

*Show all calculations. Explain all assumptions. Answer in standard MKS units.*

*Explicitly substitute units into your symbolic equations to verify solution.*

*Express answers in 5 or fewer digits. Use scientific notation as appropriate.*

Calculation Questions: Follow homework format. Make sure pages are in order.

---

1. Nuclear reactors split heavy elements into smaller fragments, and the difference in mass is radiated as energy. Use  $E=mc^2$  and assume that a reasonable estimate of the efficiency of this process is  $\sim 33\%$ . Coal burning plants liberate an average of 31MJ per kilogram of fuel and are about 7.5% more efficient than an equivalent nuclear plant.
  - a) If a particular plant is to produce an average 2200MW of power all year, find the ratio of the amount of fuel used by a coal burning plant to that used by a nuclear plant each year.

---
2. A roller coaster car ( $m=750$  kg with passengers) starts with near zero velocity at the top of a 70m section of track that is inclined at 38 degrees from the horizontal. There is a kinetic coefficient of  $\mu_k=0.1$  between the tracks and the wheels. During the descent the average drag force is 125N. At the bottom of the descent is a horizontal turn to the right. In the turn the track is banked at a 35 degree angle with respect to the horizontal.
  - a) If the occupants are to experience a maximum centripetal acceleration of 3.5 times Earth gravity, what is the minimum turn radius allowable?

---
3. A rock weighing 20 N is dropped from rest and falls from a height of 25 m and makes a hole 38 cm deep when it hits the ground.
  - a) Calculate the average force between the rock and the ground as it stops.

---
4. A pistol fires a 7.1g bullet. The pistol has a 13cm barrel with a frictional coefficient  $\mu$ . The bullet exits the barrel with a speed of 400 m/s.
  - a) How much energy was delivered to the bullet?
  - b) What average force acted on the bullet as it moved down the barrel?

---
5. At a dam used for power generation, a spillway funnels  $1350$  m<sup>3</sup> of water through the turbines each second. The water begins at an altitude of 110 m above the river surface where the turbines are located, with an effective velocity of zero.
  - a) With a turbine and generator combination that operates at 75% efficiency, what is the power output of the plant?
  - b) What is the velocity of the water at the outflow pipe? Assume smooth, non-rotational, laminar flow. In other words, ignore friction or turbulence effects.

---
6. While bird watching you note with amazement that a particular hummingbird (mass 35g) is moving in a horizontal line, and that its position can be described by a function of time:  $x(t)=4t^3-3t^2+t-42$ , with  $x$  in meters when  $t$  is in seconds.
  - a) How much work does the bird perform in the time from  $t=2$  to  $t=5$  seconds?

**Due on or before 10/30**