2023 Problem Competition

Deadline for submission: 2023 September 8, 23h59 EDT

Regulations

If your solution is presented in audio or video format, the presentation can be no longer than 10 (ten) minutes.

If your solution is in a written format, it can occupy an area of no more than 467.5 square inches (equivalent to 5 sides of 8.5 x 11 inch "letter" paper). In SI units this is 0.3016 square meters.

The mass of your solution (if measurable) must be no more than 2 (two) kilogrammes.

Your solution, in all aspects, should comply with local health and safety guidelines.

While you do not need to be an undergraduate affiliate or a graduate student member of the CAP to participate in this challenge, you do need to be someone who would qualify to become an affiliate or graduate student member – as do all members of your team if you choose to participate as a team. You can see the eligibility requirements for undergraduates here: https://www.cap.ca/membership/undergraduate-student-affiliateship/

and for graduate students here:
https://www.cap.ca/membership/graduate-student-membership/

While looking at the criteria, consider joining. There is no fee while an undergraduate student and, for graduate students, your first year as a graduate student member is free.

Adjudication

The solutions will be judged on four (4) criteria:

- physical correctness of your solution (7 marks)
- clarity of your solution (5 marks)
- creativity of your solution (5 marks)
- mathematical correctness of your solution (3 marks)

Judging will be carried out by a team selected by the CAP Student Advisory Council. The judges' decision is final.

2023 PROBLEMS

Choose *one* of the problems and present your solution, in any e-mailable form you choose, to the Director of Student Affairs (bnewling@unb.ca) before 11:59 PM (Eastern) on September 8 2023, for a chance at problem-solving fame and glory. You may submit your solution individually or as a team, perhaps representing your local Physics Student Society or Science Club.

Problem One

You may have seen a small spark when you unplug electronic devices like a desktop charger. Explain why a spark occurs when you unplug but not when you plug it in. Would you expect to see a spark in all electric devices and why/why not?

According to Faraday's Law of Electromagnetic Induction, an electromagnetic coil generates some electromotive force (emf) when placed in varying magnetic fields.

(a) Explain how a magnetic core inserted in the electromagnetic coil strengthens the produced emf.
(b) Classical electrodynamically, how can the coil ”feel” the magnetic field that passes through the magnetic core?
(c) Explain AB Effect in a way general scientists can understand. Relate the AB effect to (b) for an alternative explanation.

Problem Two

You are holding a coffee cup in your hand, and you decide to start spinning around a fixed axis. In this scenario, we will explore the effects of two factors: the distance at which you hold the coffee cup from the axis of rotation and the angular velocity at which you rotate.

a) What would you observe? Explain this phenomenon qualitatively.
b) Assuming you maintain a constant angular velocity ω as you spin, discuss the influence of the distance at which you hold the coffee from yourself on the observed phenomenon.
c) Discuss the impact of the angular velocity of the coffee, ω_c, as you spin.

Problem Three

Say you're building a roller coaster and you want to add a "loop-the-loop" right after a hill. The roller coaster consists of a sphere in which the person is placed into (the person is always upright by some mechanism, not rolling with the sphere – just to make it a bit more rider-friendly). If the roller coaster is powered by gravity only past the hill (and ignoring friction, of course), how tall does the hill before the loop have to be? Hint: you have to consider the angular momentum of the system. Assume the sphere has constant density ρ.

Problem Four

Euler's disk (named after Euler, not created by him) is a toy that consists of a dense metal disk that is commonly made to rotate on a mirror. Just like a coin, the disk spins on its edge until it starts precessing. The difference between a regular coin and Euler's disk is that Euler's disk precesses for significantly longer.

A. Determine the rate of precession of the disk, its axial rotation, and the radius traced by the contact point and the surface the disk is on, in terms of tilt angle.
B. Determine the time constant for the motion of the disk. Make any assumptions necessary.

Problem Five

A stream of water at 20 degrees Celsius flows into a lake at a rate of 1 m^3/s. The temperature of the lake, which is not disturbed significantly by the stream, is 10 degrees Celsius.

(a) What is the rate of increase of the entropy of this composite system due to this process, ignoring possible differences in chemical composition? [The density of water is 1000 kg/m^3 and the specific heat is 4.18 kJ/(K kg).]

(b) Determine the rate at which external work could be performed if the same change of state were performed reversibly. Take the lake to be a suitable thermal reservoir.

(c) The river is harnessed for hydro-electric power by erecting a dam and channeling the flow through a turbine. The efficiency of the turbine-generator set is 85%. What height should the dam be in order to generate electrical power at the same rate as in b)?