SPH3U UNIVERSITY PHYSICS

ELECTRICITY & MAGNETISM

☞ Transformers (P.605-612)

Transformers

The electrical devices you use every day all have different electrical energy requirements. An electric stove requires a lot of electrical energy, while an LED requires very little. Some devices require different currents and voltages. For example, a computer may require only 12 V to operate, so the voltage in your home needs to be lowered from 120 V to 12 V. Devices that are capable of raising or lowering AC voltage are called ***transformers****.*

Transformers

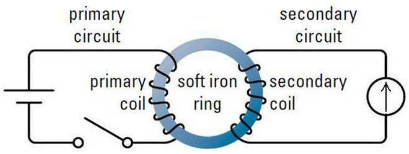
Transformers are used in many electronic devices to lower or raise the AC voltage to the value that the device is designed for. Adapters, such as cellphone chargers, have transformers as part of their circuitry. Adapters also contain a circuit that converts AC voltage to DC voltage.

TRANSFORMER

- device that can raise or lower voltage

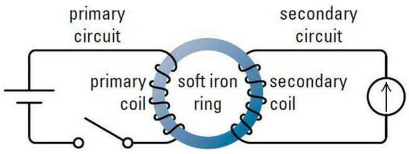
Transformers

To understand how a transformer works, recall Faraday's iron ring. When the primary circuit switch is closed, a current is momentarily produced in the secondary circuit. The same thing occurs when the switch in the primary circuit is suddenly opened. The changing current in the primary circuit produces a varying magnetic field in the ring, which passes through the secondary circuit and produces a current in the secondary circuit according to Lenz's law.



Transformers

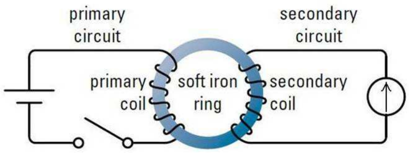
However, it is not necessary to turn the switch on and off to produce a current in the secondary circuit. All we need is a varying magnetic field in the ring, which means we need a varying or alternating current. The current produced by an AC generator is perfect for this task. An alternating current periodically reverses direction providing a means for the current to be turned on and off without manually operating a switch.



Transformers

NOTE!

Transformers have no moving parts. This is because they use AC current. According to Lenz's Law the alternating current in the primary circuit produces a varying magnetic field in the ring, which passes through the secondary circuit and produces an alternating current in the secondary circuit.

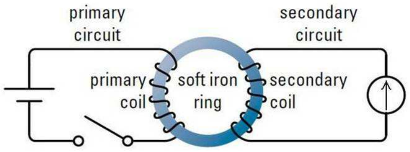


Transformers

PRACTICE

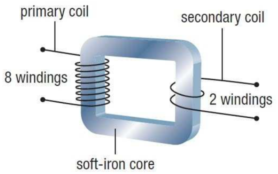
1. How does Faraday's iron ring help the manufacturer who needs a different voltage for a device?

   Transformers have different numbers of windings on the primary circuit compared to the secondary circuit.



Step-Down Transformers

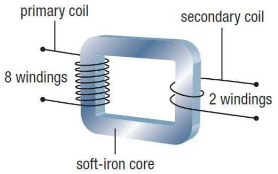
*If the secondary circuit has fewer windings than the primary circuit, the voltage on the secondary side is less than the voltage on the primary side. Transformers that have fewer windings on the secondary circuit than the primary circuit are called **step-down transformers**. They are called step-down transformers because they lower the AC voltage by a specific amount.*



Step-Down Transformers

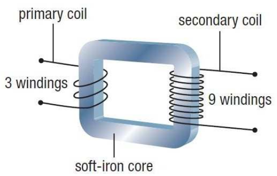
STEP-DOWN TRANSFORMER

- has fewer windings on the secondary coil
- decreases the voltage in the secondary coil



Step-Up Transformers

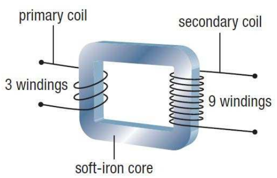
*If the situation is reversed and the secondary circuit has more windings, then the voltage is higher on the secondary side. Transformers that have more windings on the secondary circuit than on the primary circuit are called **step-up transformers**. They are called step-up transformers because they increase the AC voltage by a specific amount.*



Step-Up Transformers

STEP-UP TRANSFORMER

- has more windings on the secondary coil
- increases the voltage in the secondary coil



Transformer Equations

Transformers must obey the law of conservation of energy. Therefore, the energy going into the primary coil must equal the energy coming out of the secondary coil if there are no energy losses. Using energy and power equations we can express the law of conservation as shown below.

$\because$ $E_P = E_S$ *and* $E = Pt$

$\therefore$ $P_P t = P_S t$ *or* $P_P = P_S$

$\because$ $P = VI$

$\therefore$ $V_P I_P = V_S I_S$ *or* $\boldsymbol{V_P / V_S = I_S / I_P}$

$\because$ $V \propto N$ *we can also show* $\boldsymbol{V_P / V_S = N_P / N_S}$

Transformer Equations

TRANSFORMER EQUATIONS

$$\frac{V_P}{V_S} = \frac{I_S}{I_P} = \frac{N_P}{N_S}$$

where V is the potential difference (V) in the …
I is the electric current (A) in the …
N is the number of windings in the …

NOTE!
The subscripts P and S are used to represent the primary and secondary coils.

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Transformers

PRACTICE

2. Suppose that you increase the number of windings on the secondary coil compared to the primary coil. What would you expect the effect on voltage and current to be?

as V ↑ , I ↓

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Transformers

PRACTICE

3. A door chime designed to operate at 8.0 V is connected to a 120 V power supply through a transformer. In the secondary coil the number of windings is 100 and the current is 1.8 A.
   (a) What is the number of windings in the primary coil?
   (b) What is the current in the primary coil?
   (c) What type of transformer is this?

   (a) $N_P = 1500$
   (b) $I_P = 0.12$ A
   (c) step-down

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Transformers

PRACTICE

4. A transformer has 60 windings in the primary coil and 300 windings in the secondary coil. It is designed to supply a compressor motor requiring a current of 2.0 A at a potential difference of 550 V. What are the (i) current and (ii) potential differences in the primary coil?

   (i) I_P = 10 A
   (ii) V_P = 110 V

Transformers

PRACTICE

5. A student is discussing transformers and states that the voltage and the current both increase in a step-up transformer. Explain why this is not possible.

   transformers must obey the law of conservation of energy – since P=VI and P_{IN} = P_{OUT} , if V increases then I decreases by the same amount and vice versa

Transformers

PRACTICE

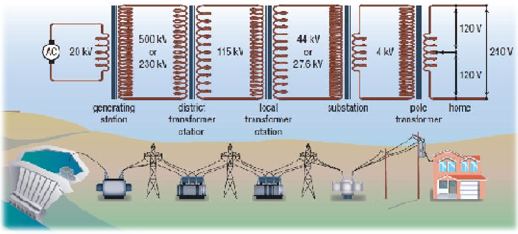
6. If DC and AC generators are equally easy to design and operate, why is the AC generator the only one used for large-scale electrical energy supply?

   Since P_{LOSS} = I^2R, to be efficient, electrical power must be transmitted at high potential differences (230 kV, 500 kV or higher) and very low currents (since P=VI). Yet to be practical the consumer needs potential differences much lower (120 V or 240 V). A device is needed to increase the electric potential difference and decrease the current for transmission, then decrease the electric potential difference and increase the current for use by the consumer. A transformer (which uses AC) performs both of these functions very efficiently.

Transformers

ENERGY GENERATION/DISTRIBITUION

- AC generator used for large-scale energy production
- step-up and step-down transformers are used to distribute the energy



Transformers

PRACTICE

7. Determine the power loss in each of the following ($P_{loss} = I^2R$). Express your answer in megawatts (MW). Recall 1 MW = 1 x 10^6 W.
   (a) A 200 MW power plant delivers a current of 2 kA in a 10 Ω wire.
   (b) A 200 MW power plant delivers a current of 200 A in a 10 Ω wire.
   (c) A 10 MW wind turbine delivers a current of 3000 A in a 0.50 Ω wire.

   (a) P_{loss} = 40 MW (20%)
   (b) P_{loss} = 0.40 MW (0.20%)
   (c) P_{loss} = 4.5 MW (45%)

✔ Check Your Learning

TEXTBOOK

P.609 Q.1-8
P.612 Q.1-3

WIKI (ELECTRICITY & MAGNETISM)

✎.... 3U4 - QUIZ#4 (Magnetism - Part 2)