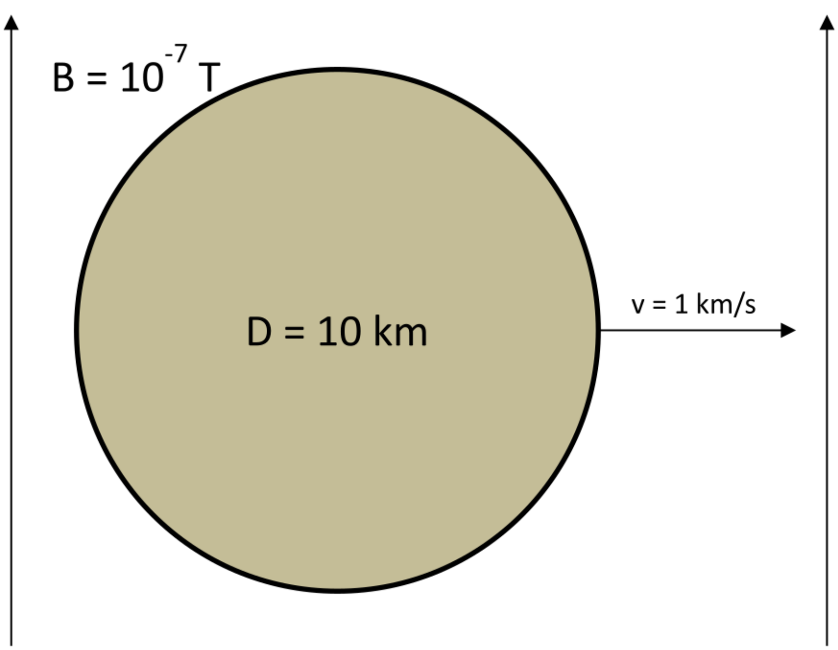
PHYS 301 - Tutorial 11

- Complete all problems and submit ONE set of answers as a group (max 4 students)
- One group member uploads a pdf to gradescope and specifies the other group members there.
- Upload is due by the end of the day of the tutorial. We will accept late submission till Thursday 11:59 pm, after which the submission will be closed.

Problem 1 – Orbiting satellite

A natural satellite whose diameter is 10 km orbits a planet at velocity 1 km/s in a direction normal to the planet's B-field ($B = 10^{-7}$ T). The satellite has appreciable conductivity. Note that for this problem we're interested in order-of-magnitude calculations, so you can approximate the sphere as a long metal bar for calculations where that is convenient.



a) What happens if the satellite moves in a vacuum? (Is there a current flowing? If so, for how long?)

b) The ambient gas has a density of about 10^{10} particles/m^3, with the particles being electrons or charged ions. As the satellite sweeps through space, each half of the satellite collects particles of the correct sign. What is the order of magnitude of the steady-state current?

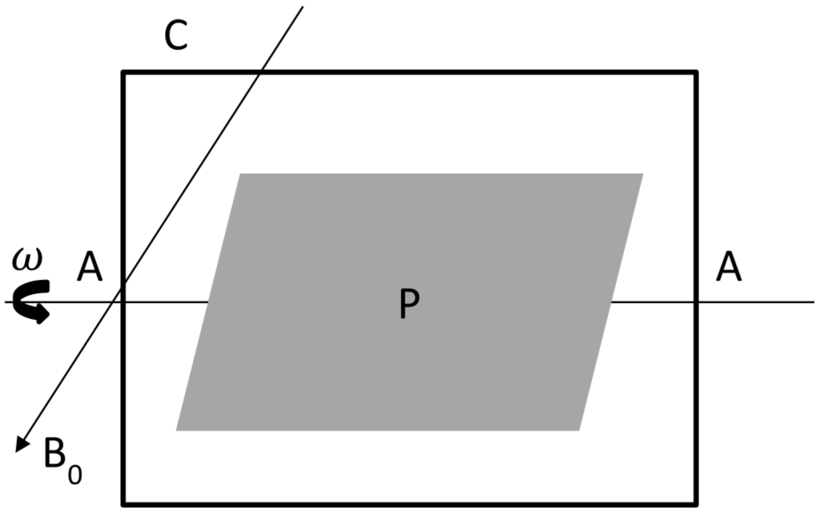
c) Calculate the order of magnitude of the braking force.

d) Could this current provide power for an artificial satellite travelling at the same velocity? Or could a current in the opposite direction propel the satellite? What is your opinion and why? ($\mathbf{v} \times \mathbf{B}$ in the ionosphere and magnetosphere ranges from ~ 100 to 320 μV/m.)

Problem 2 – Electromotive force

A loop of wire is situated in a time-dependent magnetic field $B(t) = 0.01\cos(2\pi\nu t)$ T, $\nu = 60$ Hz, perpendicular to the plane of the loop. Calculate the induced electromotive force (voltage) in a 100-turn square loop 100 mm on the side.

Problem 3 – Magnetometer



The figure shows a simple magnetometer that can measure magnetic fields as small as 10^{-8} T and up to 10^{-2} T. The Al plate P turns about the axis AA with angular velocity ω in the ambient field B_0 that we wish to measure. The fluctuating eddy currents induced in the plate P produce a fluctuating magnetic flux through the fixed coil C, which has N turns. This induces an emf V which is used to calculate B_0. Plate P is 1 mm^2 and is cemented inside of the plastic rotor of a small air turbine that operates at 1000 revolutions per second. The only magnetic parts are the plate and the coil. While an exact calculation of V depends on the geometry of the configuration, the instrument can be calibrated with a Helmholtz coil (which gives a known field).

a) How does V vary with B_0 and ω? Set $t = 0$ when the plate lies in the plane of C.

b) What is the frequency of $V(t)$?