Print your full name: ____________________________________________

Sign your name: ____________________________________________

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.
A block of mass $M$ is placed on a rough plane that is inclined at an angle $\theta$ from the horizontal. The coefficient of kinetic friction between the block and the plane is $\mu$. A rope is attached to the block, and passed over a massless, frictionless pulley, and then connected to another block, of mass $2M$ which hangs freely. This contraption is shown in the figure.

Assume that when the blocks are released, the freely hanging block moves down and pulls the sliding block up the incline.

(a) Draw free-body diagrams for both blocks.
(b) Calculate the acceleration of the blocks.
Problem 2. 20 points.

Two identical spherical planets both have mass $M$. The planets are separated by a distance $2a$ as shown. Consider two points which lie on a line that runs through the midpoint between the planets: $A$, directly between the centers of the planets; and $B$, a distance $b$ from the first point on a line perpendicular to the line joining the centers of the planets.

Calculate the magnitude and direction of the gravitational force on an observer of mass $m$ at both points $A$ and $B$.

Assume the planets remain in their current positions with respect to each other. Ignore any gravitational effects of any other bodies.
Problem 3. 20 points.

A block of mass $M$ is connected to the end of an ideal spring of force constant $k$ as shown. The block can slide along a rough horizontal surface, and the coefficient of kinetic friction between the block and the surface is $\mu$. The block is moved a distance $d$ from the spring’s equilibrium position and released from rest. The block slides back and just comes to rest at the spring’s equilibrium position.

\[
\text{Determine the coefficient of friction } \mu \text{ in terms of } M, k, \text{ and } d.
\]
Problem 4. 20 points.

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

$$F(x) = -kx + bx^2 + cx^4$$

where the direction of motion is taken to be $x$ and $k$, $b$, and $c$ are given constants.

(a) The particle starts at position $x_1$ and moves to position $x_2$. Calculate the work done on this particle by the force given above.

(b) Assume that when the particle is at $x_1$ it has zero velocity. Calculate the velocity of the particle when it is at $x_2$.

**Remember:** You must show your work. Do not just write down the answer.
A worker inserts a sharp knife into a box at a factory. Two forces act on the knife:

- The knife is pushed in by a constant force $P$ that is applied by the worker,
- The knife is pushed out by the packaging material. This force is proportional to the fourth power of the distance that the knife has been pushed into the box.

Read this carefully:
Treat this as a one dimensional problem. Take the $x$-axis to be the direction the knife is moving. Take $x = 0$ to be the outside edge of the box. Take the positive $x$ direction to be going into the box. Thus, $x$ is the distance the knife has moved into the box.

(a) Write an expression for the total force on the knife in terms of the force $P$ and the distance $x$. Use any symbol you want to indicate the proportionality constant.

(b) Assume that at $x = 0$ the knife has zero velocity. Calculate the maximum distance to which the knife will be inserted.