Rules: *This midterm is closed book and closed notes. You are allowed two sides of one-half sheet of 8.5" x 11" paper on which you can write whatever notes you wish. You are **not** allowed to use calculators of any type, and any cellular phones must remain off and in your bags for the duration of the exam. **Any violation of these rules constitutes an act of academic dishonesty, and will be treated as such.***

Numerical calculations: *This exam consists of four problems, and each one is worth 25 points. Two of the problems ask you to calculate numbers. I have chosen the parameters in these two problems so that the answers can be expressed in terms of rational numbers. However, if you find that in your calculation of these two problems you end up with an expression which you cannot evaluate, simplify the expression as much as you can and leave it. You can find the sheet of formulas from the course website on the last two pages of the exam.*

Please make sure that you do the following during the midterm:

- *Write your name, discussion number, ID number on all documents you hand in.*
- *Make sure that the grader knows what s/he should grade by circling your final answer.*

We will give partial credit on this midterm, *so if you are not altogether sure how to do a problem, or if you do not have time to complete a problem, be sure to write down as much information as you can on the problem. This includes any or all of the following: Drawing a clear diagram of the problem, telling us how you would do the problem if you had the time, telling us why you believe (in terms of physics) the answer you got to a problem is incorrect, and telling us how you would mathematically solve an equation or set of equations once the physics is given and the equations have been derived. Don't get too bogged down in the mathematics; we are looking to see how much physics you know, not how well you can solve math problems.*

If at any point in the exam you have any problems, just raise your hand, and we will see if we are able to answer it.

Before the exam begins, write the following information on the front page of your bluebook and sign your bluebook!

Name: _____   *Disc Sec Number:* _____

*Signature:* _____   *Disc Sec GSI:* _____

Student ID Number: _____   *Disc Sec Time:* _____

You must show your student ID when you hand in your exam!

1. Bill and Ted are on the roofs of two buildings separated by a distance $D = 100$ m (see figure). The height of both buildings is $H = 19.6$ m (note that $19.6 = 2 \times 9.8$). One hundred meters is farther than Bill can throw his superball, so he decides to throw the ball so that it bounces once on the ground between the two buildings before it reaches Ted. Bill throws the ball so that when it leaves his hand, its velocity is parallel to the ground. We want to find the minimum velocity, v_0, with which the ball should be thrown so that it just reaches Ted. You should know that the superball is such that when it hits the ground:

$$v_x(right\ before\ it\ hits\ the\ ground) = v_x(right\ after\ it\ hits\ the\ ground),$$
$$v_y(right\ before\ it\ hits\ the\ ground) = -v_y(right\ after\ it\ hits\ the\ ground).$$
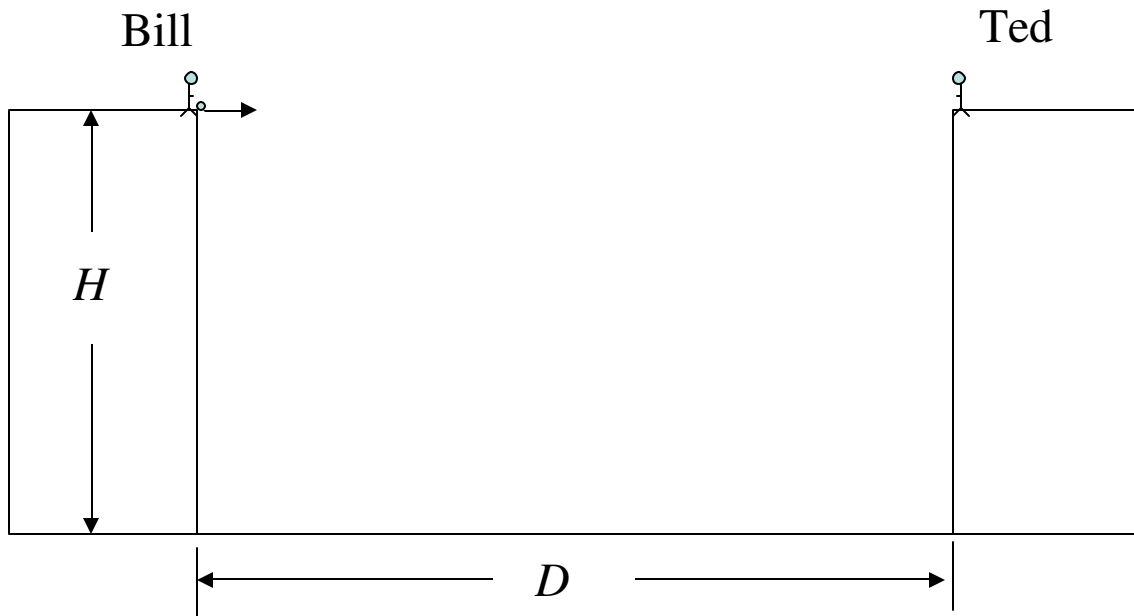
a. Draw the above figure in your bluebook, and on the figure *sketch* what you think the trajectory of the ball should be.
b. What is v_0?

2. Three blocks, with masses m_1, m_2, and, m_3, are sitting on a table, and you apply a force F onto the leftmost block. The coefficient of static friction between the table and the blocks is μ_s.
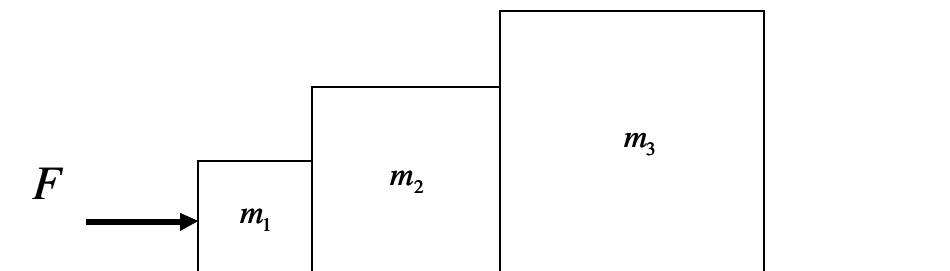
a. Draw a free body diagram for each of the three blocks.

b. Suppose no blocks are moving. What is the smallest that μ_s can be so that there will be no horizontal forces acting on the rightmost block?

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3. A block with mass m_1 is placed on an incline, and connected to second block with mass m_2 by a string that passes over a pulley (see figure). The string and the pulley both have negligible mass. By varying the masses of the two blocks, you find that if the ratio $\dfrac{m_2}{m_1} < \dfrac{1}{5}$, the blocks will slide to the left. For the incline, $\sin\theta = \dfrac{3}{5}$ and $\cos\theta = \dfrac{4}{5}$.

a. What is the coefficient of static friction, μ_s, between the block with mass m_1 and the incline?

b. When $\dfrac{m_2}{m_1} = \dfrac{1}{5}$, the blocks were jiggled, and the block with mass m_1 started moving to the left with an acceleration, a, that has the magnitude $\dfrac{a}{g} = \dfrac{1}{6}$. What is the coefficient of kinetic friction, μ_k, between the block with mass m_1 and the incline?

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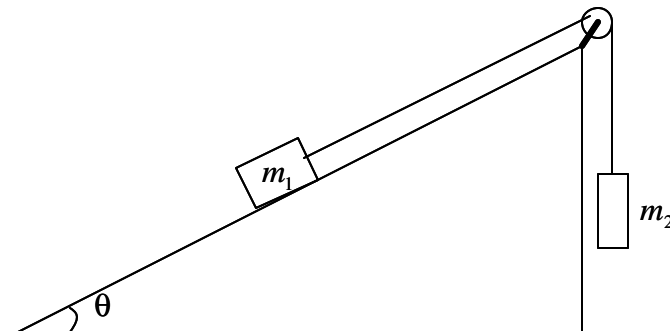
4. Nora and her husband Nick decided to go canoeing on their wedding anniversary. Towards the end of the day, the two are sitting in a canoe in the middle of a lake with two identical bottles, and they start taking about physics. Pretty soon, they have a heated discussion as to what would happen if they threw the two bottles in opposite directions from the canoe (see figure).
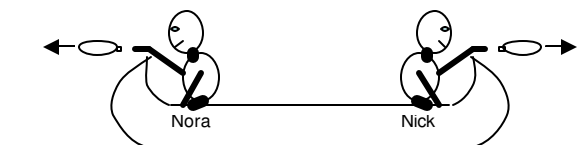
Specifically, they considered the following two cases:

Case 1: Nick and Nora throw their bottles *at the same time*.
Case 2: Nick throws his bottle first, and then Nora throws her bottle.

Nick claims that in both cases, the velocity of the canoe relative to the lake will be the same. Nora, on the other hand, claims that he is wrong; the velocity of the canoe in the two cases will be different. Determine whether Nick or Nora is correct by doing the following:

a. ***Calculate*** the velocity of the canoe relative to the lake in the first case.
b. ***Calculate*** the velocity of the canoe relative to the lake in the second case.

The mass of the canoe and everything on it except for the bottles is M. The mass of a bottle is m. The speed of the bottle as it leaves either Nick's or Nora's hand is the same, and is v_0. This speed is measured with respect to the canoe. (Do the calculations. You will not receive any credit if all you do is state that Nick or Nora is correct.)

Physics 8A

Possibly useful formulas:

$x = x_0 + vt + \frac{1}{2}at^2$	$v = v_0 + at$	$v^2 = v_0^2 + 2ax$
$y = \frac{v_{y0}}{v_{x0}}x - \frac{g}{2v_{x0}^2}x^2$	$v = \frac{dx}{dt}$	$a = \frac{dv}{dt}$
$F = ma = m\frac{dv}{dt}$	$F_G = G\frac{mM}{r^2}$	$F_{fr} = \mu_k N$ $F_{fr} \leq \mu_s N$
$\omega = 2\pi f$	$v = r\omega$	$a = \frac{v^2}{r} = r\omega^2$
$F = m\frac{v^2}{r} = mr\omega^2$	$f = \frac{1}{T}$	$I = \Delta p = m\Delta v = \int F\,dt \approx F\Delta t$
$p = \sum_i m_i v_i$	$F_{ext} = \frac{dp}{dt}$	$x_{cm} = \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$ $= \frac{\sum_i m_i x_i}{\sum_i m_i}$
$y_{cm} = \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2}$ $= \frac{\sum_i m_i y_i}{\sum_i m_i}$	$v_{cm} = \frac{\sum_i m_i v_i}{\sum_i m_i}$	$F_{ext} = \left(\frac{1}{\sum_i m_i}\right)\frac{dv_{cm}}{dt}$
$U = mgh$	$U = \frac{1}{2}kx^2$	$K = \frac{1}{2}mv^2$
$E = U + K$	$F = -kx$	$W = \mathbf{F} \cdot \mathbf{x} = Fx\cos\theta = \int F\,dx$
$P = \frac{dE}{dt}$	$P = \mathbf{F} \cdot \mathbf{v} = Fv\cos\theta = \int F\,dv$	$\alpha = \frac{d\omega}{dt}$
$\theta = \theta_0 + \omega t + \frac{1}{2}\alpha t^2$	$\omega = \omega_0 + \alpha t$	$\omega^2 = \omega_0^2 + 2\alpha\theta$
$\omega = \frac{d\theta}{dt}$	$L = I\omega$	$\tau = I\alpha = I\frac{d\omega}{dt} = \frac{dL}{dt}$
$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F} = rF\sin\theta$	$I = \sum_i m_i r_i^2 = \int r^2\,dm$	$I = \frac{2}{5}mr^2$ Solid Sphere
$I = \frac{2}{3}mr^2$ Hollow Sphere	$I = mr^2$ Hoop	$I = \frac{1}{2}mr^2$ Disk
$I = \frac{1}{12}mL^2$ Thin Rod about Center	$I = \frac{1}{3}mL^2$ Thin Rod about End	$K = \frac{1}{2}I\omega^2$
$P = \frac{F}{A}$	$\text{const} = P \quad \rho gh \quad \frac{1}{2}\rho v^2$	$F = \eta A\frac{dv}{dy}$

$\text{const} = vA$	$\dfrac{d^2 x}{dt^2} = -\omega^2 x$	$x = x_0 \sin(\omega t + \phi)$
$x = x_0 \cos(\omega t + \phi)$	$\omega = \sqrt{\dfrac{k}{m}}$	$\omega = \sqrt{\dfrac{g}{L}}$
$f(x \pm vt) \Leftrightarrow \sin(kx \pm \omega t)$	$k = \dfrac{2\pi}{\lambda}$	$v = f\lambda = \dfrac{\omega}{k}$
$v = \sqrt{\dfrac{T}{\mu}}$	$v = 330\,m/s$	$I = \dfrac{P}{A} \propto \text{Amplitude}^2$
Moving Source: $f = \dfrac{f_0}{1 \pm v_s/v}$	Moving Observer: $f = (1 \pm v_s/v) f_0$	$\omega = \dfrac{n}{2L} v$
$A\left[\sin(\omega_1 t) + \sin(\omega_2 t)\right]$ $= 2A\sin\left[\tfrac{1}{2}(\omega_1 \quad \omega_2)t\right]$ $\times \sin\left[\tfrac{1}{2}(\omega_1 - \omega_2)t\right]$	$\dfrac{d}{2\lambda}\cos\theta = 0, 2, 4, 6, 8\ldots$	$\dfrac{d}{2\lambda}\cos\theta = 1, 3, 5, 7\ldots$
$\dfrac{dQ}{dt} = \kappa \dfrac{A}{L}\Delta T$	$\dfrac{dQ}{dt} = \kappa \dfrac{A}{L}\Delta T$	$I = e\sigma T^4$
$\lambda = \dfrac{B}{T}$	$\dfrac{\Delta l}{l} = \alpha \Delta T$	$W = p\Delta V = \int p\,dV$
$pV = Nk_B T$	$pV = nRT$	$U = \tfrac{3}{2} k_B T$
Isothermal: $W = Nk_b T \ln \dfrac{V_f}{V_i}$	$C_v = \tfrac{3}{2} R$ (monatomic)	$C_p = \tfrac{5}{2} R$ (monatomic)
Adiabatic monatomic: $TV^{2/3} = \text{const}$	Adiabatic monatomic: $pV^{5/3} = \text{const}$	$\Delta E = W + Q$
$\Delta S = \dfrac{\Delta Q}{T}$	$\Delta S \geq 0$	$e = 1 - \dfrac{T_L}{T_H}$
$\cos(45) = \sin(45) = \dfrac{\sqrt{2}}{2} = 0.707$	$\cos(60) = \sin(30) = \dfrac{1}{2}$	$\cos(30) = \sin(60) = \dfrac{\sqrt{3}}{2} = 0.866$
$\sin^2(\theta) + \cos^2(\theta) = 1$	$\sin(a+b) = \sin a \cos b + \cos a \sin b$	$\cos(a+b) = \cos a \cos b - \sin a \sin b$