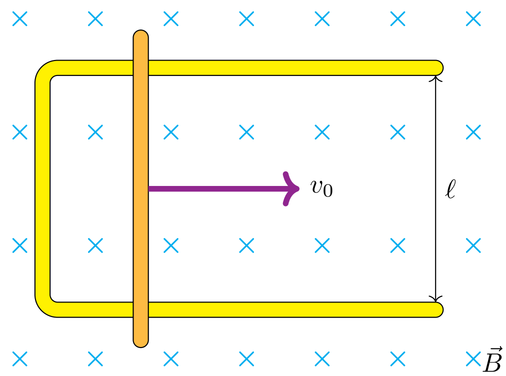
Chapter 29 - Electromagnetic Induction

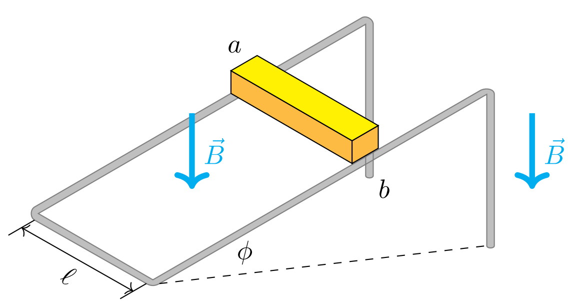
Physics 207

1. A rectangular loop is created with width ℓ and a slide wire with mass m. A uniform magnetic field $\vec{B}$ is directed perpendicular to the plane of the loop into the plane of the figure. The slide wire is given an initial speed of v_0 and then released. Assume that friction is negligible in this system, the resistance in the wire is R and the resistance in the rest of the system is negligible.
a) Obtain an expression for F, the magnitude of the force exerted on the wire as a function of its speed v.
b) Show that the distance Δx that the wire moves before coming to rest is

$$\Delta x = \frac{mv_0R}{\ell^2B^2}$$

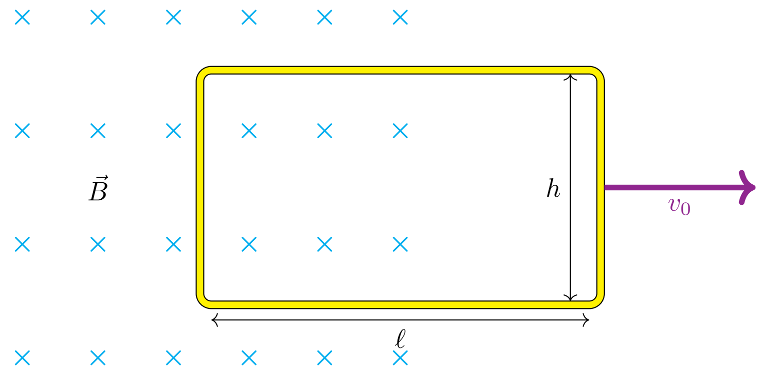


2. A metal bar with length ℓ, mass m, and resistance R is placed on frictionless metal rails that are inclined at an angle ϕ above the horizontal. The rails have negligible resistance. A uniform magnetic field of magnitude B is directed downward. The bar is released from rest and slides down the rails.
a) Is the direction of the current induced in the bar from a to b or from b to a?
b) What is the terminal speed of the bar?
c) What is the induced current in the bar when the terminal speed has been reached?
d) After the terminal speed has been reached, at what rate is electrical energy being converted to thermal energy in the resistance of the bar?
e) After the terminal speed has been reached, at what rate is work being done on the bar by gravity? Compare your answer to that in part (d).
f) Why is this result not surprising?



3. A square, conducting wire loop of side ℓ, total mass m, and total resistance R initially lies in the horizontal xy-plane, with corners at $(x, y, z) = (0, 0, 0)$, $(0, \ell, 0)$, $(\ell, 0, 0)$, and $(\ell, \ell, 0)$. There is a uniform, upward magnetic field $\vec{B} = B\hat{k}$ in the space within and around the loop. The side of the loop that extends from $(0, 0, 0)$ to $(\ell, 0, 0)$ is held in place on the x-axis; the rest of the loop is free to pivot around this axis. When the loop is released, it begins to rotate due to the gravitational torque (note that gravity acts in the $-\hat{z}$ direction).
a) Find the net torque (magnitude and direction) that acts on the loop when it has rotated through an angle ϕ from its original orientation and is rotating downward at an angular speed ω.
b) Find the angular acceleration of the loop at the instant described in part (a).

4. A rectangular loop of wire with dimensions $\ell \times h$ and resistance R is being pulled to the right out of a region of uniform magnetic field. The magnetic field has a magnitude of B and is directed into the plane of the page. Find the following at the instant when the speed of the loop is v_0 and it is still partially in the region with the magnetic field.
a) What force does the magnetic field exert on each branch of the loop?
b) What is the total force exerted on the loop?



5. A conducting ring with radius R begins to rotate from rest with a constant angular acceleration α_0. The ring is in the presence of a magnetic field $\vec{B} = B_0\hat{k}$. Assume that the ring is initially in the xy-plane and that it rotates about its center with the rotation axis parallel to $\hat{\jmath}$. What is the induced emf in the ring as a function of time?

6a. A solenoid with 500 turns has an 8.00 mm radius and is 4.00 cm long. The current in the solenoid is changing at a rate of 150 mA/s. What is the magnitdue of the induced electric field created by this solenoid as a function of r from the central axis both inside and outside the solenoid? Are the induced electric fields inside and outside the solenoid in the same direction?
6b. There is a magnetic field $\vec{B} = B_0\hat{k}$ in a region of space. This magnetic field is centered on the origin and covers a circular area in the xy-plane that has a radius of r_0. The radius then begins to increase by b every second. What is the induced electric field at a distance R from the origin as a function of time?