UNIVERSITY OF OTTAWA
Principles of Physics
PHY1321/1331 FALL 2012
Dr. A. Czajkowski

CLASS: PHY_____

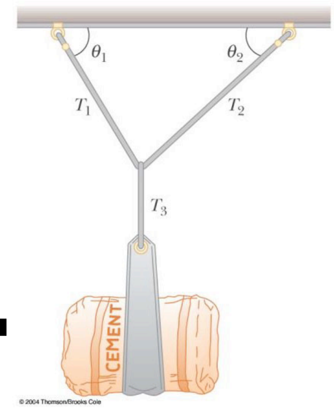
STUDENT #: ________________

NAME: ______________________

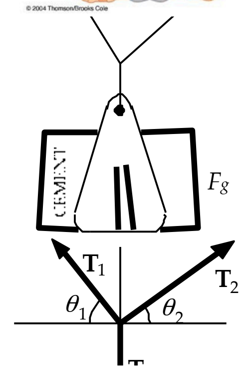
Assignment 3: Forces I. Lows of Dynamics

Assigned: Sept 28 12:00 *Due: October 5 10:00*

1 A bag of cement of weight of F_g hangs from three wires as shown. Two of the wires make angles θ_1 and θ_2 with the horizontal. If the system is in equilibrium, show that the tension in the left-hand wire is $T_1 = F_g \cos\theta_2 / \sin(\theta_1 + \theta_2)$



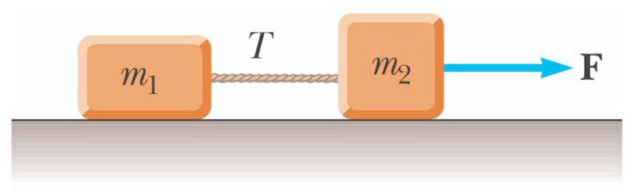
$$T_3 = F_g \quad (1)$$
$$T_1 \sin\theta_1 + T_2 \sin\theta_2 = F_g \quad (2)$$
$$T_1 \cos\theta_1 = T_2 \cos\theta_2 \quad (3)$$



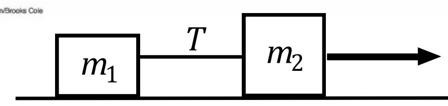
Eliminate T_2 and solve for T_1

$$T_1 = \frac{F_g \cos\theta_2}{(\sin\theta_1 \cos\theta_2 + \cos\theta_1 \sin\theta_2)} = \frac{F_g \cos\theta_2}{\sin(\theta_1 + \theta_2)}$$

2 Two blocks connected by a rope of negligible mass are being dragged by a horizontal force **F.** Suppose that $F = 68.0$ N, $m_1 = 12.0$ kg, $m_2 = 18.0$ kg, and the coefficient of kinetic friction between each block and the surface is 0.100. (a) Draw a free-body diagram for each block. (b) Determine the tension T and the magnitude of the acceleration of the system.



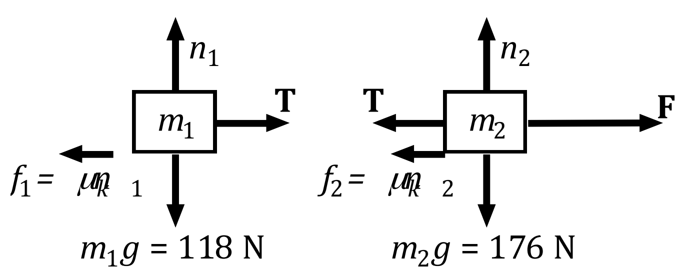
See Figure to the right



$$68.0 - T - \mu m_2 g = m_2 a \quad \text{(Block \#2)}$$
$$T - \mu m_1 g = m_1 a \quad \text{(Block \#1)}$$

Adding,

$$68.0 - \mu(m_1 + m_2) g = (m_1 + m_2) a$$
$$a = \frac{68.0}{(m_1 + m_2)} - \mu g = \boxed{1.29 \text{ m/s}^2}$$
$$T = m_1 a + \mu m_1 g = \boxed{27.2 \text{ N}}$$



3 You are pushing a wooden crate across the floor at constant speed. You decide to turn the crate on end, reducing by half the surface area in contact with the floor. In the new orientation, to push the same crate across the same floor with the same speed, the force that you apply must be about

A four times as great B twice as great C equally great
D half as great E one-fourth as great

As the force required before the change of orientation.
TO GET ANY MARKS YOU NEED TO EXPLAIN YOUR REASONING in FEW SENTENCES

4 A crate of weight $\mathbf{F}_g$ is pushed by a force **P** on a horizontal floor. (a) If the coefficient of static friction is μ_s and **P** is directed at angle θ below the horizontal, show that the minimum value of P that will move the crate is given by

$$P = \frac{\mu_s F_g \sec\theta}{1 - \mu_s \tan\theta}$$

(b) Find the minimum value of P that can produce motion when $\mu_s = 0.400$, $F_g = 100$ N, and $\theta = 0°, 15.0°, 30.0°, 45.0°$, and $60.0°$.

The crate is in equilibrium, just before it starts to move.
Let the normal force acting on it be n and the friction force f_s.

Resolving vertically: $n = F_g + P\sin\theta$

Resolving Horizontally: $P\cos\theta = f_s$

But, $f_s \le \mu_s n$

i.e., $P\cos\theta \le \mu_s\left(F_g + P\sin\theta\right)$

or $P\left(\cos\theta - \mu_s\sin\theta\right) \le \mu_s F_g$.

Divide by $\cos\theta$: $P\left(1 - \mu_s\tan\theta\right) \le \mu_s F_g \sec\theta$.

Then $\boxed{P_{\text{minimum}} = \frac{\mu_s F_g \sec\theta}{1 - \mu_s\tan\theta}}$.

(b) $P = \frac{0.400(100\text{ N})\sec\theta}{1 - 0.400\tan\theta}$

$\theta(\text{deg})$	0.00	15.0	30.0	45.0	60.0
$P(N)$	40.0	46.4	60.1	94.3	260

If the angle were $68.2°$ or more, the expression for P would go to infinity and motion would become impossible.

5 A 1.30-kg toaster is not plugged in. The coefficient of static friction between the toaster and a horizontal countertop is 0.350. To make the toaster start moving, you carelessly pull on its electric cord. (a) For the cord tension to be as small as possible, you should pull at what angle above the horizontal? (b) With this angle, how large must the tension be?

SOLUTION:

With motion impending,

$$n + T\sin\theta - mg = 0$$

$$f = \mu_s\left(mg - T\sin\theta\right)$$

and $T\cos\theta - \mu_s mg + \mu_s T\sin\theta = 0$

So that: $T = \frac{\mu_s mg}{\cos\theta + \mu_s\sin\theta}$.

To minimize T, we maximize $\cos\theta + \mu_s\sin\theta$ $\quad \frac{d}{d\theta}\left(\cos\theta + \mu_s\sin\theta\right) = 0 = -\sin\theta + \mu_s\cos\theta$.

(a) $\theta = \tan^{-1}\mu_s = \tan^{-1}0.350 = \boxed{19.3°}$

(b) $T = \frac{0.350(1.30\text{ kg})\left(9.80\text{ m/s}^2\right)}{\cos 19.3° + 0.350\sin 19.3°} = \boxed{4.21\text{ N}}$