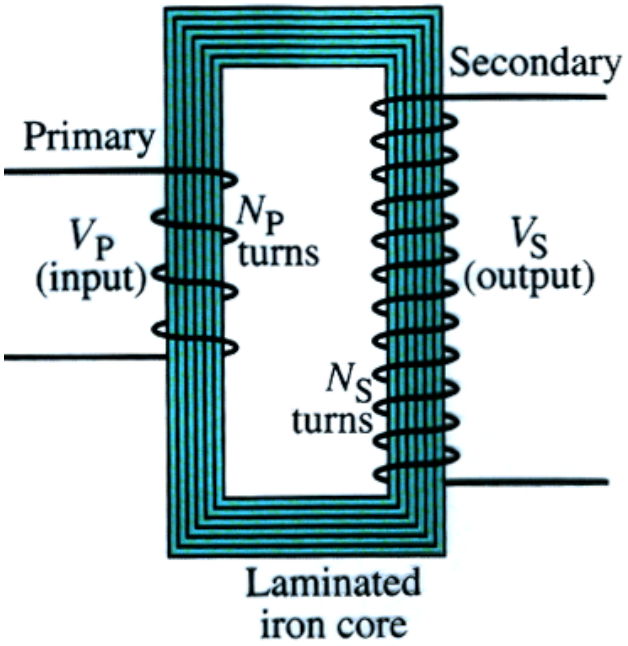
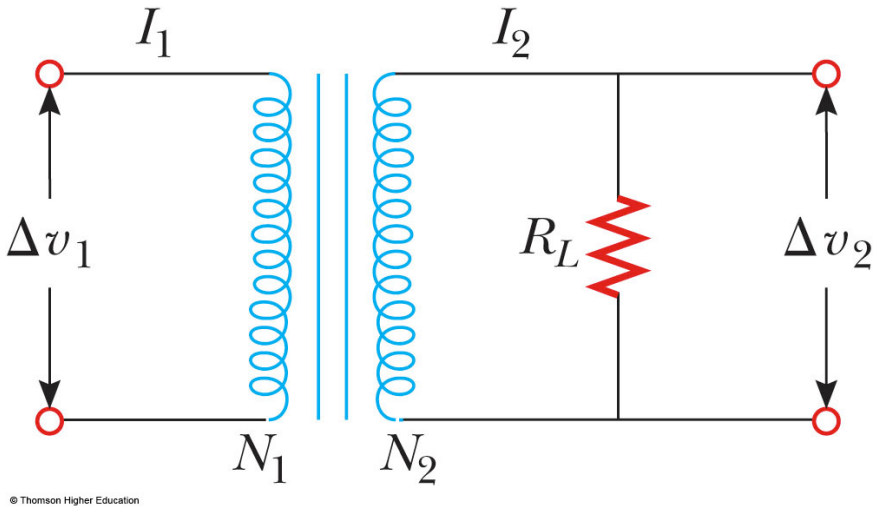
21-7 Transformers; Transmission of Power

- A transformer is a device for increasing or decreasing an ac voltage. It has two coils: **primary** and **secondary** coils.
- A transformer operates only on ac power source.
- All the magnetic flux produced by the current in the primary coils also passes through the secondary coil.





- The input primary voltage, V_p, is driving the flux changes in the primary coil:

$$V_p = N_p \frac{\Delta\Phi}{\Delta t}$$

The flux induces an emf in the secondary coil (Faraday's law):

$$V_s = N_s \frac{\Delta\Phi}{\Delta t}$$

Thus, $\boxed{\frac{V_S}{V_P} = \frac{N_S}{N_P}}$ Transformer equation

If $N_S > N_P$, then $V_S > V_P$ Step-up transformer.
If $N_S < N_P$, then $V_S < V_P$ Step-down transformer.

- A transformer cannot create power, even with ideal 100% efficiency, the power output:

$$\boxed{P_S = V_S I_S = V_P I_P = P_P}$$

or $\boxed{\frac{I_P}{I_S} = \frac{N_S}{N_P}}$

Example: A transformer for home use of a portable radio reduces 120V ac to 9V ac. The secondary contains 30 turns and the radio draws 400 mA.

(a) Find the number of turns in the primary coil.

$$N_P = \frac{N_S V_P}{V_S} = \frac{(30)(120V)}{9V} = 400 turns$$

(b) Find the current in the primary.

$$I_P = \frac{I_S N_S}{N_P} = \frac{(0.4A)(30)}{400} = 0.03A$$

(c) Find the power transformed.

$$P = I_S V_S = (9V)(0.4A) = 3.6W$$

Which is the same as the power in the primary,

$$P = I_P V_P = (120V)(0.03A) = 3.6W$$

Example: An average of 120 kW of electric power is send to a small town from a power plant 10 km away. The transmission lines have a total resistance of 0.40Ω. Calculate the power loss if the power is transmitted at (a) 240V and (b) 50,000V.

(a) If use V=240V, to transmit 120 kW power, the current is

$$I = \frac{P}{V} = \frac{120,000W}{240V} = 500A$$

the power loss in the lines is

$$P_L = I^2 R = (500A)^2 (0.4\Omega) = 100,000W$$

(b) If use V=50,000V, to transmit 120 kW power, the current is

$$I = \frac{P}{V} = \frac{120,000W}{50,000V} = 2.4A$$

the power loss in the lines is

$$P_L = I^2 R = (2.4A)^2 (0.4\Omega) = 2.3W$$

Which is 0.023% of the loss in case (a).

(Now you know why power companies use high voltage lines to transmit electricity.)