Massachusetts Institute of Technology
Department of Physics

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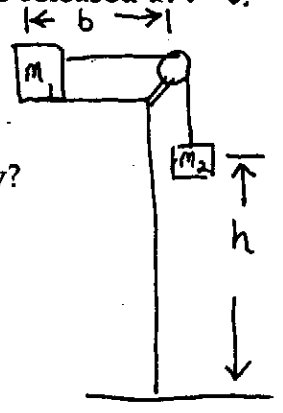
Practice Exam 2

Problem 1: Newton's Laws; two masses hanging over edge of table

A mass of m_1 is initially held in place on the surface of table a distance b from the edge of a table. The contact surface between the mass and the table has a coefficient of kinetic friction μ. One end of the mass is attached to a massless inextensible string of length f which is wrapped around a massless pulley attached to the edge of the table. The other end of the string is attached to a larger second mass $m_2 \gg m_1$ which is initially suspended a height $h > d$ above the ground. The mass m_1 is released at $t = 0$. Assume the radius of the pulley is negligible.



a) What is the acceleration of mass m_1 before it reaches the pulley?

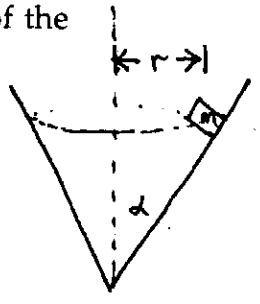
b) What is the tension in the string before mass m_1 reaches the pulley?

c) How long does it take for the mass m_1 to reach the pulley?

d) What is the speed of the mass m_1 just before it reaches the pulley?

Problem 2: Circular motion on the inside of a cone

A mass is moving in an horizontal circle of radius r with a constant speed on the inside wall of a cone. Assume the wall of the cone is frictionless. The wall of the cone makes an angle α with the vertical.



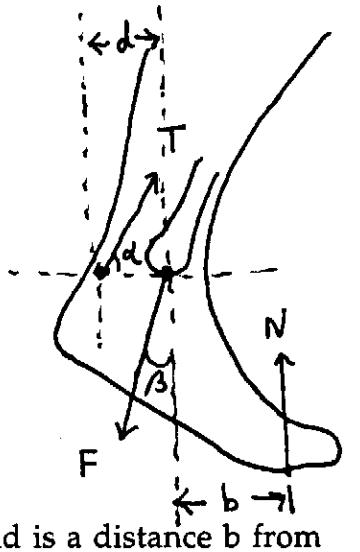
a) Draw a free body force diagram showing all the forces acting on the mass.

b) What is the speed of the mass?

c) How long will the mass take to go around the circle?

d) Now assume there is a coefficient of static friction μ. Find the maximum speed the mass can move on the inside of a cone and still move in a circular orbit of radius r.

Problem 3: Static Equilibrium: The ankle



Consider one foot of a man who is crouching on the ground with his weight evenly distributed on his two feet. The mass of the man is m. In this position on tiptoes, the Achilles tendon in under considerable tension T and makes an angle α with the horizontal. The tibia acts on the ankle with a force $\vec{F}$ at a point that is at the same height above the ground as the point where the Achilles tendon acts on the ankle. These points are separated by a distance d. This force $\vec{F}$ makes an angle β with the vertical. Assume the contact point of the foot on the ground is a distance b from a vertical line passing through the point of contact between the tibia and the ankle. Assume the center of mass of the foot lies directly below the contact point between the tibia and the ankle. The foot has a mass m_f.

a) Find the magnitude of the tension, T, in the Achilles tendon.

b) Find an expression that the angle β makes with the vertical.

c) Find an expression for the magnitude of the force, $\vec{F}$, of the tibia on the foot.

Problem 4: Experiments

Part A: Experiment Centripetal Force

Consider an ideal massless rubber-band which has an unstretched length l_0 A roll of 50 pennies of total mass m_p is attached to the rubber band. The new stretched length of the rubber band with the pennies hanging down from the end of the rubber-band is l.

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

A small nut with mass m_n is then attached to the rubber band and both are rotated by a motor at an unknown constant frequency f. The rubber band is stretched to a length d.

b) Find an expression for the frequency f in terms of r, m_p, l, l_0, g, and m.

c) How long does it take for the nut to complete one rotation?

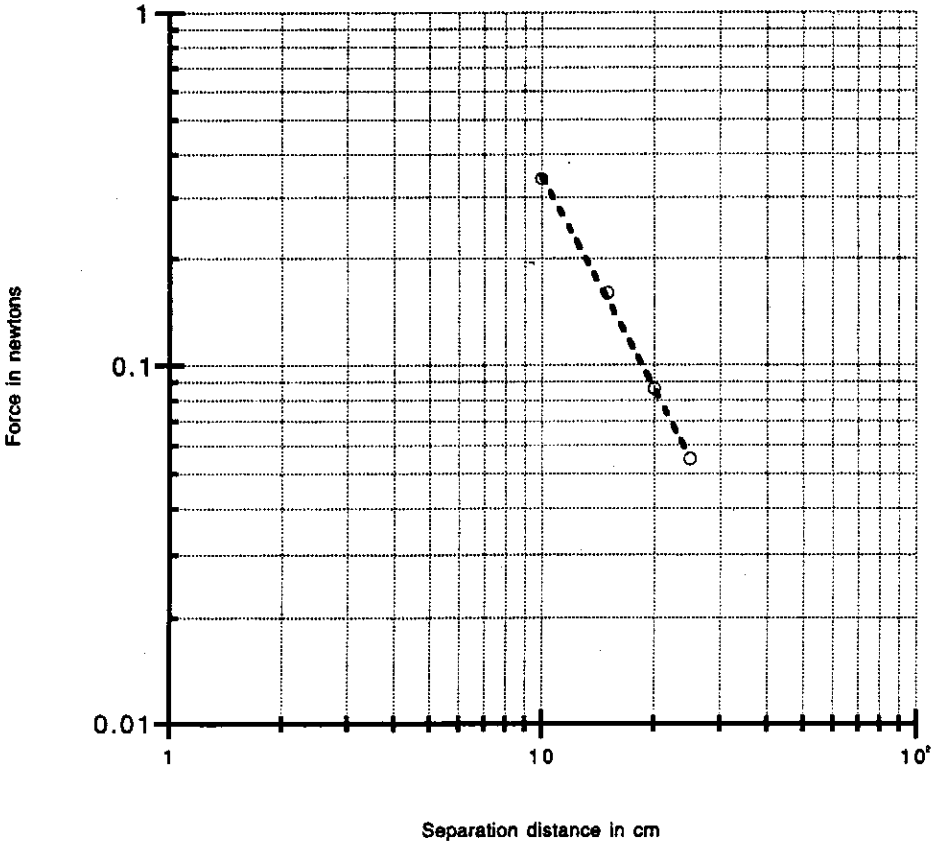
d) What is the angular frequency of the nut?

Part B: Experiment Magnetic Force

Table 1 shows the results of experiment FM.

Center to center distance S_c between magnets in cm	Force F_m in newtons on upper magnet
25	.055
20	.086
15	.16
10	.34

The points lie on a straight line in on the log-log graph shown below with force plotted on the vertical axis and separation distance on the horizontal axis.



Graph 1

Calculate the power law dependance of the force bewteen magnets as a function of the distance between the centers of the faces, i.e calculate the power b in the expression $F_m = a\,(S_c)^b$.