Dr. Burke
Dr. Gould
Dr. Johnson

Physics 151L

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Midterm I
February 19, 2004

Name ____

Signature ____

Student ID ____

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First Letter
of Your
Last Name:

Problem	Score	Max	Grader
1.	______	(20)	______
2.	______	(25)	______
3.	______	(30)	______
4.	______	(25)	______
Total	______	(100)	______

Do Not Tear Off This Page

Possibly Useful Formulae

For constant acceleration in one dimension:

$$\mathrm{v} = at + \mathrm{v}_0$$

$$x = \tfrac{1}{2}at^2 + \mathrm{v}_0 t + x_0$$

$$\mathrm{v}^2 - \mathrm{v}_0^2 = 2a\Delta x$$

Newton's Second Law:

$$\vec{\mathbf{F}}_{\mathbf{net}} = m\vec{\mathbf{a}}$$

Circular Motion:

$$a_r = \frac{\mathrm{v}^2}{R} = \omega^2 R$$

$$a_t = \frac{d\mathrm{v}}{dt}$$

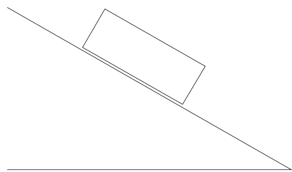
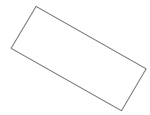
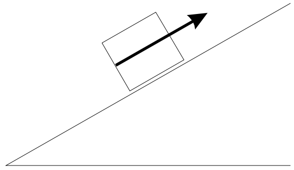
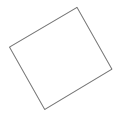
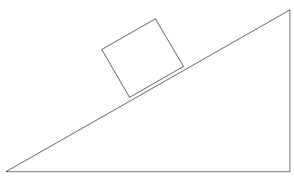
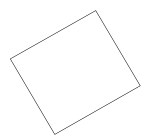
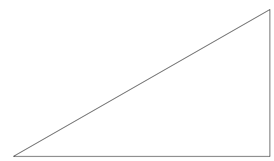
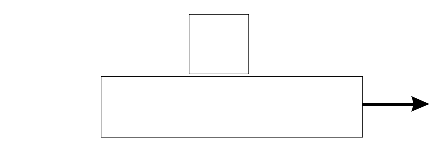
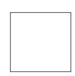
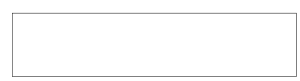
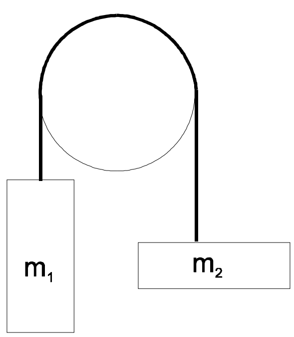
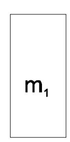
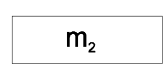
Friction:

$$f_k = \mu_k N$$

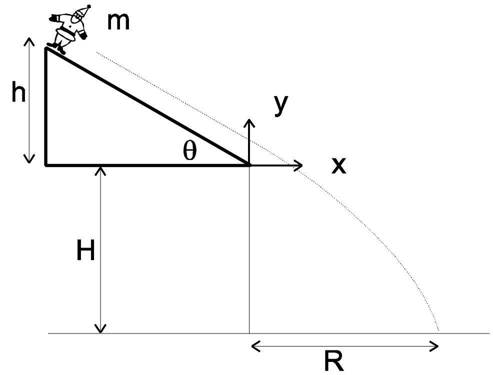
$$f_s \le \mu_s N$$

1. (20 pts) Free Body Diagrams. In each of the following problems draw the forces in the free body diagram for each body which can move. To make your job easier we have drawn the movable bodies in separate boxes to the right of each problem's description.

After drawing the forces, connect any action-reaction pairs with a dotted or dashed line as done in the textbook.

A block slides down an incline which has a non-zero coefficient of kinetic friction 		
A worker pushes a package up an inclined ramp which itself has friction. 		
A block slides down an inclined plane, and the inclined plane slides horizontally. There is friction at the incline's upper surface, but not at its lower surface. 		
A block rests on top of a platform. The platform is pulled horizontally by a string. There is friction on both sides of the platform. 		
Two masses, $m_1 > m_2$, are connected to each other by a massless string which loops over a massless frictionless pulley. 		

2. (25 pts) Slippery Santa. Santa Claus is perched precariously at the top of a frictionless roof which is angled at θ with respect to the horizontal. Unfortunately, he loses his balance and slips from the top. His reindeer use a convenient radar gun to measure his speed as he leaves the roof to be v_0. His mass is *m*.



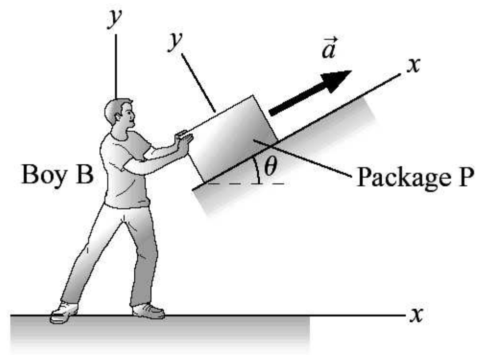
(a) (6 pts) In the space below (*not on the right*) draw the free-body diagram for Santa as he slides down the roof. Then show that his displacement from the rooftop down the incline is given by $s=\frac{1}{2} g t^2 \sin\theta$.

(b) (6 pts) Calculate the height of the roof, *h*, in terms of *g*, *H*, θ, *m*, and v_0, or a subset of these.

(c) (6 pts) Now consider the second portion of Santa's path. Using the coordinate system shown in the figure above (in particular, the origin is at the edge of the roof) write down equations for Santa's *x*- and *y*- coordinates as he sails through the air.

(d) (7 pts) Calculate the distance away from the edge of the roof at which Santa lands, denoted *R* in the figure above, in terms of *g*, θ, *m*, *H*, and v_0, or a subset of these quantities.

3. (30 pts) Pushing a Package (Ex 8.10). A boy of mass m works at his dad's hardware store. One of the boy's jobs is to unload the delivery truck. He places each package, of mass $m/5$, on a ramp angled at θ above the horizontal and shoves it up the ramp into the storeroom. He needs to shove the package with an acceleration of at least a in order for the package to reach the storeroom. There is a coefficient of kinetic friction μ_k between the package and ramp, and coefficient of static friction μ_s between the boy and the floor.



(a) (12 pts) In the space below, *not on the figure to the right*, draw the free body diagrams for the boy and for the package.

(b) (6 pts) Along each relevant coordinate in the figure above, write down the component of Newton's Second Law for the package.

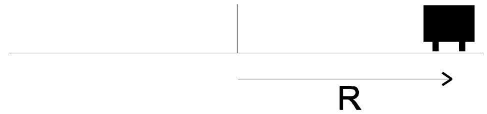
(c) (2 pts) Calculate the magnitude of the frictional force on the package in terms of m, g, μ_k, and θ, or a subset of these.

(d) (4 pts) Along each relevant coordinate in the figure above, write down the component of Newton's Second Law for the boy, assuming he doesn't slip.

(e) (6 pts) Take the following numerical values: $\theta=45°$, $\mu_k=1$, and $a=\sqrt{2}g/3$. What is the condition on μ_s (against the ground) such that the boy's feet *do not slip against the ground* when he pushes the package with the requisite acceleration? Simplify your answer, but you can leave it in terms of square roots, logs, and fractions. (Note: your answer should be an inequality.)

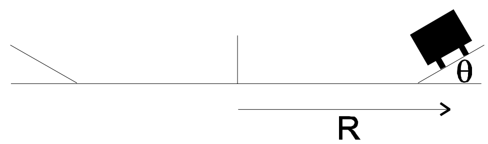
4. (25 pts) Circular Race Track. A race car of mass *m* travels around a perfectly circular race track of radius *R*.

(a) (5 pts) At first, the ground upon which race cars travel is horizontal, draw the free-body diagram of a race car in the space below, not on the figure to the right.



(b) (5 pts) If the race car speeds along at speed v, what is the minimum coefficient of static friction between the tires and ground required in order that the car is able to stay on the track? Give your answer in terms of *m*, *g*, *R*, and v, or a subset of these quantities.

(c) (10 pts) The race track is then improved by banking the road on which the cars travel at an angle θ with respect to the horizontal. Unfortunately, the new road surface is frictionless so race cars immediately slip off unless they are traveling at precisely the right speed. Draw the free body diagram of the race car now in the space below, not on the figure to the right.



(d) (5 pts) At what speed must race cars now travel in order to stay on the banked track? Give your answer in terms of *m*, *g*, *R*, and θ, or a subset of these quantities.