Homework Assignment 3

Due: Monday, June 6, 2016

Problem 1: A block sits on a horizontal, frictionless table. A force of 100 N pushes horizontally on the block, to the right.

(a) Draw a free-body diagram for the block. What are the x- and y-components of the net force?

(b) If the block accelerates with $\vec{a} = 2.5\,\hat{x}$ m/s^2, what is the mass of the block?

(c) The force is now removed and the table is slanted. At what angle θ must the table be inclined for the block to have the same acceleration as in part (b)?

Problem 2: A 5000 kg spaceship floats at rest in deep space, far away from any other object. The ship's computer suddenly malfunctions, causing three of the ship's thrusters to randomly fire. The thrusters push with the following forces:

$$\vec{F}_1 = (5500\,\hat{x} + 1200\,\hat{y})\,\text{N},$$
$$\vec{F}_2 = (-3300\,\hat{x} - 2600\,\hat{y})\,\text{N},$$
$$\vec{F}_3 = (-2000\,\hat{x} + 4000\,\hat{y})\,\text{N}.$$

It takes the astronaut on board 90 s to fix the computer malfunction. What is the magnitude of the ship's displacement when the computer is fixed?

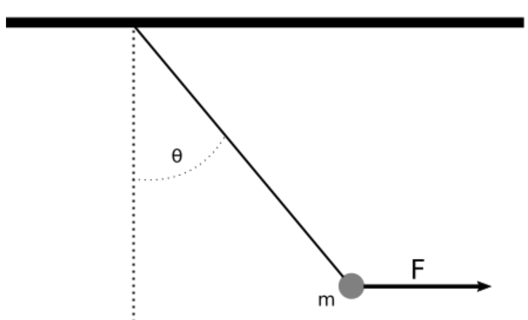
Problem 3: Brad, an MMA fighter, has failed to qualify for his next fight by being slightly over the cut-off weight during his weigh-in. He steps on the scale (on the surface of the Earth) and finds that his weight is 3 N greater than the Middleweight cutoff of 840 N. He decides to solve this problem by fighting on Mars instead of Earth (naturally) where the acceleration due to gravity is roughly $g_{\text{mars}} = 4.0$ m/s^2.

(a) What is Brad's mass? How does it change on the surface of Mars?

(b) Does Brad qualify for a Middleweight fight on Mars at his current mass? Assume there is no minimum weight cutoff. How much *more* mass could Brad "bulk up" and still qualify for his weight class on Mars?

(c) Will the current rules for defining weight classes be valid in the distant future, when humans have colonized multiple planets? What physical quantity would be better used to categorize fighters, and why?

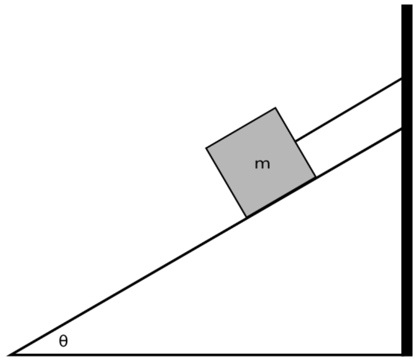
Problem 4: A ball of mass $m = 3.0$ kg hangs from a massless string. A force $F = 45$ N pushes on the ball horizontally, such that the ball hangs motionless as in the figure below:



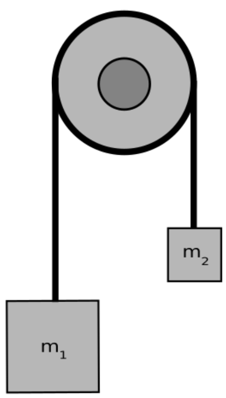
(a) Find the tension in the string.

(b) What is the angle θ?

Problem 5: A block, weighing 600 N, sits tied to a wall on a frictionless incline. The rope tying the block to the wall can support a maximum tension $T_{\max} = 400$ N before it snaps. What is the maximum allowed angle of inclination, θ, before the string breaks? Assume that the tension is parallel to the incline.



Problem 6: The Atwood machine (pictured below) is a useful tool for comparing the masses of two objects; two objects hang from a massless string around a massless, frictionless pulley, and are released from rest. When $m_1 = m_2$, the system remains at rest. When the masses are unbalanced, the system accelerates. Assume for this problem that $m_1 = 12$ kg and $m_2 = 5$ kg.

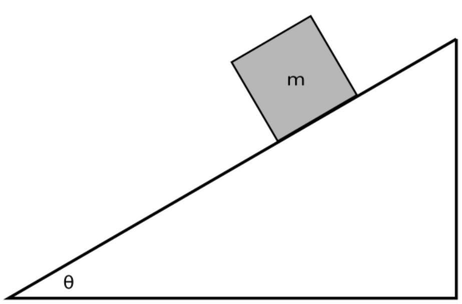


(a) Draw a free-body diagram for each mass, and write the net force equations for each.

(b) Find the acceleration of the system. What direction does each mass accelerate?

(c) What is the tension in the string connecting the two masses?

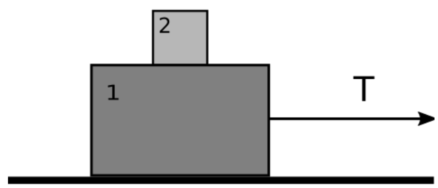
Problem 7: A cereal box of mass m rests on an incline, $\theta = 30°$. The coefficients of static and kinetic friction between the cereal box and incline are $\mu_s = 0.55$ and $\mu_k = 0.3$, respectively.



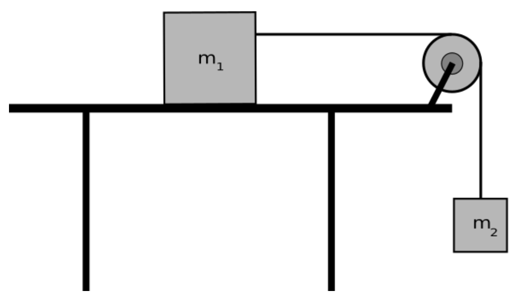
(a) What amount of cereal (i.e. what mass m of the box) will cause the box to slip down the incline? Will it ever slip on its own? Explain your answer.

(b) The box has now been pushed and is sliding down the ramp. If the box has a mass $m = 50$ kg (lots of cereal!), what is its acceleration down the incline?

Problem 8: Block 1 rests on a frictionless table. Block 2 sits atop Block 1, and the coefficient of static friction between Blocks 1 and 2 is $\mu_s = 0.7$. A rope, tied to Block 1, pulls horizontally with a tension T. What maximum tension is allowed in the rope, such that the blocks move without Block 2 slipping? The masses of Blocks 1 and 2 are $m_1 = 25$ kg and $m_2 = 6$ kg, respectively. HINT: start by drawing a free-body diagram for each block and consider the third-law-pair between Blocks 1 and 2.



Problem 9: Two masses, $m_1 = 7$ kg and $m_2 = 13$ kg, are tied together by a massless rope run over a massless, frictionless pulley. Mass m_1 sits on a rough, horizontal table surface (not frictionless!). Both masses are released from rest. If mass m_2 falls a distance of 1.5 m in 0.7 s, what is the coefficient of friction between m_1 and the table? Is it static or kinetic?



Problem 10: Francine steps onto a scale in her bathroom and reads a weight of 168 N. She then enters a 1500 kg elevator (with her scale) and measures her weight to be 220 N as the elevator begins to move. What is the tension in the cable supporting the elevator? Ignore the mass of the scale.