Name: PC 241—Intro Physics
Honor Code: Fall 2004

First Mid-Block Exam

Answer all of the following questions, showing your work in the regions following each problem. If you need more room you may staple extra sheets to this exam. You must show work to get credit, and the more work you show the more partial credit we can give. Please be neat so we can follow what you are doing. Clearly cross out any incorrect work and answers. **Put a box around your final answer to each part of a question.**

This test is closed book. You may use a calculator to do arithmetic, and you may refer to the equations given below. You may use no other aid.

There is no time limit for this exam. You must turn it in no later than **5 PM on Friday December 3** either to Kristine in her office or to Kristine's box in the physics department office.

Equations and Conversion Factors:

$\mathbf{F}_{tot} = m\mathbf{a}$ $\quad \mathbf{v} = \frac{d\mathbf{r}}{dt}$ $\quad \mathbf{a} = \frac{d\mathbf{v}}{dt}$ $\quad F_k = \mu_k F_N$ $\quad F_s \le \mu_s F_N$ $\quad x(t) = x(0) + v_o t + \frac{1}{2}at^2$

$\vec{\mathbf{v}}(t) = \vec{\mathbf{v}}_o + \vec{\mathbf{a}}t$ $\quad F_g = mg$ $\quad$ 1 kg weighs 2.2lbs $\quad$ g = 9.8m/s^2

1. (10 points) A baseball is thrown straight up into the air. Just after it is thrown, what is its acceleration? When it reaches its highest point, what is its acceleration? Just before it returns to its original position, what is its acceleration?

After the ball leaves the person's hand, the only force acting on it (neglecting drag) is gravity. So for all 3 positions $\sum F = ma \Rightarrow mg = ma$. So $\boxed{a = g}$ pointing toward the center of the earth throughout the entire flight.

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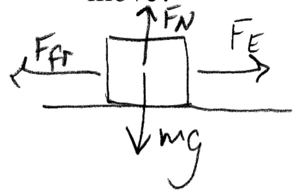
2. (25 points) Eugene is planning on dragging a box across a floor. The maximum force Eugene can exert is 400 N. The coefficient of static friction between the box and the floor is 0.5 and the coefficient of kinetic friction between the box and the floor is 0.3.

a) If Eugene pulls in a horizontal direction, what is the mass of the heaviest box he can move?



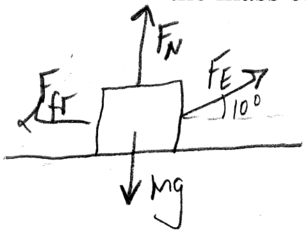
Static friction is greater than kinetic friction so this is what will break rope so use μ_s for F_{fr}.

$$\sum F_x = F_E - F_{fr} = \emptyset \text{ (just before box begins to move)} \rightarrow$$

$$\sum F_y = F_N - mg = \emptyset$$

$$\rightarrow F_E - \mu_s F_N = F_E - \mu_s mg = \emptyset \Rightarrow m = \frac{F_E}{\mu_s g} = \frac{400N}{0.5 \cdot 9.8 m/s^2} = \boxed{81.6 kg}$$

b) Now suppose that Eugene pulls in a direction that is 10° above the horizontal; what is the mass of the heaviest box he can move?



again static friction determines the maximum mass of the box that can be moved

$$\sum F_x = F_E \cos 10° - F_{fr} = \emptyset \quad \text{(just before box begins to move)} \rightarrow$$

$$\sum F_y = F_N - mg + F_E \sin 10° = \emptyset$$

$$\emptyset = F_E \cos 10° - \mu_s F_N = F_E \cos 10° - \mu(mg - F_E \sin 10°) =$$

$$\rightarrow m = \frac{F_E(\cos 10° + \mu \sin 10°)}{\mu g}$$

$$\boxed{87.5 kg} = \frac{400N(\cos 10° + \sin 10° \cdot 0.5)}{0.5 \cdot 9.8 m/s^2}$$

c) Suppose Eugene gives an initial yank to the box at 10° above the horizontal as in part (b), gets the box moving, and then continues pulling the box in a horizontal direction. Will Eugene be able to keep the box moving?

The heaviest box he can start moving with this strategy weighs 87.5 kg.
Assuming he has started this box moving, can he keep it moving?
Using the diagram + equations from part (a), he can if

$$F_E - \mu_K mg \geq \emptyset \Rightarrow 400N - 0.3 \cdot 87.5 kg \cdot 9.8 m/s^2 = 143 N$$

So he can keep the box moving.

3. (5 points) If a suitcase is dropped out of an airplane, it speeds up until it reaches its terminal velocity. After that point, what is the net force on the suitcase?

When an object moves with constant velocity, its acceleration is $\varnothing$. Since $F = ma$, $a = \varnothing \frac{m}{s^2} \Rightarrow F = \varnothing N$. So the net force on the suitcase is $\boxed{\varnothing N}$

4. (15 points) On an afternoon stroll you find yourself on a bridge over a small creek on a quiet country lane. Your friend wonders how high the bridge is. Using only items you are likely to have or be able to find on your stroll, explain how you can measure the height of the bridge. Be sure to state what quantities you will measure and how you will measure them. Also clearly show how you will use those quantities to determine the height of the bridge. If it is helpful to you, you may make up some reasonable data and use that to demonstrate your method.

We will measure the height of the bridge using a small stone and a watch. We drop the stone off the bridge & time how long it is until we hear the splash. Since I happen to remember that $g = 9.8\,m/s^2$ we may then use the equation $y = \frac{1}{2}gt^2$ to find y the height of the bridge. Say if we time 3s for the stone's fall, then $y = \frac{1}{2} \cdot 9.8\,m/s^2 \cdot 3s^2 = 44.1\,m$ is the height of the bridge.

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5. (25 points) You're standing in an elevator on the first floor and are holding a ten-pound dumbbell in your right hand.
a) The elevator door closes, and the elevator begins to ascend, reaching its cruising speed of 2 m/s after one second. As it approaches the third floor, it slows down, taking 0.75 s to come to a stop. During the three time intervals (speeding up, cruising, slowing down), how heavy does the dumbbell feel?

speeding up: $a = \frac{\Delta V}{\Delta t} = \frac{2 m/s - 0 m/s}{1 s} = 2 m/s^2$

↑ F_{hand} • dumbbell ↓ mg   ↑ +a

$\Sigma F = ma \Rightarrow F_{Hand} - mg = +ma \Rightarrow F_{hand} = mg + ma = mg + mg \cdot \frac{a}{g} = 10 lbs \left(1 + \frac{2 m/s^2}{9.8 m/s^2}\right)$

$\boxed{F_{hand} = 12 lbs = 5.5 kg}$

Cruising: $a = \frac{\Delta V}{\Delta t} = \emptyset$

↑ F_{Hand} ↓ mg

$\Sigma F = ma \Rightarrow F_{hand} - mg = \emptyset$

$F_{hand} = mg = \boxed{10 lbs = 4.5 kg}$

Slowing down: $a = \frac{\Delta V}{\Delta t} = \frac{2 m/s}{0.75 s} = 2.67 m/s^2$

↑ F_{hand} ↓ mg   ↓ a

$\Sigma F = ma = F_{hand} - mg = -ma$

$F_{hand} = mg - ma$
$= mg - mg \cdot \frac{a}{g}$
$= 10 lbs \left(1 - \frac{2.67 m/s^2}{9.8 m/s^2}\right) = \boxed{7.3 lbs} = \boxed{3.3 kg}$

b) On the third floor the elevator door closes again and while you are cruising up to the fifth floor the elevator cable snaps (too bad!). How heavy does the dumbbell feel while you continue upwards? At the moment you reach the highest point? As you descend? As the elevator smashes into the basement floor? For this last question you may give a qualitative (non-numerical) answer.

After the cable breaks and before the elevator hits the ground the elevator + everything in it is in freefall accelerating toward the earth at g. So the force of the dumbbell on the hand is $\emptyset$ lbs as the elevator continues upwards, when it reaches it highest point and as it descends.

As the elevator smashes into the basement floor it decelerates very rapidly, so $\Sigma F = ma \Rightarrow F_{Hand} - mg = +ma \Rightarrow F_{hand} = mg + ma$

↑ F_{hand} ↓ mg   ↑ a (large)

and so the dumbbell feels very heavy.

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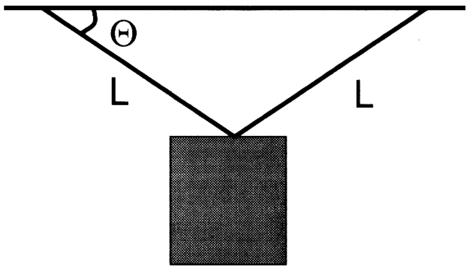
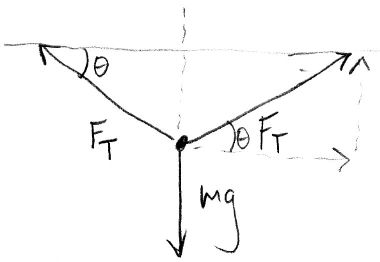


6. (20 points) The figure above schematically depicts a 5 kg picture hanging from the center of a piece of twine, which is attached to two pegs that are attached to a wall. You decide you don't want that much sag in the twine, so you start shortening the twine by winding it around one of the pegs. As you shorten the twine, the picture slides along the twine so that the geometry shown above is always the same. To your surprise, the twine breaks, even though it is guaranteed to be safe at tensions up to 300 Newtons. However, after a little thought (you know, featuring a free-body diagram, perhaps), you realize that it was all your fault. You realize that of course the twine *ought* to have broken once the angle Θ with the horizontal reached a certain value. What is the minimum safe value of that angle?



F_T is the same throughout the twine.

$$\Sigma F_x = F_T\cos\theta - F_T\cos\theta = \emptyset$$

$$\Sigma F_y = F_T\sin\theta + F_T\sin\theta - mg = \emptyset$$

$$2F_T\sin\theta = mg$$

$$\sin\theta = \frac{mg}{2F_T} = \frac{5\text{kg}\cdot 9.8\text{m/s}^2}{2\cdot 300\text{N}} \Rightarrow \boxed{\theta = 4.7^\circ}$$