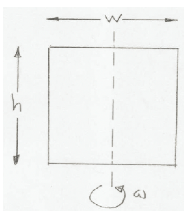
PHYSICS 322 ELECTROMAGNETISM

4 Feb . 2020 Problem Set 4 These problems are due in **tutorial boxes 11 am,Tuesday, 11 Feb.**

1. *Motional EMF* In 1996 astronauts on the space shuttle Columbia experimented to test the idea for generating electric power in satellites in orbit around the Earth, using a *conducting tether.* Columbia used a satellite attached to the space shuttle by a 20-km long tether. Motion of the tether through the Earth's magnetic field generates a voltage drop across the tether. (in vacuum, charge would accumulate on the ends, but in the ionosphere current would flow, the return current being in the ionospheric plasma.) Assume the tether is a straight wire, held taut by the shuttle and satellite at its ends. The whole system revolves around the Earth with speed 8 km/s. Assume for simplicity that the wire direction **L**, velocity **v** and Earth's magnetic field **B** are all mutually orthogonal. The strength of **B** is 0.3 $\times 10^{-4}$ T at the height of the satellite. Compute the voltage difference between the ends of the wire. (In the experiment the tether broke or melted through before the end of the experiment, but data collected before this catastrophe showed the potential for generating power by this method.



2. *Rotating rectangular loop in B field* A rectangular loop rotates as shown with angular frequency ω. A uniform and constant magnetic field **B** points into the page.

(a) Find the emf around the loop. This should be a function of time.

(b) Now suppose that not only is the loop rotating, but the magnitude of the magnetic field is changing as $B(t) = B_0 \sin(\omega t)$. At $t = 0$, the direction of **B** is perpendicular to the plane of the loop and inward. Find the emf around the loop.

3. *Sliding bar and resistor*

Consider the sliding-bar and resistor apparatus in Griffiths figure 7.17. Suppose a constant force of magnitude F pushes the bar through the region of perpendicular magnetic field of magnitude B.

(a) Starting from zero velocity, determine the velocity of the bar as a function of time? (ignore self-inductance.)

(b) Determine the current as a function of time.

4. *Circular disk in a time-dependent magnetic field* A metal disk of radius a, thickness d, and conductivity σ is located in the xy plane, and centered at the origin. There is a time-dependent uniform magnetic field $\mathbf{B} = B(t)\hat{\mathbf{z}}$. Determine the induced current density $\mathbf{J}(\mathbf{r}, t)$.