MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Department of Physics

Physics 8.01T   **Fall Term 2004**

Problem Set 3: Newton's Laws of Motion, Motion: Force, Mass, and Acceleration, Vectors in Physics

Available on-line September 17; Due: September 28 at 4:00 p.m.

Please write your name, class section, table and group number, and the name of the instructor on the top right corner of the first page of your homework solutions. Please place your solutions in the box labeled with your instructor and your table number.

Sept 17
Hour One: Problem Solving Session 2: Projectile Motion
Reading: YF 3.3

Problem Set 2: Due Tues Sept 21 at 4:00 pm.

Sept 20
Hour One: Newton's Laws of Motion: Force, Mass, and Acceleration with Experiment 3: Force Laws and F = ma, Hooke's Law.
Reading: YF 4.1-4.6, Experiment 3

Hour Two: Problem Solving Session 3: Vectors in Physics; Principle of Relativity: Relative Inertial Frames: Newton's First Law
Reading: YF 1.8-1.11; 3.5

Sept 22
Hour One: Applying Newton's Laws of Motion
Reading: YF 5.1-5.3, 5.5

Hour Two: Experiment 3: Modeling Forces

Sept 24
Hour One: Problem Solving Session 4: Newton's Laws of Motion; Spring Forces, Tension.
Reading: YF 5.1-5.3, 5.5

Problem Set 3: Due Tues Sept 28 at 4:00 pm.

Sept 27
Hour One: Circular Motion Kinematics: Uniform Circular Motion.
Reading: YF 3.4, 5.4

Hour Two: Problem Solving Session 5: Uniform Circular Motion

Reading: YF 5.4

Sept 29
Hour One: Experiment 4: Circular Motion
Reading: Experiment 4

Hour Two: Test Review

Sept 30 QUIZ ONE: Fundamental Concepts; Kinematics; Newton's Laws
7:30 - 9:30 pm

Oct 1 No class

**Problem Set 4: Due Tues Oct 5 at 4:00 pm.**

Problem 1: (*Relative Inertial Frames*)

You and a friend are in an elevator that is rising at constant but unknown velocity v_0. You are curious to know what speed the elevator is moving. You each happen to be carrying altimeters. You get an idea and drop your keys from a height h above the floor of the elevator. You hold one altimeter at the point where you dropped the keys and your friend places the other one on the floor. You check your altimeter when you release the keys and find the keys are a height d above sea level. Your friend checks the other altimeter when the keys hit the floor and finds the keys are the same height d above sea level. Assume that the gravitational constant is g. You will analyze this problem from two different reference frames. The first reference frame moves with the elevator. The second reference frame is fixed to the ground.

a) As seen from a reference frame moving with elevator, how long does it take for the keys to hit the floor?

b) As seen from a reference frame fixed to the ground, using your result from part a), find an expression for the speed of the elevator in terms of the height h.

c) As seen from a reference frame fixed to the ground, what maximum height above sea level did the keys reach?

Problem 2 Concept Question: (*Hooke's Law*)

A body of mass m is suspended from a spring with spring constant k in configuration (a) and the spring is stretched $0.1m$. If two identical bodies of mass $m/2$ are suspended from a spring with the same spring constant k in configuration (b), how much will the spring stretch? Explain your answer.

(a)   (b)
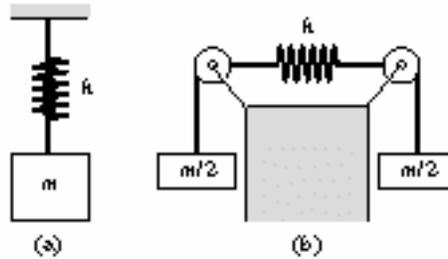
Problem 3: Free Body Diagrams

Two teams, A and B, are competing in a tug-of-war. Team A is stronger, but neither team is moving because of friction.

TEAM A   TEAM B
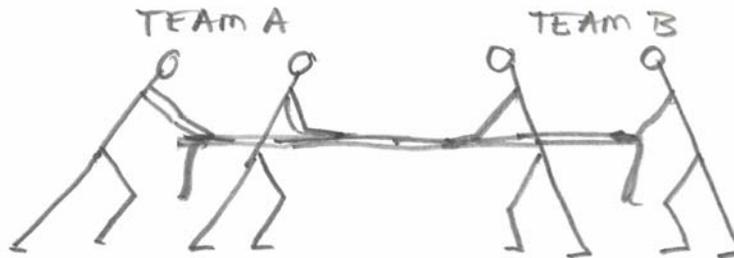
a) Draw free-body diagrams for team A, for team B, and for the rope.

b) Both the following statements are true; explain them. Two teams having a tug of war must always pull equally hard on one another. The team that pushes harder against the ground wins.

## Problem 4: *Second Law and projectile motion*

An object with mass $m = 2.0\,kg$ slides down a roof a distance 6.0 m on a roof that is inclined at an angle of 3.0×10^1 deg to the horizontal. The roof has a coefficient of kinetic friction $\mu_k = 2.0\times10^{-1}$. The edge of the bottom of the roof is at a height $h = 9.0m$ above the ground. What is the horizontal displacement from the edge of the roof to the point where the object hits the ground?

Problem 5: (*Experiment 4 Circular Motion Pre-Lab Question*)

Consider a spring with negligible mass that has an unstretched length $l_0 = 8.8 \times 10^{-2} m$. A body of mass, $m_1 = 1.5 \times 10^{-1} kg$, is suspended from one end of the spring. The other end of the spring is fixed. After a series of oscillations has died down, the new stretched length of the spring is $l = 9.8 \times 10^{-2} m$.
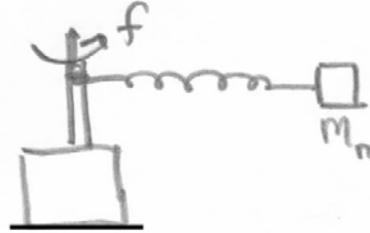
part a)   parts b) - d)

a) Assume that the spring satisfies Hooke's Law when it is stretched. What is the spring constant?

The body is then removed and one end of the spring is attached to the central axis of a motor. The axis of the motor points along the vertical direction. A small ball of mass, $m_n = 3.0 \times 10^{-3} kg$, is then attached to the other end of the spring. The motor rotates at a constant frequency, $f = 2.0 \times 10^{1} Hz$.

b) How long does it take the ball to complete one rotation?

c) What is the angular frequency of the ball in radians per sec?

Neglect the gravitational force exerted on the ball. Assume that the ball and spring rotate in a horizontal plane.

d) What is the radius of the circular motion of the ball?

Problem 6: *Experiment 3: Analysis*

Suppose the function

$$y = A \frac{9170\, z}{z^4 + 500\, z^2 + 5000}$$

with

$$z = x + B$$

fits the force law you measured in an experiment to determine the force between two magnets, where y is the force and x is the gap between the magnets, measured in mm. The parameters obtained from the fit are $A = 0.60$ N and $B = 3$ mm. Now suppose you approximate the force with a different law

$$y = A_1 e^{-Cx} = A_1 e^{-C(z-B)}$$

a) Find the parameters A_1 and C so that this function will give the same force as the first one when $z = 5$ mm and $z = 15$ mm.

b) As you saw in the notes for Experiment 03, both of these functions fit the measurements equally well (in the sense that the RMS error is the same for both) when the force was measured over the approximate range $5 \le z \le 20$ that you were able to measure. If you were able to measure the force out to $z = 30$, do you think it would be possible to decide which of the two functions was a better representation of the force law? (Use the parameters you have from above, and explain your answer.)