1. In an early science fiction "Pole to Pole" by George Griffith, he describes a fictional tunnel that spans from the North Pole to the South Pole. Using this tunnel, we want to deliver a mail (mass "m") from one pole of the earth to the other side.
    a. Assuming that the earth is uniform density (ρ), prove that the force acting on the mail at any giver r (distance from the earth center) is
    $$F = \frac{4\pi\, Gm\rho}{3}\, r$$
    b. Find the estimate speed of the mail when reaching the earth core.
    (In all the variables above)
    c. If the radius of the earth is 6,371 Km and the density of the earth is 5.514 g/cm^3, what is the speed of the mail?

    (Note: when the mail is at radius r, the portion of earth that lies outside of the sphere radius r does not produce a net force to the mail. The portion that lies inside however, produces a net force and can be assumed as a particle located at the earth center)

2. A 20 kg satellite has a circular orbit with a period of 2.4h and a radius of 8 x 10^3 Km. If the magnitude of the gravitational acceleration in the planet's surface is 8.0 m/s^2, what is the radius of the planet?

3. A long uniform rod (m = 0.6kg) freely rotating on a horizontal plane about a vertical axis in the center of its center. The rod is connected to a nearby wall by a spring (k = 1850 N/m) at one of its end. On the equilibrium state, the rod is parallel to the wall. When the rod is rotated slightly,
    a. Write the torque equation of the rod.
    b. Prove that the period of the rod is $T = \frac{2\pi}{root\left(\frac{3k}{m}\right)}$ while stating the assumptions.
    c. What is the period?

4. During each cycle, a Carnot engine absorbs 750J as heat from a high temperature reservoir at 360K with the low temperature reservoir at 280K. How much work is done per cycle? The engine is then made to work in reverse to function as Carnot refrigerator with the same two reservoirs. During each cycle, what is the work required to remove 1200J as heat from the low temperature reservoir?

5. In a solar water heater, energy from the sun is gathered by a semiconductor plate to heat up 200L of water in a tank from 293K to 313K in 1h with an efficiency of the system is 20%.
    a. What is the collector area when the intensity of the incident sunlight is 700W/m^2?
    b. After achieving 313K, the water is then flowed out of the tank into the house piping system while new water (293K) with a flow of 1/18 kg/s is being brought into the tank achieving a steady current. If the heat flow has also reached a steady state with the convection coefficient of alpha, what is the temperature of the semiconductor plate?
    (Assume the temperature of the water in contact with the semiconductor plate remains constant at 313K)