Name:

You have 1 hour and 15 minutes to complete this exam. You may not use your notes, textbook, or calculators.

Read all questions carefully and show your work as much as possible for partial credit. Circle your final answers. Be careful with units!

Remember these problem solving tips:

- Include units in your answer and check that your units make sense
- Compare your answer to your intuition
- Draw a picture of the scenario described in the problem

There are 5 problems. Good luck!
Problem 1 (24 points)

A block of mass 2 kg is at rest on a flat surface. At time $t = 0$ s, I apply a force to the right (+$x$) as shown. Let $g = 10$ m/s$^2$.

a) If I apply a force of 10 N for 2 seconds and then remove the force at $t=2$ s. Draw a graph of the block’s velocity as a function of time from $t=0$ s to $t=5$ s if the block is moving over a frictionless surface.

b) What is the minimum force I must apply to overcome static friction? Express your answer as a vector.

c) I apply a force of 10 N for 2 seconds then remove the force. What is the net force on the block (during the interval $t=0$ s to $t=2$ s)? Express your answer as a vector.
A 70 kg person swings circularly on a spinning carnival ride as shown in the figure. The swing is on a 4 meter arm that makes an angle $\theta = 45^\circ$ with respect to the vertical ($\cos 45^\circ = \sin 45^\circ = \sqrt{2}/2 = 0.7$; $\tan 45^\circ = 1$) and is located 2 meters from the central axis. Let $g = 10$ m/s$^2$.

a) Draw a free body diagram for the person.

b) What is the net force on the person? Express your answer in terms of a vector.

c) What is the magnitude of the ride’s azimuthal velocity? (You do not have to simplify your answer.)
Problem 3 (20 points)

A ball of mass $m$ is hanging from two strings of length $L$ as shown in the left figure. The strings are massless and cannot change in length. The strings make an angle $\theta = 60^\circ$ with respect to the ceiling ($\cos 60^\circ = 1/2$, $\sin 60^\circ = \sqrt{3}/2$; $\tan 60^\circ = \sqrt{3}$). Let $g = 10$ m/s$^2$.

a) Draw a free body diagram for the mass.
b) Find the magnitude of the tension in each string.
c) At a later time, I cut the string on the left and the ball swings down as shown in the right hand figure. Without using the kinematic equations for, e.g. $x(t)$ or $v(t)$, what is the speed of the ball when it reaches its lowest point? Neglect air resistance. You do not need to simplify your answer.
Problem 4 (12 points)

A block of mass 8 kg hangs on a spring that is attached to the ceiling of an elevator. At time $t=0$ the elevator is at rest. The spring constant $k = 20$ N/m. Let $g = 10$ m/s$^2$.

a) How long is the spring compared to its unstretched/uncompressed length?

At a later time $t$ the elevator accelerates downward with a constant acceleration $a = -5$ m/s$^2$ as shown in the figure.

b) Now that the elevator is accelerating, how long is the spring compared to its unstretched/uncompressed length? Is this longer or shorter than your answer in part a?
Problem 5 (24 points)

A block of mass \( m = 5 \text{ kg} \) sits on a ramp. The coefficient of static friction \( \mu_s = 0.75 \). The angle \( \theta = 30^\circ \) (let \( \sin 30^\circ = 1/2, \cos 30^\circ = \sqrt{3}/2 = 0.8; \tan 30^\circ = 1/\sqrt{3} = 0.5 \)). Use \( g = 10 \text{ m/s}^2 \).

a) What is the force from static friction? Express your answer as a vector.

Another block (also with \( m = 5 \text{ kg} \)) slides down the ramp with an initial velocity of 2 m/s down the ramp and slides a distance of 10 meters down the ramp.

b) How much work does the gravitational force do on the second block during its slide down the ramp?

c) If \( \mu_k = 0.2 \), how much work does friction do on the block during its slide down the ramp?

d) Using the work-energy theorem (not the kinematic equations or conservation of mechanical energy), what is the block’s final speed?
BONUS Problem 6! (+10 points possible extra credit)

You do not have to answer this problem but if you do, you may earn up to 10 bonus points of extra credit. You will not lose any points for a wrong answer here. This problem is worth less than the other 5 problems so please do your best to answer those problems before attempting this one!

A sailboat is moving across a river. There are strong winds that give the sailboat a force \( F_{\text{wind}} = 2\ \text{N} \ x + 4\ \text{N} \ y \). There is a current in the river that provides a force on the boat \( F_{\text{current}} = 2\ \text{N} \ x - 1\ \text{N} \ y \).

a) What is the net force on the boat?
b) If the boat travels a total distance of 100 meters, what is the work done on the boat by the wind? (Hint: what is the vector for the distance that the boat travels? Use Newton's second law!)
c) What is the work done on the boat by the river current?
d) What is the total work done on the boat?