MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Experimental Study Group

Physics 8.012

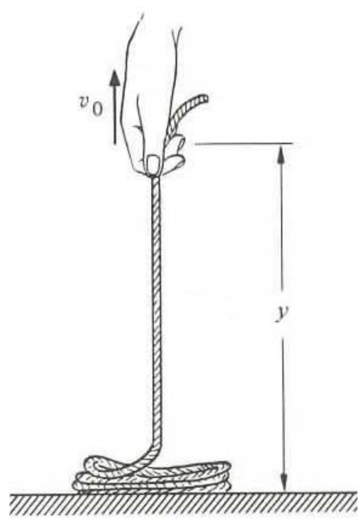
Problem Set 7

Handed out: October 21
Suggested Due: October 30
Test Two Date: Nov 6
Readings: (KK) Kleppner, Daniel and Kolenkow, Robert, An Introduction to Mechanics, McGraw Hill, Inc., New York, 1973, Chapter 4.

Problems: Chapter 4: 21, 23, 25, 27, 28, 30

Problem 21:

An unknown rope of linear mass density λ (mass per unit length), is coiled on a smooth horizontal table. On end is pulled straight up with constant speed v_0.

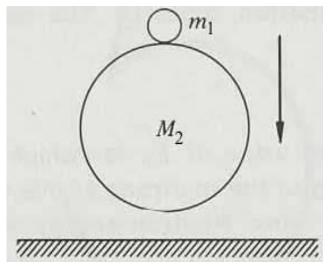


a) Find the force exerted on the end of the rope as a function of the height y of the rope above the table.

b) Compare the power delivered to the rope with the rate of change of the rope's total mechanical energy. Explain whether they should or should not be equal. Remember that the rope is not a rigid body.

Problem 23:

Two superballs are dropped from a height above the ground. The ball on top has a mass m_1. The ball on the bottom has a mass m_2. Assume that the lower ball collides elastically with the ground. Then as the lower ball starts to move upward, it collides elastically with the upper ball that is still moving downwards. How high will the upper ball rebound in the air? Assume that $m_2 >> m_1$. Hint: consider this collision from an inertial reference frame that moves upward with the same speed as the lower ball has after it collides with ground. What speed does the upper ball have in this reference frame after it collides with the lower ball?

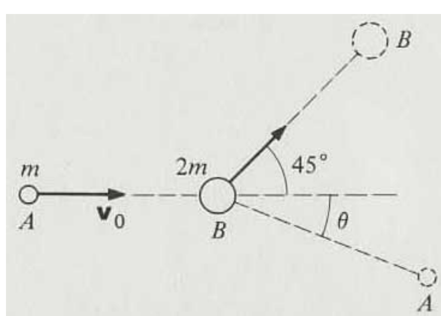


Problem 25: ***(Elastic collision in two dimensions)***

A proton makes a head-on collision with an unknown particle at rest. The proton rebounds straight back with $4/9$ of its initial kinetic energy. Find the ratio of the mass of the unknown particle to the mass of the proton, assuming that the collision is elastic.

Problem 27:

A particle A of mass m is initially moving in the positive x-direction with a speed $v_{A,0}$ and collides elastically with a second particle B of mass $2m$, which is initially at rest.. After the collision the particle A moves with an unknown speed $v_{A,f}$, at an unknown angle $\theta_{A,f}$ with respect to the positive x-direction. After the collision, particle B moves with an unknown speed $v_{B,f}$, at an angle $\theta_{2,f} = 45^o$ with respect to the positive x-direction. Find $\theta_{A,f}$.



Problem 28:

A thin target of lithium is bombarded by helium nuclei of energy E_0. The lithium nuclei are initially at rest in the target but are essentially unbound. When a helium nucleus enters a lithium nucleus, a nuclear reaction can occur in which the compound nucleus splits apart into a boron nucleus and a neutron. The collision is inelastic, and the final kinetic energy is less than E_0 by $2.8\,\text{MeV}$. ($1\,\text{MeV}=10^6\,\text{eV}=1.6\times10^{-13}\,\text{J}$). The relative masses of the particles are: helium, mass 4; lithium, mass 7; boron mass 10; neutron, mass 1. The reaction can be symbolized

$$^{7}\text{Li} + {}^{4}\text{He} \rightarrow {}^{10}\text{B} + {}^{1}\text{n} - 2.8\,\text{MeV}\,.$$

a) The minimum initial kinetic energy necessary for the reaction to take place is called the threshold energy, $E_{0,\text{threshold}}$. What is $E_{0,\text{threshold}}$ for which neutrons can be produced? What is the energy of the neutrons at this threshold?

b) Show that if the incident kinetic energy falls in the range

$$E_{0,\text{threshold}} < E_0 < E_{0,\text{threshold}} + 0.27\,\text{MeV}\,,$$

the neutrons ejected in the same direction as the incoming helium (forward direction) do not all have the same energy but must have one or the other of two possible energies. By considering the reaction in a reference frame moving with the velocity of the center of mass of the system, explain why there must be two distinct energies.

Problem 30:

A particle of mass m_1 and velocity $\vec{v}_{1,0}$ by a particle of mass m_2 at rest in the laboratory frame is scattered elastically through a scattering angle Θ in the center of mass frame.

a) Find the final velocity of the incoming particle in the laboratory reference frame.

b) Find the fractional loss of kinetic energy of the incoming particle. Is this the same in every reference frame. Explain.