EXAM 2

Please print your name and section number (or TA’s name) clearly on all pages. Show all your work in the space immediately below each problem. Your final answer must be placed in the boxes provided. Problems will be graded on reasoning and intermediate steps as well as on the final answer. Be sure to include units wherever necessary, and the direction of vectors. Each problem is worth 20 points. Try to be neat! Check your answers to see that they have the correct dimensions (units) and are the right order of magnitude. You are allowed one sheet of notes (8.5” x 11”, 2 sides), a calculator, and the constants in this exam booklet. The exam lasts exactly 90 minutes.

Constants:

Acceleration due to gravity at the earth’s surface: \( g = 9.81 \text{ m/s}^2 \)

SCORE:

Problem 1: __________
Problem 2: __________
Problem 3: __________
Problem 4: __________
Problem 5: __________

TOTAL: __________

Don't open the exam until you are instructed to start.

“I have no special talent. I am only passionately curious.” A. Einstein
Problem 1

a.) A 1000 kg car climbs a 5.0° slope at a constant velocity of 80.0 km/h. Assuming that air resistance may be neglected, at what rate must the engine deliver energy to the drive wheels of the car? Express your answer in kW. (10 pts)

b.) Truck brakes can fail if they get too hot. In some mountainous areas, ramps of loose gravel are constructed to stop runaway trucks that have lost their brakes. The combination of a slight upward slope and a large coefficient of rolling friction as the truck tires sink into the gravel brings the truck safely to a halt. Suppose a gravel ramp slopes upward at 6.0° and the coefficient of friction is 0.40. Find the length of a ramp that will stop a 15,000 kg truck that enters the ramp at 35 m/s (about 75 mph). (10 pts)
Problem 2

This problem is related to the Air Track Collisions lab. Suppose two gliders of equal masses, $m$, move toward each other at equal velocities, $v$, as shown. One of the gliders has a massless spring attached to it with spring constant $k$ so that the gliders bounce off each other. Assume there is no friction.

![Diagram of gliders colliding with a spring]

a.) In terms of $m$, $v$ and $k$, compute $\Delta x$, the maximum amount of compression that occurs in the spring. (4 pts)

b.) In terms of $m$, $v$, and $k$, what is the maximum force experienced by glider 1 (magnitude and direction)? (4 pts)

c.) What is the magnitude and direction of the impulse felt by glider 1? (4 pts)

d.) Make an approximate plot of the force felt by glider 1 as a function of time. (Don’t try to come up with an equation for $F(t)$.) There’s no need to put units on the time axis.) (4 pts)

e.) Estimate the duration, $\Delta t$, of the impact. State any assumptions that you make. (4 pts)
Problem 3

A flywheel of mass \( M = 150 \, \text{kg} \) and radius \( R = 2.0 \, \text{m} \) rotates about a vertical axis through its center of mass. The flywheel is in the shape of a hollow disk so its moment of inertia is \( I = MR^2 \). 

a) The flywheel is initially rotating with an angular speed of 100 revolutions per minute (rpm). Find the initial kinetic energy of the flywheel. (4 pts.)

b) Find the angular momentum of the flywheel (magnitude and direction). (4 pts)

c) The flywheel is stopped by applying a brake pad to the rim with force \( F \). The coefficient of kinetic friction between the brake pad and the flywheel is \( \mu_k = 0.25 \) and the wheel stops rotating after 10 s. Find the magnitude of the force \( F \). (4 pts.)
d.) What is the torque (magnitude and direction) on the flywheel? (4 pts)

e.) Find the work done by the force on the flywheel (make sure to indicate whether the work is positive or negative) (4 pts.)
Problem 4
Timbie and Chung want to determine whose car is more massive. They are advised by Physics 207 students to find out the answer by colliding the cars together.

In experiment 1, Timbie’s car, with mass \( m_T \), is at rest when Chung’s car, \( m_C \), crashes into it with initial velocity \( v_i \). After the impact the two cars remain locked together and move with velocity \( v_f \).

In experiment 2, the cars are pulled apart from each other and collided again, this time with Chung’s car at rest and Timbie’s crashing into it with the same initial velocity, \( v_i \), as in experiment 1. The cars remain locked together after the impact and this time move with velocity \( v_f' \).

a.) In experiment 1, what is the ratio of the final kinetic energy to the initial kinetic energy? Express your answer in terms of \( m_T \) and \( m_C \). (7 pts)

b.) Using the results of both experiments, what is the mass of \( m_T \) in terms of \( m_C \), \( v_f \), and \( v_f' \)? (7pts)
Now for a different problem:
c.) A 1.6 kg particle moving along the x-axis experiences the net force shown in the figure. The particle's velocity is 4.0 m/s in the positive x direction at x = 0 m. What is its velocity at x = 2 m? (6 pts)
Problem 5

Suppose you want to compute the kinetic energy of a football thrown by Bret Favre. You measure the mass, \( m \), of the football on a two-pan balance in the lab and determine that the mean mass is 0.40 kg with a standard deviation of 0.02 kg. You measure the speed, \( s \), of the football (measured off your TV screen in instant replay mode) multiple times and record the values given in the table below:

<table>
<thead>
<tr>
<th>Measurement #</th>
<th>Speed (m/s)</th>
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<tbody>
<tr>
<td>1</td>
<td>36</td>
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<tr>
<td>2</td>
<td>36</td>
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<td>3</td>
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<td>8</td>
<td>38</td>
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<tr>
<td>9</td>
<td>36</td>
</tr>
</tbody>
</table>

Assume that each measurement is independent and distributed according to a Gaussian distribution.

a.) What is your best estimate of the speed of the football and its standard deviation? (10 pts)

b.) Based on these measurements, what is your best estimate of the kinetic energy of the ball and its standard deviation (i.e. the spread in the distribution of this derived quantity)? (10 pts)