Instructions

1) Do not open this exam until you are instructed to do so. Meanwhile, write your name and section number above. Allowed section numbers are 513, 514, or 516.

2) There are six problems worth a total of 150 points on this exam. The point value for each problem is noted on the problem page.

3) Write your answers to each problem on the question page or the facing page. If you need more room and use extra work sheets be sure to indicate that you have done so. Write your name clearly on each sheet.

4) Remember most of the credit is given for correctness in setting up the problem, so if you are pressed for time, indicate the numbers you would like to evaluate in the expression and leave the calculations for later.

5) If you are unable to answer a question whose result is needed in a subsequent part of the problem, make an assumption for the needed result, indicating clearly what you are doing and then continue.

6) Partial credit will be given, however your work must be shown and clearly labeled if you expect to receive it.

7) You have 120 minutes to complete this exam.

8) Remember to hand in your formula sheet along with your exam.

Good luck and have a very pleasant summer.
PROBLEM 1 (25 points)

A cannon fires a shell of mass 10 kg from ground level at an angle of 36.9° above the horizontal. The shell is launched by an explosive charge with an energy of $2 \times 10^4$ joules. Assuming that the energy of the explosive charge is transferred to the projectile with an efficiency of 100%, answer the following:

(a) What is the initial velocity of the shell as it leaves the cannon?

(b) How high will the shell rise above the horizontal?

(c) How far from the launch point will the projectile strike the ground?

(d) Suppose that during the flight the shell explodes into two pieces. The two pieces are observed to hit the ground at the same time. One piece lands a distance 2m to the right of the impact point found in (c) and the other lands 1m to the left of this point. Calculate the masses of these two pieces.
A train composed of an engine and two cars sits on an incline of 30°. The cars each have a mass of 10^4 kg and the engine can pull on the chain connecting it to car A with a maximum force of 2 \times 10^5 N up the incline. There is friction between the engine and the incline only (the cars have no friction between themselves and the incline). The three parts of the train are connected via massless chains. Answer the following:

(a) The train begins to accelerate the system by exerting its maximum pull on the cars. What is the acceleration of the system?

(b) Once the train has gotten the cars moving at a reasonable velocity it reduces its pull so that the train now travels with a \textbf{constant} velocity. What force does the engine exert on car A under these circumstances?

(c) Find the tension in the light chains connecting cars A and B while the train is moving at this constant velocity.
A uniform disc of mass, $M$ and radius, $R$, spins in a counterclockwise direction about an axis passing through its center. This disc is oriented in a horizontal plane and is rotating about a fixed vertical axle. The initial angular velocity of this disc is $\omega_0$. At a distance from this spinning disc a piece of putty of mass, $m$, approaches with a velocity of $v_0$ in the horizontal plane. The path of this piece of putty will pass within a distance $b$ of the center of the disc as shown in the figure. Assume that when the putty hits the disc, it sticks to the rim. Neglecting the effects of gravity and friction, answer the following:

(a) What is the total angular momentum of the disc and the putty about the center of the spinning disc before the collision?

(b) What is the kinetic energy of the system before the collision?

(c) Find the angular velocity of the disc/putty system after the collision.

(d) Is this collision elastic or inelastic? Why?
PROBLEM 4 (25 points)

We can construct a conical pendulum with a point mass, $M$ and a string of length $L$. The mass is suspended by the string and displaced by an angle $\Theta_o$ from the vertical. The mass is then given a tangential shove and it then begins to swing along a circular path in the horizontal plane as shown in the figure above. It moves along this path with a constant speed, $v_T$.

(a) Draw the force diagram for the mass.

(b) Find the tension in the string in terms of the quantities given.

(c) Find the value of $v_T$ necessary to allow the mass to swing along this path (in terms of $M$, $L$, $\Theta_o$ and $g$).
PROBLEM 5 (25 points)

You are given a block of mass, $M$, that is attached to a wall by a perfect, massless spring of spring constant $k$. This spring is initially at its equilibrium length with the mass resting on a frictionless horizontal surface as shown. At $t = 0$ a bullet of mass, $m$ and initial velocity, $v_o$, collides with the block and imbeds itself into the block. Assume that this collision takes place over a short time (eg. the bullet and the block become one object before the spring is compressed in the collision).

(a) Find the maximum displacement of the block-bullet system from the initial equilibrium position.

(b) What is the “natural” frequency of oscillation of this system ( $\omega = ?$).

(c) Find the position of the block for all times, $t$, after the collision.
PROBLEM 6 (25 points)

A travelling wave on a string has a displacement versus time, t and position along the string, x, of:

\[ Y(x, t) = (2 \times 10^{-3} m)(sin(.5x -.75t)) \]

(a) What is the amplitude of this wave?

(b) What is the wavelength of this disturbance?

(c) What is the frequency, \( f \), of this disturbance?

(d) What is the velocity of propagation of this wave?