2022/23 Problem Competition

Deadline for submission: 2023 January 15, 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 metres.

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.

2022/23 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 January 7th 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

The Tennis Racket (or Intermediate Axis) Theorem.

Sometimes, when you throw an object in the air spinning in a certain direction, you will get an odd revolution in surprising directions. The most famous demonstration is performed with a tennis racket (but you can try it, carefully, with your phone). If the tennis racket is thrown upward while spinning about an axis that points along its handle, the rotation is stable i.e. the axis of rotation stays the same. If the racket is thrown upward while spinning about an axis that is perpendicular to the plane of the racket head, the rotation is also stable. If the racket is thrown upwards while spinning about an axis in the plane of the racket head then the tumbling is unstable (the rotation axis keeps changing).

Explain why this is the case.

Problem Two

The cliff divers of Acapulco take pride and pleasure in hurling themselves from a height of 35 m into a channel of water which is only 4-6 m deep (depending on the swell of the sea). A diver launches himself with a speed of 1 m/s from the top of the cliff. He has a mass of 70 kg. His speed is 25 m/s just as he enters the water. How much thermal energy is produced during the fall (before the impact with the water)? Where does the thermal energy end up (i.e. which objects experience a [small] change in temperature)?

Problem Three

Suppose a cube of side length l is placed atop of a hemisphere or radius r. Calculate the potential energy of the cube atop the hemisphere. Assuming the hemisphere is frictionless and the cube is given a small initial velocity, calculate the angle at which the cube leaves the top of the hemisphere. Say instead the cube is given some initial angular velocity about an axis perpendicular to one of the faces and going through its center of mass, how does your answer differ from the previous one?

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 as 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.