1. (10%) In a collision with a nucleus of unknown mass, an α-particle scatters directly backward and loses 75% of its energy. What is the mass ratio of the nucleus to the α-particle, assuming that the scattering is elastic?

2. (10%) Three stars of equal mass M revolve in the same circular orbit with radius R. Find the period of the stars. Let the gravitational constant be G.

3. (10%) Hot fluid passes through a cylindrical pipe of length L with inner radius a and outer radius b. Find the rate of heat conduction through the wall of the pipe. Let the thermal conductivity be x and the temperatures at the inner and outer surfaces be T_a and T_b respectively.

4. (10%) Two identical objects with different temperatures T_H and T_C are placed inside an insulated box and allowed to come to equilibrium. Presuming that their heat capacities are independent of temperature, show that the entropy increase in this process is

$$\Delta S = \frac{2Q}{T_H - T_C} \ln \frac{(T_H + T_C)^2}{4 T_H T_C},$$

in which Q represents the total heat transfered from the hot object to the cooler one.

5. (10%) A mass m attached at one end of a rod of length L with a uniform mass M, and the rod is suspended at its other end by a frictionless pivot. The rod is released from rest at an angle $\theta_0 < \pi/2$ with the vertical. At what angle θ does the force in the rod change from compression to tension?

6. (8%) A point charge q is located at the center of a tetrahedron with sides of length L as in Fig.6 , (a) What is the electric flux through each face of the tetrahedron? (b) What is the average value of the electric field over one face of the tetrahedron?

Fig.6
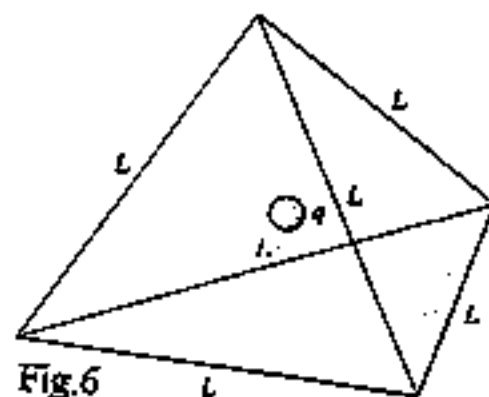
7. (10%) A dielectric slab of thickness d and dielectric constant k is inserted in the middle of a parallel-plate capacitor of plate separation D . (a) What is the new capacitance of the capacitor given that the area of each plate is A ? (b) If the potential difference between the plates is V, what are the electric fields in the empty space and inside the dielectric?

8. (12%) A straight wire carries a current $I = 10$ A near a rod that moves across two conducting wires , as in Fig.8 . The resistor has $R = 5.0\ \Omega$, and the rod moves at speed 3.0 cm/s. (a) What is the emf induced in the rod? (b) What is the current in the circuit? (c) How much work is done to move the rod 10 cm to the right?

Fig.8
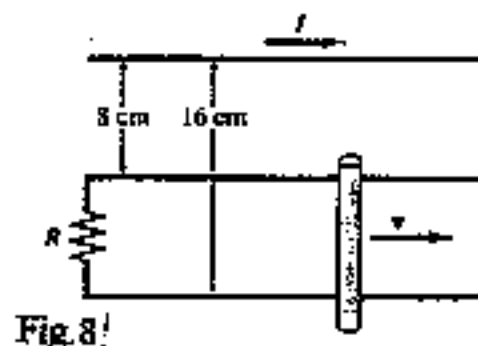
9. (10%) Given that the maximum voltage in the circuit shown in Fig. 9 is 110 V and the frequency of oscillation is 60 Hz, (a) Calculate the maximum current across the circuit. (b) What is the resonant angular frequency ω_0 of the circuit? (c) Suppose that the voltage generator has a variable angular frequency ω , for what values ω of will the current have half the value it has at resonance?

Fig. 9
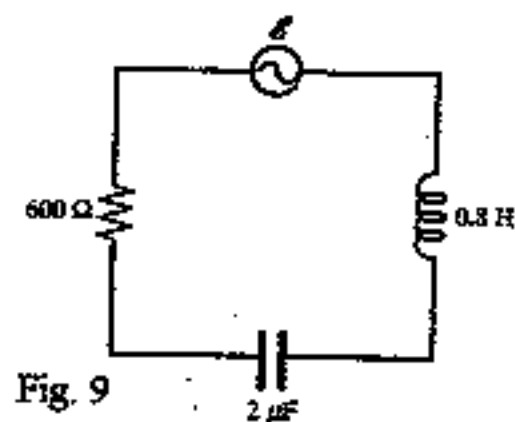
10. (10%) A meter stick is tilted so that it makes an angle of 30° with the x-axis. How will an observer at rest in a frame F' that moves at velocity $v = 0.8\ c$ in the +x-direction relative to the meter stick describe the stick?