Print your full name: ________________________________

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Please fill in your Student ID number: __ __ __ __ __ __ __ __ __

IMPORTANT

Read these directions carefully:

• There are 5 problems totalling 100 points. Check your exam to make sure you have all the pages. Work each problem on the page the problem is on. You may use the back. If you need extra pages, I have plenty up front.

• Indicate what you are doing! We cannot give full credit for merely writing down the answer. Neatness counts! I will give generous partial credit if I can tell that you are on the right track. This means you must be neat and organized.

• Each problem with its associated figure is self explanatory. If you must ask a question, then come to the front, being as discrete as possible so as not to disturb others.

• Put your name on each page it is asked for. You will lose credit if you fail to print your name on each page it is asked for.
Problem 1. 20 points.

A box of mass $M_2$ slides with friction on a rough horizontal plane. The coefficient of kinetic friction between this box and the plane is $\mu$. A constant force $P$ is applied to the box at an angle $\theta$ from the horizontal. A strong light rope is connected to the box, fed over a massless pulley, and connected to a mass $M_1$ which is hanging freely. This contraption is shown in the figure:

(b) (8 points) Draw free-body diagrams for both the box and the hanging mass.

(b) (12 points) Assume that $P$, $\mu$, and $\theta$ have values such that the box accelerates to the left (away from the pulley.) Calculate the acceleration of the box.

If you work neatly I will find more partial credit for you!
Problem 2. 20 points.

The starship *Enterprise* is investigating a small new star of mass $M_1$, and is holding position a distance $b$ from the star. There is another star (a binary companion) of mass $M_2$ a distance $b$ from the first along a line perpendicular to that connecting the *Enterprise* with the first star. (The geometry is shown in the figure.)

Suppose the starship experiences total engine failure. Calculate the $x$ and $y$ components of its acceleration. Use the coordinate system provided.
Problem 3. 20 points.

A particle of mass $m$ moves in one dimension under the influence of a force that is given by:

$$F(x) = Ax + Bx^2 - Cx^3$$

where the direction of motion is taken to be $x$ and $A$, $B$, and $C$ are given constants.

(a) The particle starts at position $-x_0$ and moves to position $+x_0$. Calculate the work done on this particle by the force given above.

(b) Assume that when the particle is at $-x_0$ it has zero velocity. Calculate the velocity of the particle when it reaches $+x_0$.

Remember: You must show your work. Do not just write down the answer.
A block of mass $M$ slides on a horizontal plane. The plane is rough, but the coefficient of kinetic friction depends on position. At $x = 0$ the coefficient of kinetic friction is $\mu_0$, and decreases linearly to zero at $x = L$. Thus, the coefficient of friction can be written as:

$$\mu(x) = \begin{cases} 
\mu_0 \left(1 - \frac{x}{L}\right) & 0 < x < L \\
0 & x > L 
\end{cases}$$

This is shown in the figure. Suppose that when the box reaches $x = 0$ its velocity is given to be $v_0$ and that $v_0$ is large enough that the box makes it past $x = L$ and keeps sliding. Note that after it passes $x = L$ it will continue sliding with constant velocity.

Calculate the velocity of the box when it passes $x = L$.

You may continue on the next page if you like. Don’t forget to be neat!
You may remove this sheet.
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Potentially useful equations

Calculus:

Derivatives: If \( x(t) = C t^n \) then

\[
\frac{dx}{dt} = C n t^{n-1}
\]

Integrals:

\[
\int_{t_1}^{t_2} C t^n \, dt = C \left[ \frac{t_2^{n+1}}{n+1} - \frac{t_1^{n+1}}{n+1} \right]
\]

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