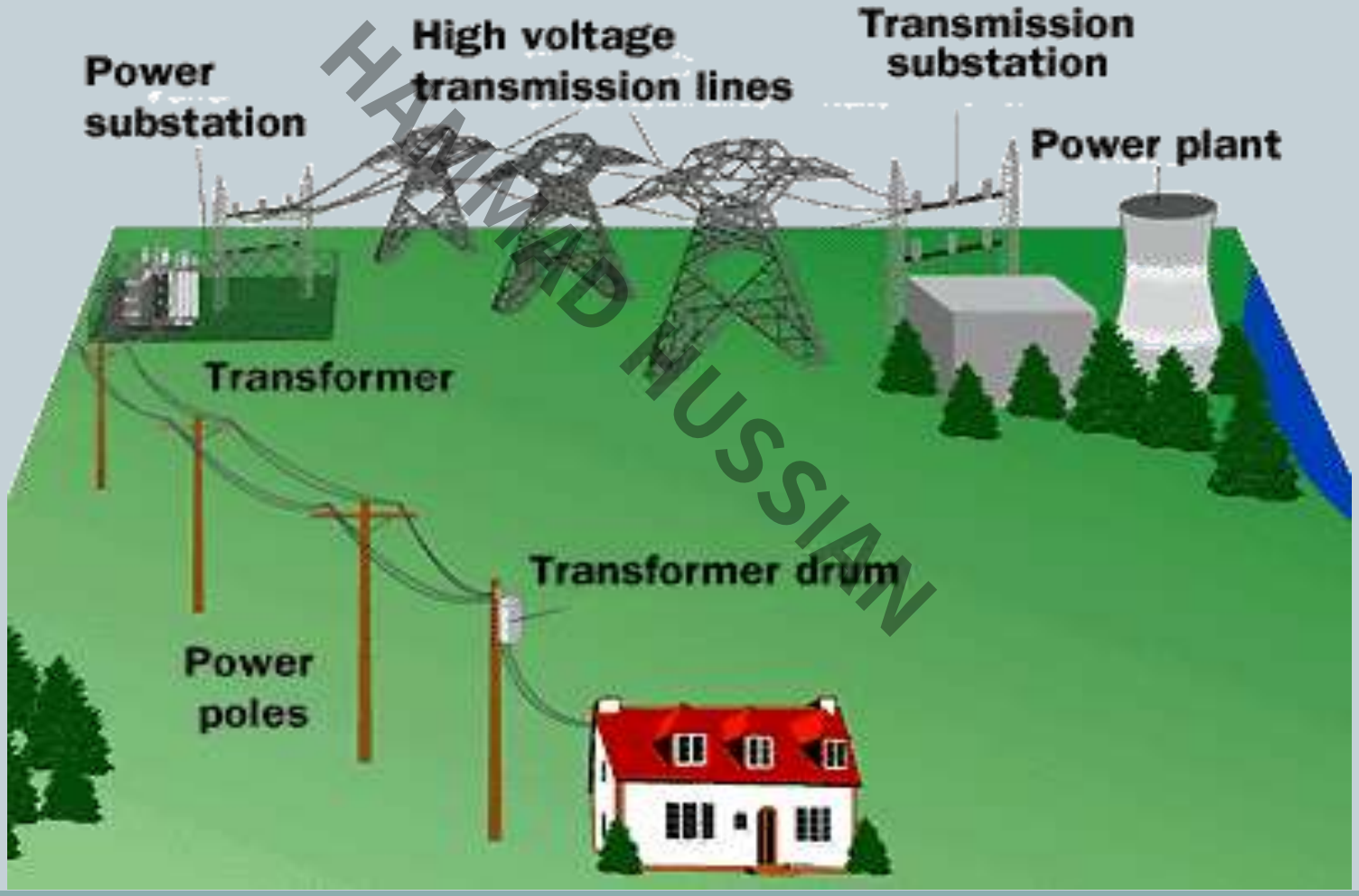
STATE THE ADVANTAGES OF HIGH VOLTAGE TRANSMISSION.

The Transformer

DISCUSS THE ENVIRONMENTAL AND COST IMPLICATIONS OF UNDERGROUND POWER TRANSMISSION COMPARED TO OVERHEAD LINES.

Power Transmission




HAMMADHUSAIN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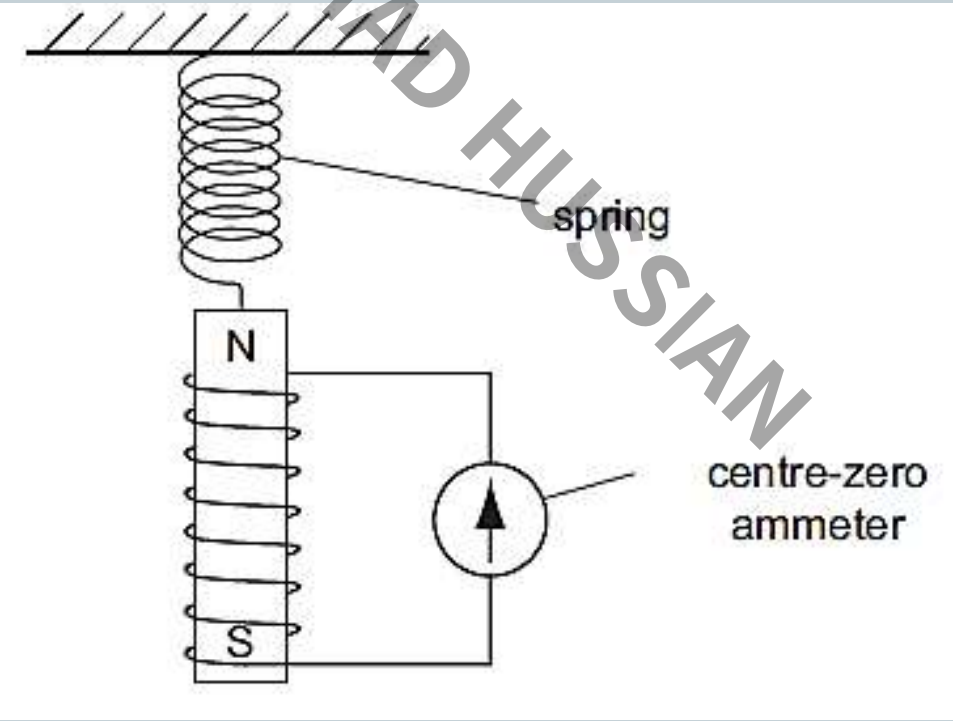
The Power Plant

- AC has at least three advantages over DC in a power distribution grid:
  - Large electrical generators happen to generate AC naturally.
  - Transformers must have alternating current to operate.
  - It is easy to convert AC to DC but expensive to convert DC to AC.

- Disadvantage of underground cable.
  - It costs five to 15 times more to install transmission lines underground.
  - Underground power lines are more costly to repair. In addition, it generally takes longer to repair than overhead lines due to the difficulty in reaching the underground problem.
  - Electrical lines pass over wetlands and fragile ecosystems and it becomes easier to avoid injury to those areas when the lines are overhead as opposed to digging up trenches to bury electrical lines.

- Power loss due to the heating effect of current in the grid cables – heat loss given by I^2R.
  - To reduce this is to use a very thick cable although it is heavy and uneconomical.
  - Another way to reduce is by stepping up the voltage by using a transformer.

1. A magnet is suspended from a spring so that it can move freely inside a coil which is connected to a sensitive centre-zero ammeter.

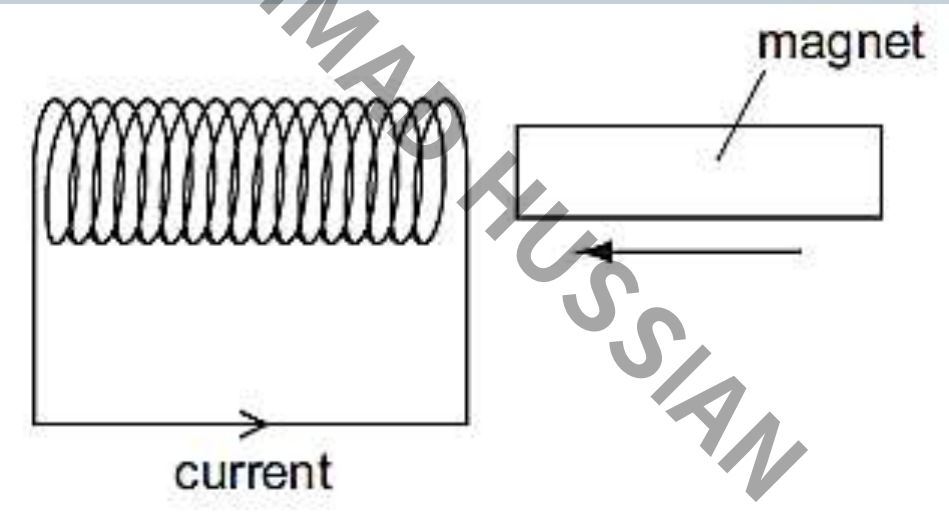


What does the ammeter show when the magnet vibrates slowly up and down?

A. a reading constantly changing from left to right and right to left
B. a steady reading to the left
C. a steady reading to the right
D. a steady zero reading

2. The e.m.f. induced in a conductor moving at right-angles to a magnetic field does not depend upon
   A. the length of the conductor.
   B. the resistance of the conductor.
   C. the speed of the conductor.
   D. the strength of the magnetic field.

3. A magnet is pushed slowly into a coil and there is a current in the coil in the direction shown.



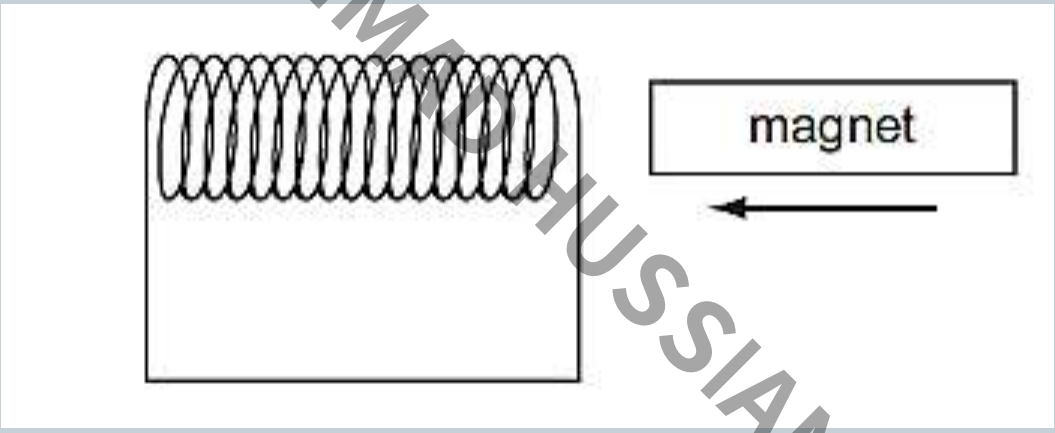
The magnet is then pulled out quickly from the same end of the coil.

What happens to the direction and the size of the current?

	direction	size
A	reversed	decreased
B	reversed	increased
C	unchanged	decreased
D	unchanged	increased

B

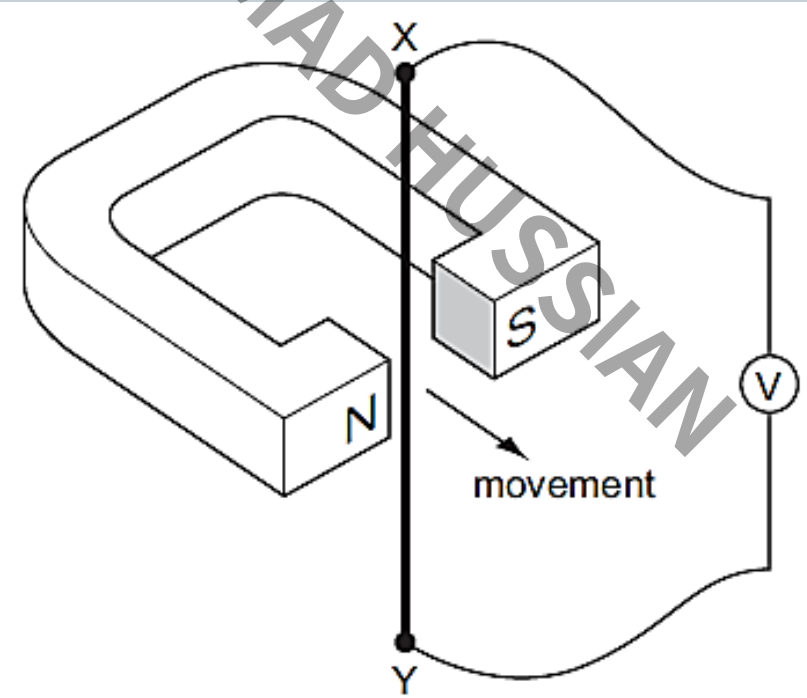
4. A magnet is pushed horizontally towards a coil of wire, inducing an e.m.f. in the coil.



In which direction does the induced e.m.f. make the coil move?

A. away from the magnet
B. towards the magnet
C. downwards
D. upwards

5. The wire XY shown in the diagram is connected to a sensitive voltmeter with a centre zero. XY is then moved quickly once through the magnetic field.



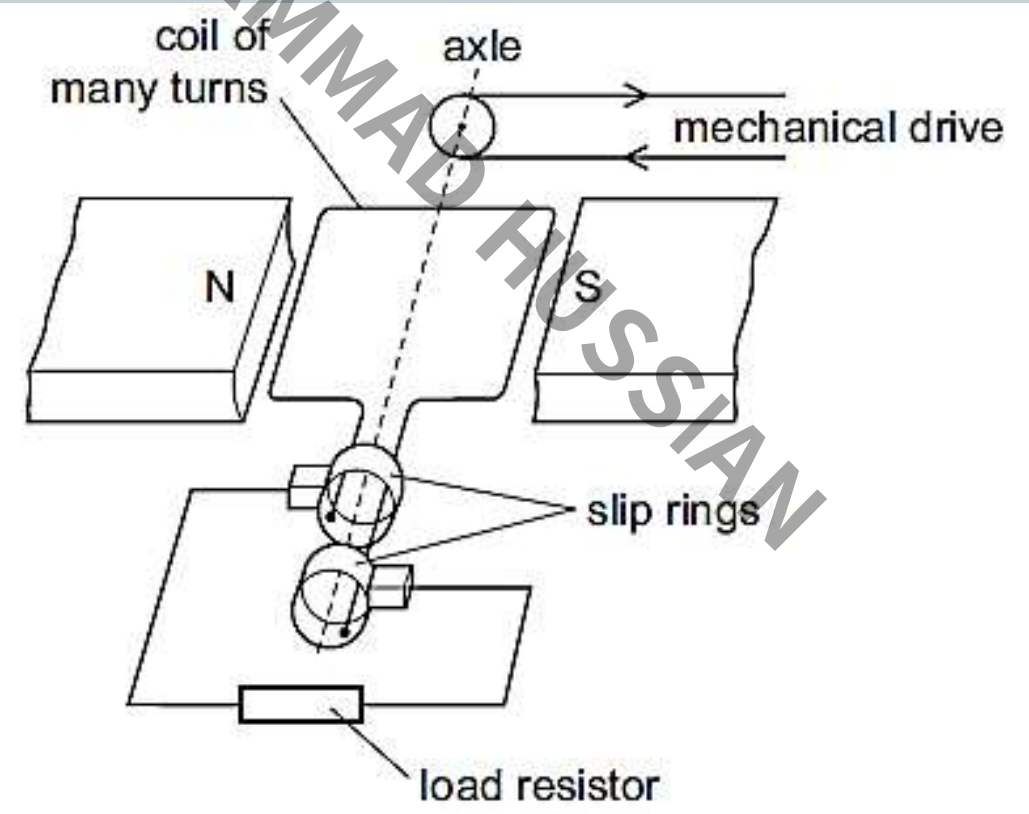
What is observed on the voltmeter?

A. The needle moves briefly in one direction and then returns to the centre.
B. The needle moves quickly in one direction and stays deflected.
C. The needle vibrates rapidly from side to side whilst XY is moving.
D. The needle stays still.

6. Which parts of an a.c. generator slide past each other when the generator is working?

A. brushes and coil
B. coil and magnets
C. magnets and slip rings
D. slip rings and brushes

7. The diagram shows an a.c. generator connected to an electrical circuit (load resistor).



Which statement is correct?

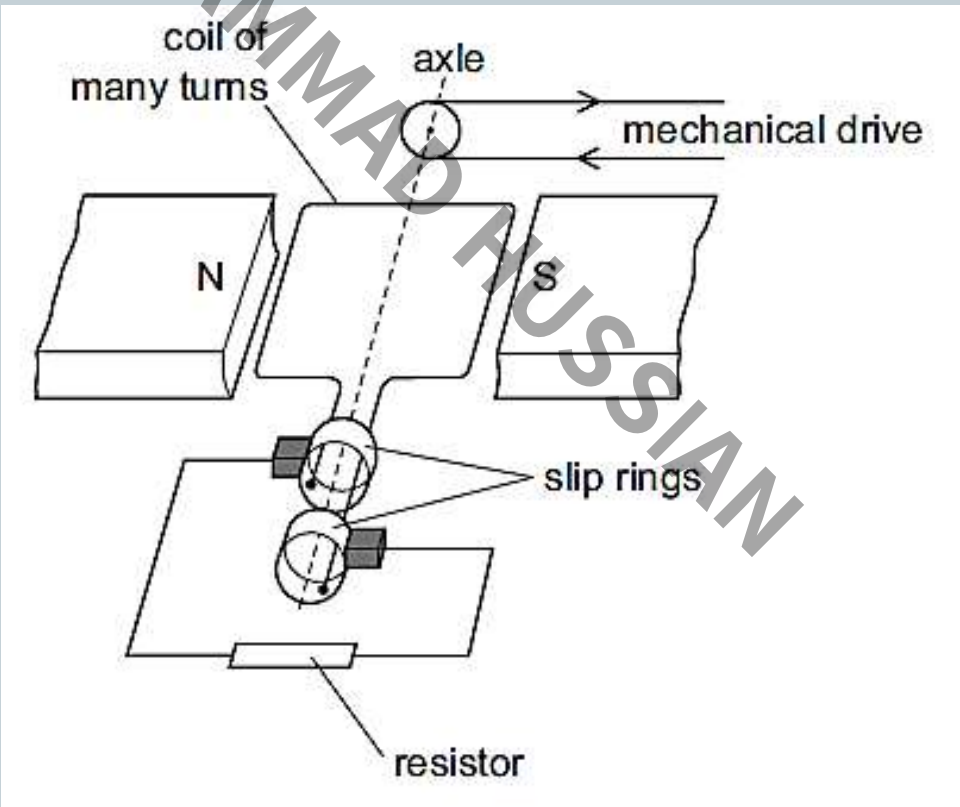
A. The direction of the potential difference across the load resistor is always the same.

B. The size of the induced e.m.f. depends on the number of turns in the coil.

C. The size of the induced e.m.f. does not change as the coil turns.

D. Winding the coil on a soft-iron cylinder makes no difference to the induced e.m.f.

8. The diagram shows an a.c. generator connected to a resistor.



Some changes are made, one at a time.

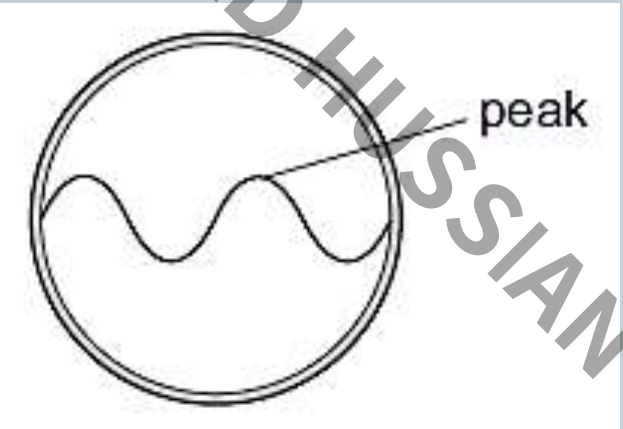
- The speed of the drive is changed.
- The strength of the magnets is changed.
- The number of turns in the coil is changed.
- The value of the resistor is changed.

How many of these alter the value of the e.m.f. generated in the coil?

A. 1
B. 2
C. 3
D. 4

9. A cathode-ray oscilloscope is connected to an a.c. generator.

   A wave is seen on the screen of the oscilloscope.

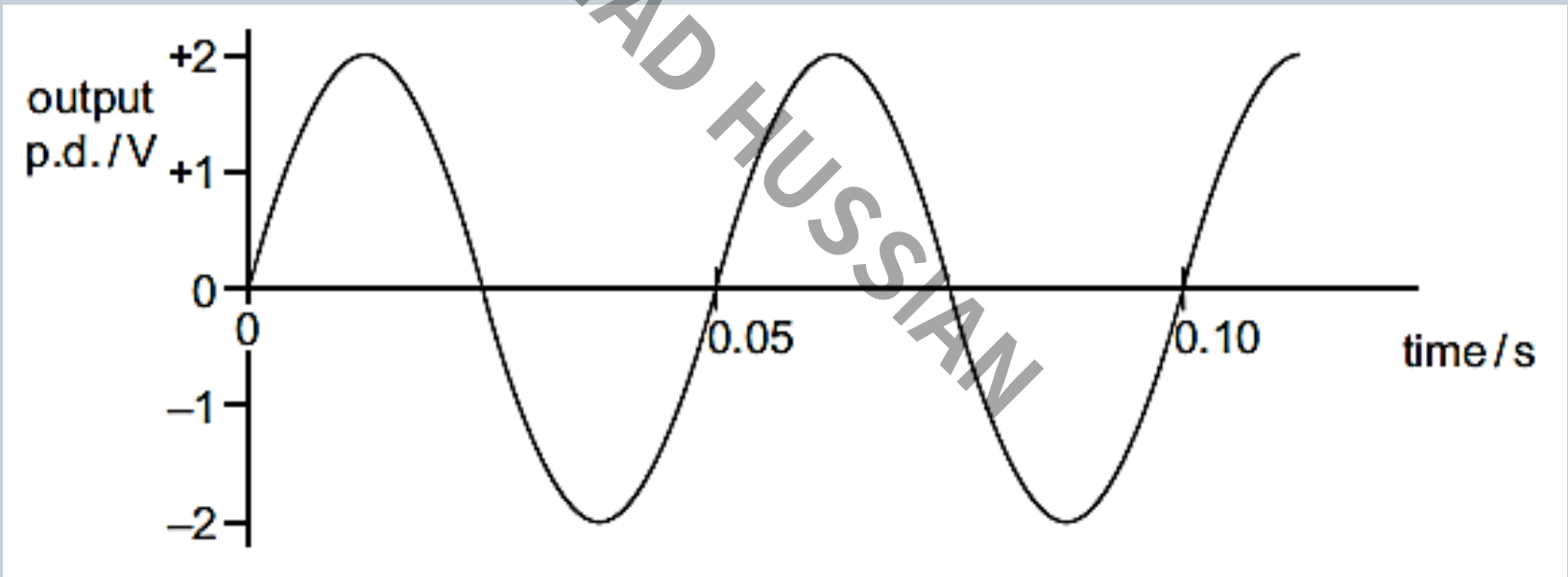


The speed of rotation of the generator is doubled. What is the effect on the wave?

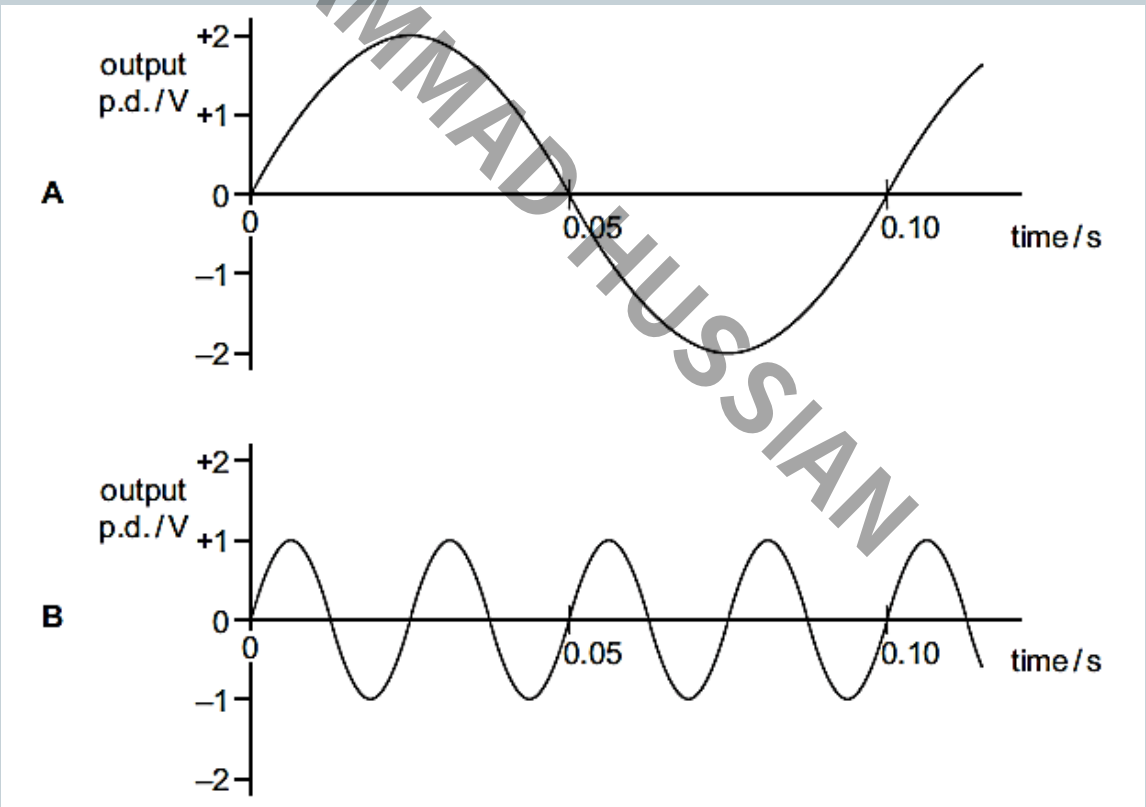
	number of peaks on the screen	amplitude of wave on the screen
A	doubled	doubled
B	doubled	same
C	same	doubled
D	same	same

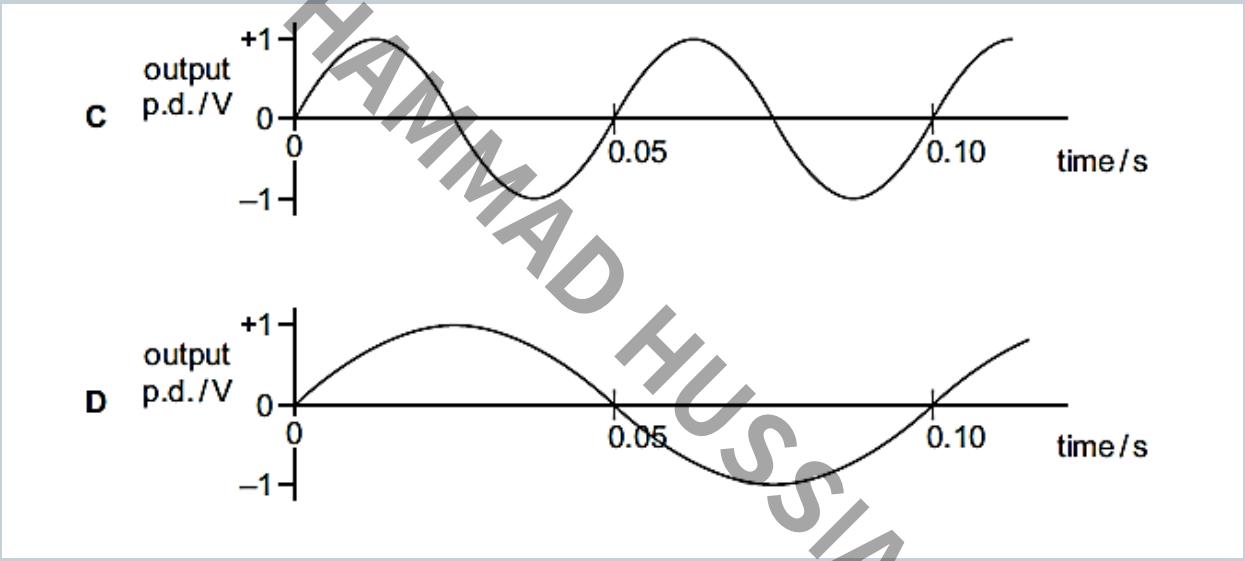
A

10. The graph shows the output of an a.c. generator. The coil in the generator rotates 20 times in one second.



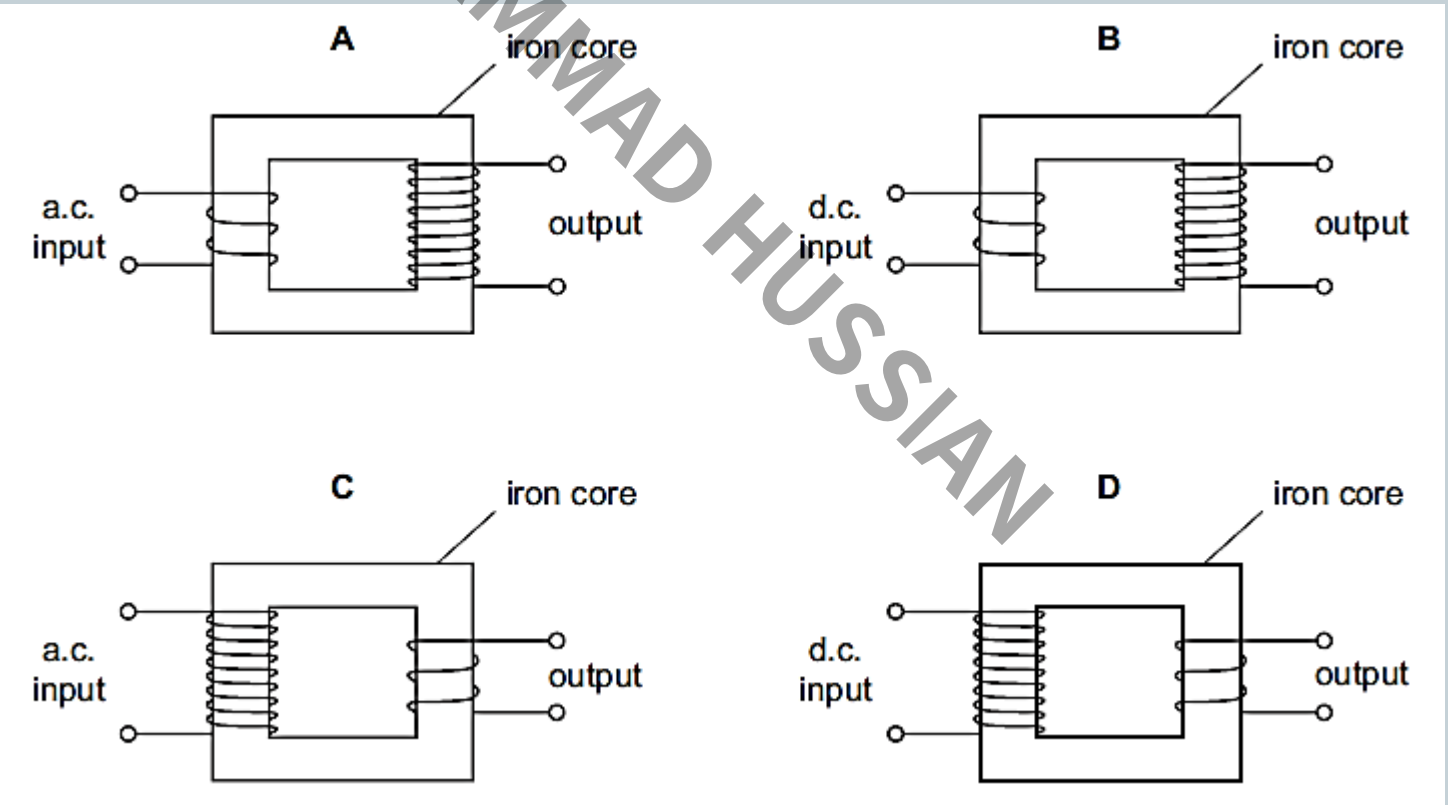
Which graph shows the output when the coil rotates 10 times in one second?





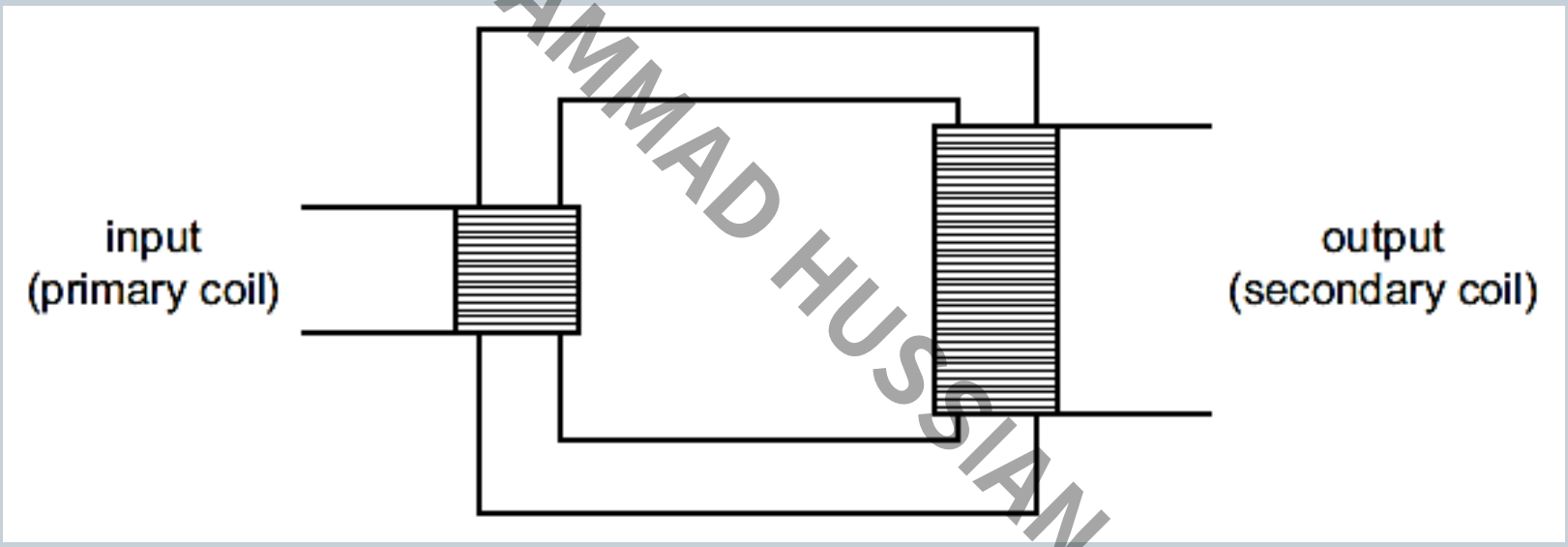
D

11. Which arrangement may be used to step up a voltage?



A

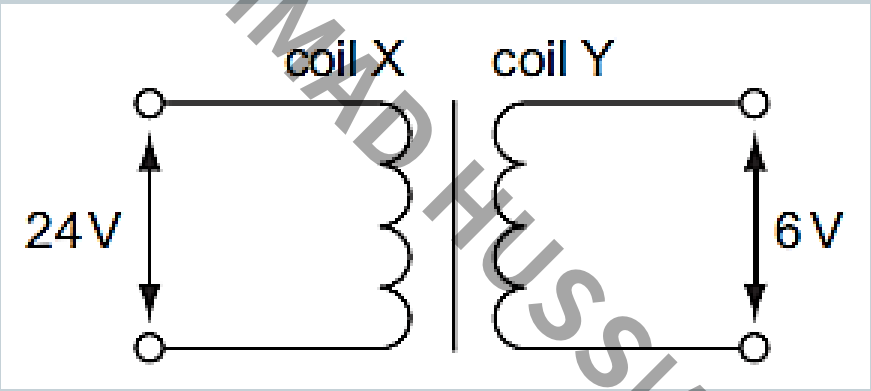
12. The diagram shows a working transformer.



Which statement is correct?

A. The input voltage is d.c.
B. The input voltage is greater than the output voltage.
C. The input voltage is less than the output voltage.
D. The input voltage is the same as the output voltage.

13. A transformer is to be used to produce a 6 V output from a 24 V input.

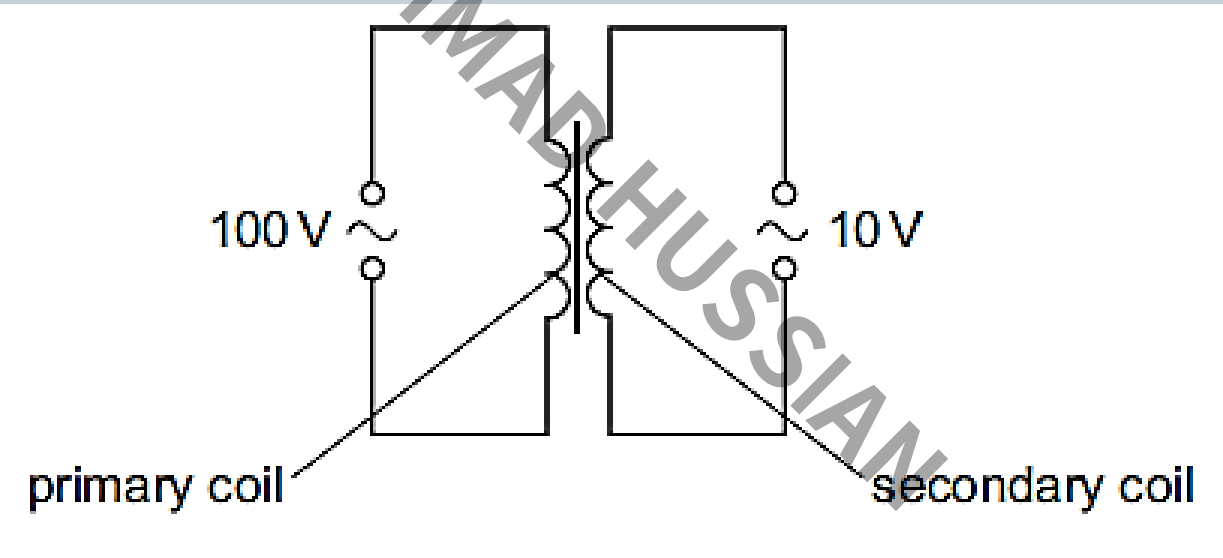


What are suitable numbers of turns for coil X and for coil Y?

	number of turns on coil X	number of turns on coil Y
A	240	60
B	240	240
C	240	960
D	960	60

A

14. A transformer is to be used to provide a 10 V output from a 100 V supply.

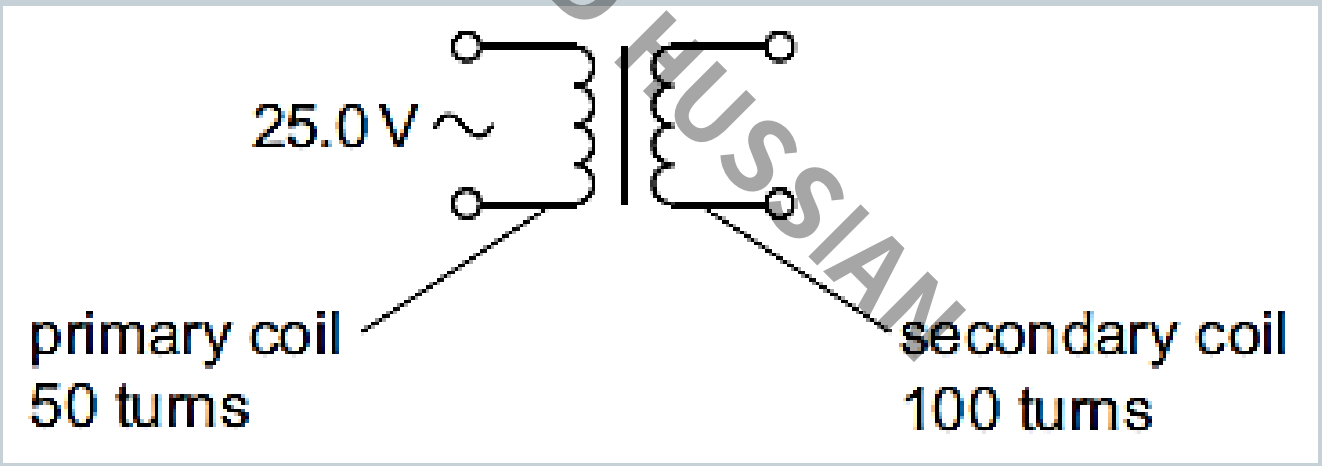


What are suitable numbers of turns for the primary coil and for the secondary coil?

	number of turns on the primary coil	number of turns on the secondary coil
A	100	1000
B	200	110
C	400	490
D	800	80

D

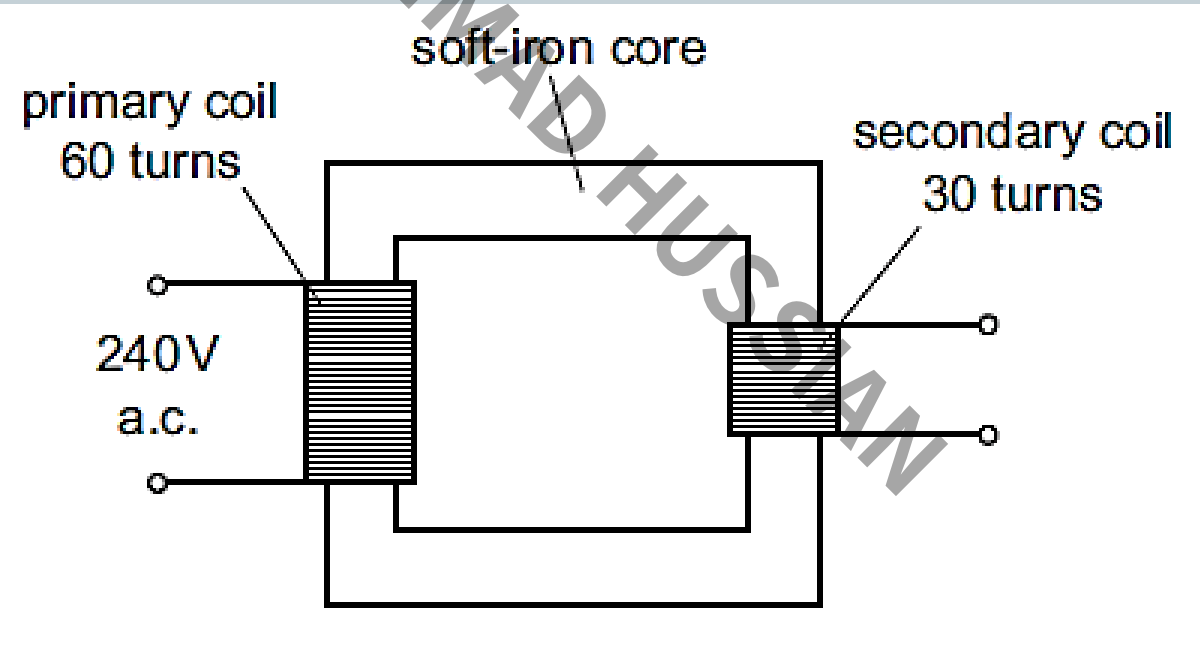
15. A transformer has 50 turns on its primary coil and 100 turns on its secondary coil. An alternating voltage of 25.0 V is connected across the primary coil.



What is the voltage across the secondary coil?

A. 12.5 V
B. 50.0 V
C. 175 V
D. 200 V

16. The diagram shows a transformer connected to a 240 V a.c. supply.



What is the potential difference across the secondary coil of the transformer?

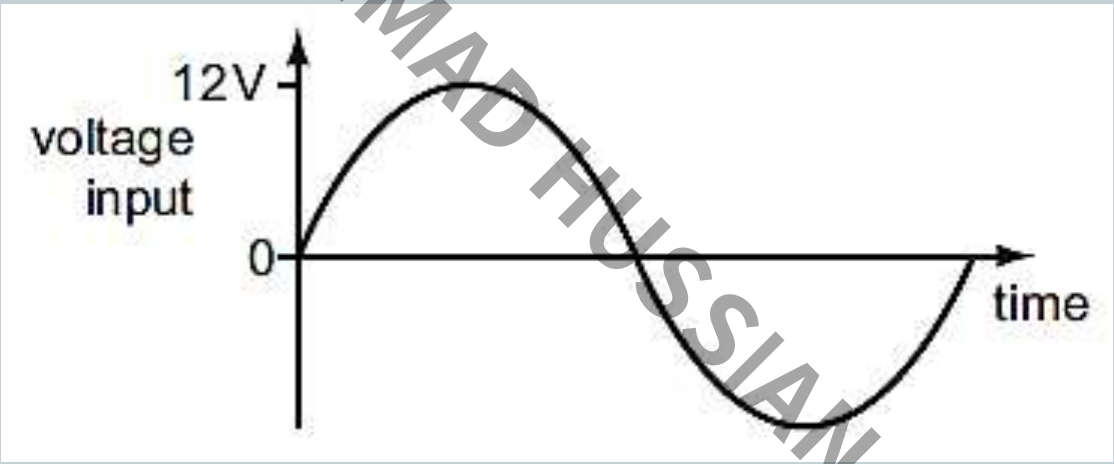
A. 30 V
B. 120 V
C. 240 V
D. 480 V

17. A transformer has 15 000 turns on its primary coil and 750 turns on its secondary coil.

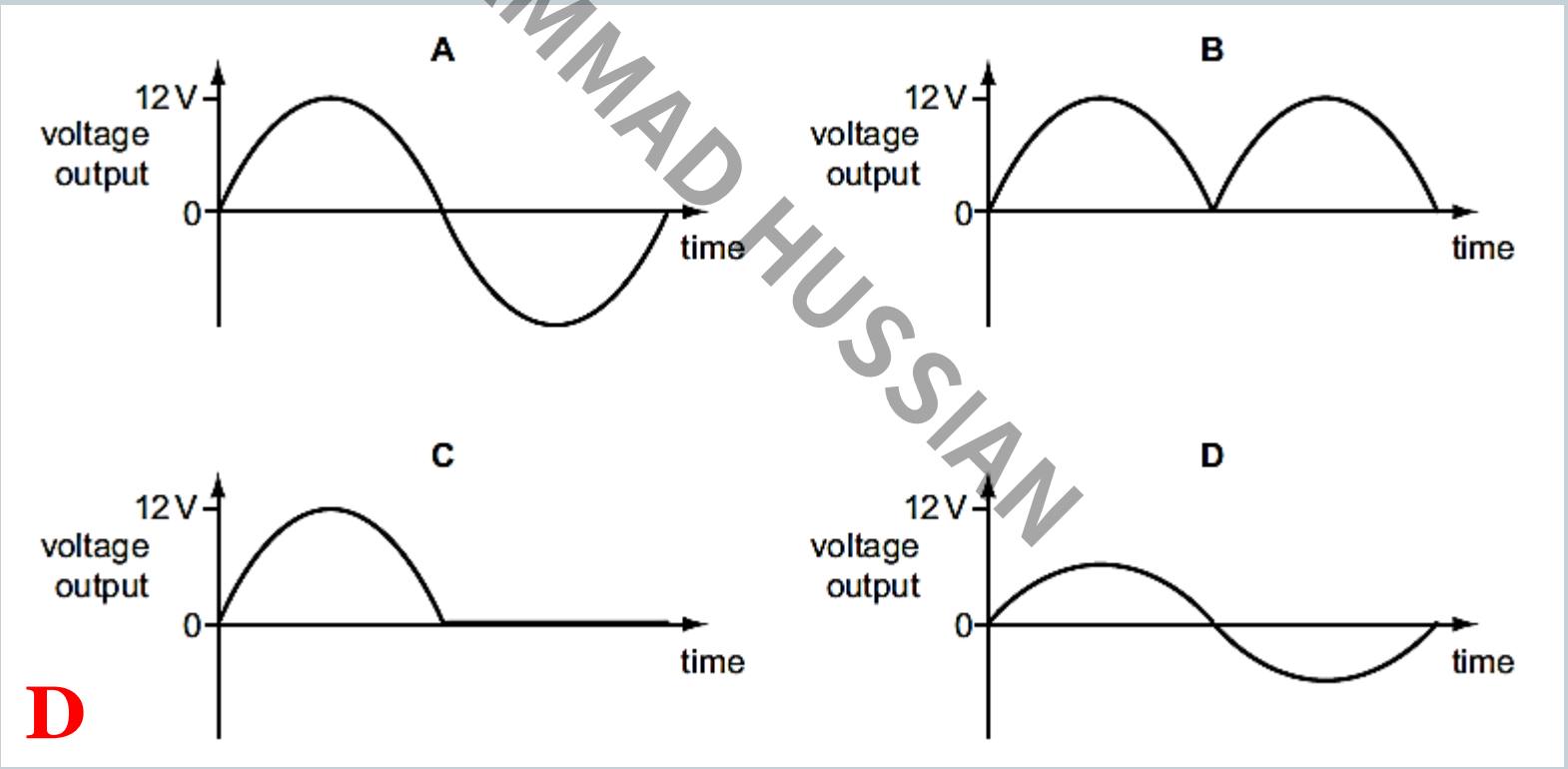
    Connected in this way, for what purpose could this transformer be used?

    A. to convert the 8000 V a.c. output of a power station to 160 000 V for long-distance power transmission
    B. to convert the 160 000 V d.c. supply from a power line to 8000 V for local power transmission
    C. to use a 12 V d.c. supply to operate a 240 V razor
    D. to use a 240 V a.c. mains supply to operate a 12 V motor

18. The graph shows the voltage input to a step-down transformer.



Which diagram shows the voltage output from the transformer?



D

19. Why is electrical energy usually transmitted at high voltage?

A. As little energy as possible is wasted in the transmission cables.
B. The current in the transmission cables is as large as possible.
C. The resistance of the transmission cables is as small as possible.
D. The transmission system does not require transformers.

20. Electric power cables transmit electrical energy over large distances using a high voltage, alternating current.

What are the advantages of using a high voltage and of using an alternating current?

	advantage of using a high voltage	advantage of using an alternating current
A	a higher current is produced in the cable	the resistance of the cable is reduced
B	a higher current is produced in the cable	the voltage can be changed using a transformer
C	less energy is wasted in the cable	the resistance of the cable is reduced
D	less energy is wasted in the cable	the voltage can be changed using a transformer

D