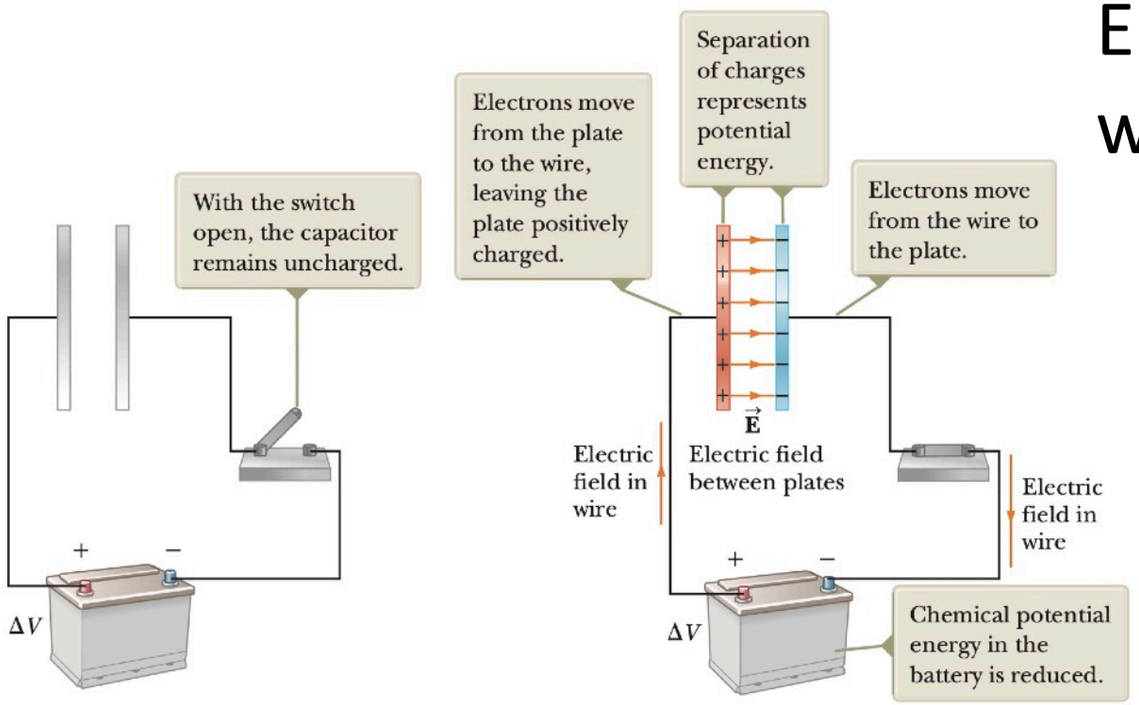
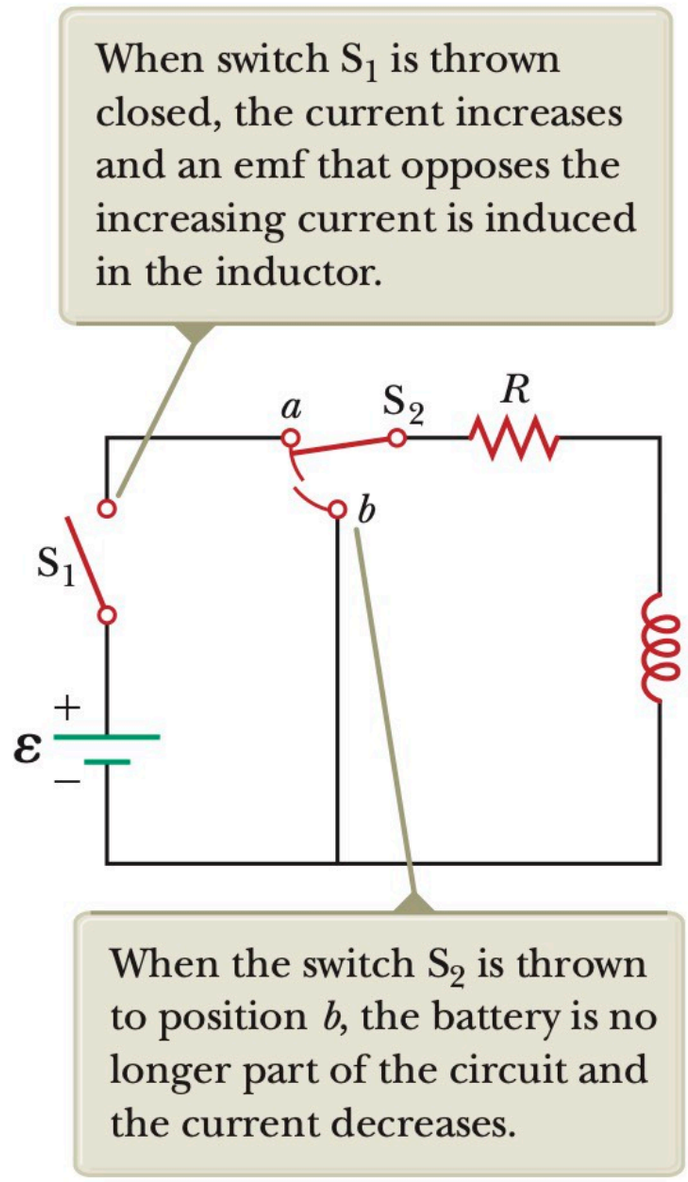
Energy carried by electromagnetic waves



Energy per unit volume associated with an electric field:

Energy per unit volume associated with an magnetic field:



Energy carried by electromagnetic waves

Exercise

In SI units, an electromagnetic wave has an electric field described by

$$\vec{E} = \hat{k}1000\sin(20y + \omega t)$$

- What is the angular frequency ω?
- What is the frequency f?
- What is the direction of $\vec{E}$?
- What is $\vec{B}$?
- What is the average energy density and average intensity?

Exercise

In the region of free space, the electric field at an instant of time is

$$\overrightarrow{E} = (80.0\hat{i} + 32.0\hat{j} - 64.0\hat{k})\ \text{N/C}$$

and the magnetic field is

$$\overrightarrow{B} = (0.200\hat{i} + 0.0808\hat{j} + 0.290\hat{k})\ \mu\text{T}.$$

- Show that the two fields are perpendicular to each other
- Determine the Poynting vector for these fields

Exercise

Assuming the antenna of a 10.0 kW radio station radiates spherical electromagnetic waves, compute the maximum value of the magnetic field 5.00 km from the antenna.

Momentum and radiation pressure

Exercise

A 15.0 mW helium-neon laser emits a beam of circular cross section with a diameter of 2.00 mm.

- Find the maximum electric field in the beam
- What total energy is contained in a 1.00 m length of the beam
- Find the momentum carried by a 1.00 m length of the beam

Exercise

The electromagnetic power radiated by a nonrelativistic particle with charge q moving with acceleration a is

$$P = \frac{q^2 a^2}{6\pi\epsilon_0 c^3}$$

where ϵ_0 is the permittivity of free space (also called the permittivity of vacuum) and c is the speed of light in vacuum.

(A) Show that the right side of this equation has units of watts.

(B) When an electron is placed in a constant electric field of magnitude 100 N/C, determine the acceleration of the electron and the electromagnetic power radiated by this electron.

(C) An electron is released from rest and falls under the influence of gravity. In the first centimetre, what fraction of the potential energy lost is radiated away.

Exercise

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