## Physics 206 - Exam III

## Fall 2019 (all UP sections) November 11 ${ }^{\text {th }}, 2019$

Please fill out the information and read the instructions below, but do not open the exam until told to do so.

## Rules of the exam:

1. You have 90 minutes ( 1.5 hrs ) to complete the exam.
2. Formulae are provided to you with the exam on a separate sheet. Make sure you have one before the exam starts. You may not use any other formula sheet.
3. Check to see that there are 8 numbered ( 4 double-sided) pages in addition to the scantron-like cover page. Do not remove any pages.
4. If you run out of space for a given problem, the last two pages have been left blank and may be used for extra space. Be sure to indicate at the problem under consideration that the extra space is being utilized (and also on the extra sheets, which problem the work refers to) so the graders know to look at it!
5. Calculators of any type are not allowed. In the case of questions with numerical values, the math should be simple enough you will not need a calculator. For purely symbolic questions, ensure that all your answers are in terms of the known variables given in the question.
6. Cell phone use during the exam is strictly prohibited. Please turn off all ringers as calls during an exam can be quite distracting.
7. Be sure to put a box around your final answer(s) and clearly indicate your work. Credit can be given only if your work is legible, clearly explained, and labelled.
8. Unless explicitly stated otherwise in the question, all of the free-response problems in this exam require you show your work and reasoning. You do not need to show your work for the multiplechoice problems.
9. Have your TAMU ID ready when submitting your exam to the proctor.

> Fill out the information below and sign to indicate your understanding of the above rules

## MAKE SURE YOU FILL OUT ALL THE BUBBLES ON THE PREVIOUS PAGE BEFORE CONTINUING!!

Name:
(printed legibly)

Signature: $\qquad$

UIN: $\qquad$

Section Number: $\qquad$
(circle one)

## Short Problems:

A) A homeowner places a fulcrum a distance $d=0.25 \mathrm{~m}$ from a rock, which has a mass of 400 kg , and fits one end of a rod under the rock's center of mass as shown. The length of the entire rod is $L=4.25 \mathrm{~m}$. Assume that the rod is massless and nearly horizontal so that the weight of the rock and the homeowner's force are both essentially vertical.

(i) Indicate on the picture a positive sense of rotation, and where the homeowner should push down on the rod so she applies the smallest force necessary to move the rock.
(ii) What is the minimum force needed to move the rock?

Ans: $\qquad$

| LO | S | U |
| ---: | ---: | ---: |
| 9.1 |  |  |
| 54.1 |  |  |
| 54.2 |  |  |
| 54.3 |  |  |
| 55.1 |  |  |

B) A sign of weight $W$ is supported by two ropes via a hoop at the top of the sign as shown. One rope pulls up and to the right of the vertical at $\theta_{1}=53.1^{\circ}$ with a tension $T_{1}$, and the other rope pulls up and to the left of the vertical at $\theta_{2}=36.9^{\circ}$ with a tension $T_{2}$.
(i) On the figure below, define your coordinate system (which directions are positive) and turn it into a free-body diagram, breaking up all forces into components acting on the hoop along the axes of the coordinate system you defined.
(ii) Use Newton's Law to find the tensions $T_{1}$ and $T_{2}$ in terms of $W$.


Ans: $\qquad$

| LO | S | U |
| ---: | ---: | ---: |
| 1.1 |  |  |
| 1.2 |  |  |
| 9.2 |  |  |
| 23.1 |  |  |
| 4.1 |  |  |
| 21.1 |  |  |
| 21.2 |  |  |
| 24.1 |  |  |
| 24.2 |  |  |

C) A hockey puck sliding on a frictionless surface strikes a box at rest. After the collision, the two objects stick together and move at some final speed.
( $i$ ) Check the statement below (there is only one) which describes the change in momentum and energy of the puck during the collision:

$$
\square \text { The puck loses all of its original momentum, but only loses some (not all) of its mechanical energy. }
$$The puck conserves its original momentum and mechanical energy.

The puck loses some, but not all, of its original momentum and mechanical energy.
The puck loses some, but not all, of its original momentum, but conserves its mechanical energy.
The puck conserves its original momentum, and loses some, but not all, of its mechanical energy.
(ii) Check the statement below (there is only one) which describes the change in momentum and energy of the combined puck and box during the collision:
$\qquad$ The system loses some, but not all, of its momentum and mechanical energy


The system conserves its original momentum and mechanical energy.
The system loses some momentum in the collision, but conserves its mechanical energy.
The system conserves its original momentum, but loses all of its mechanical energy.
The system conserves its original momentum and loses some, but not all, of its me-

| LO | S | U |
| ---: | ---: | ---: |
| 40.1 |  |  |
| 46.1 |  |  |
| 48.1 |  |  |
| 50.1 |  |  |
| 40.2 |  |  |
| 46.2 |  |  |
| 48.2 |  |  |
| 50.2 |  |  | chanical energy.

D) A uniform, thin rod of mass $M$ pivots about a frictionless axis through its center and perpendicular to its length. Two small (point-like) beads, each of mass $m$, are attached to the ends of the rod. A top view of the object is shown below.

(i) What is the moment of inertia of the rod, in terms of $L$ and $M$ ?

Ans: $\qquad$
(ii) What is the moment of inertia of one of the beads, in terms of $L$ and $m$ ?

Ans: $\qquad$
(iii) What is the total moment of inertia of the rod and two beads, in terms of $L, m$ and $M$ ?

Ans: $\qquad$
(iv) What must the length $L$ of the rod be so that the system will have an angular acceleration of $\alpha$ when a force $F$ is applied to one of the balls perpendicular to the rod? Express the length $L$ of the rod in terms of $M, m, F$ and $\alpha$.

Ans: $\qquad$

| LO | S | U |
| :---: | :---: | :---: |
| 51.1 |  |  |
| 51.2 |  |  |
| 53.1 |  |  |
| 54.4 |  |  |
| 55.2 |  |  |

Prob 1 An arrow of mass $m=250 \mathrm{~g}$ is shot horizontally into an archery target at a velocity of $v_{0}=40 \mathrm{~m} / \mathrm{s}$. The $14.75-\mathrm{kg}$ target is on a frictionless horizontal surface and a little bit in front of a spring with a spring constant of $k=1500 \mathrm{~N} / \mathrm{m}$ as shown. The arrow embeds in the target, which both continue to move with a speed $v_{f}$ after the collision. The combined object runs into the spring, compressing it some maximum distance, $\Delta x$, before momentarily coming to rest.
(a) What is the momentum of the arrow before it hits the target?

Ans: $\qquad$

(b) What type of collision do the arrow and target experience? (check one)

(c) What is the speed after the collision, $v_{f}$, before the arrow-and-target encounter the spring?

Ans: $\qquad$
(d) What will be the maximum compression of the spring, $\Delta x$ ?

| LO | S | U |
| ---: | ---: | ---: |
| 3.1 |  |  |
| 10.1 |  |  |
| 46.3 |  |  |
| 50.3 |  |  |
| 46.4 |  |  |
| 48.3 |  |  |
| 3.2 |  |  |
| 34.1 |  |  |
| 38.1 |  |  |
| 39.1 |  |  |

Ans: $\qquad$

Prob 2 Two weights ( $m_{1}=20 \mathrm{~kg}$ and $m_{2}=4 \mathrm{~kg}$ ) are attached to the ends of a massless rope which passes over a pulley, which is a solid disk of mass $m_{p}=2 \mathrm{~kg}$ and radius $R_{p}=50 \mathrm{~cm}$. Assume that the rope does not slip on the pulley, and that the pulley rotates without friction. The weights are released from rest and begin to move. Take the acceleration due to gravity to be $g=10 \mathrm{~m} / \mathrm{s}^{2}$.
(a) What is the moment of inertia of the pulley, in $\mathrm{kg} \mathrm{m}^{2}$ ?

Ans: $\qquad$
(b) When the weights are moving at $v=4 \mathrm{~m} / \mathrm{s}$, what is the angular speed of the pulley and what is the kinetic energy associated with its rotation?


Ans: $\qquad$
(c) If the heavier weight is a distance $h_{0}=5 \mathrm{~m}$ above the ground when it is released, use energy conservation to determine the speed, $v$, at which the weight hits the ground.

Ans: $\qquad$
(d) If the pulley was replaced by a thin-walled cylinder with the same mass and radius as the solid pulley, then the weight would hit the ground at:
a higher speed
the same speed
a slower speed

| LO | S | U |
| ---: | ---: | ---: |
| 10.2 |  |  |
| 51.3 |  |  |
| 16.1 |  |  |
| 35.1 |  |  |
| 3.3 |  |  |
| 16.2 |  |  |
| 34.2 |  |  |
| 35.2 |  |  |
| 38.2 |  |  |
| 38.3 |  |  |
| 39.2 |  |  |
| 51.4 |  |  |

Prob 3 A weight with mass $m$ is tied to a piece of thread wrapped around a pulley, which is suspended in such a way that it can rotate freely and without friction about its centre of mass. Answer all of the following in terms of the given variables $(m, M, R)$ and the acceleration due to gravity, $g$.
(a) Turn the drawing into a free-body diagram, clearly indicating your $x-y$ coordinate system and positive sense of rotation for the pulley.
(b) The pulley is constructed from a thin cylinder of radius $R$ and mass $M$ with 6 spokes each of length $R$ and mass $\frac{1}{2} M$. Determine:
$i$. the moment of inertia of the cylinder.

Ans: $\qquad$
ii. the moment of inertia of one of the spokes.

Ans: $\qquad$
iii. the total moment of inertia of the pulley.

Ans: $\qquad$
(c) When the weight is released, it accelerates toward the floor as the thread unwinds. Find a relationship between the angular acceleration of the pulley and the tension in the thread. If you didn't get part (b) iii, use $I_{\text {tot }}$ for the moment of inertia of the pulley here and below.

Ans: $\qquad$
(d) How is the angular acceleration of the pulley related to the acceleration of the block and radius of the pulley?

Ans: $\qquad$
(e) Use the answers above and Newton's Laws to find the acceleration of the weight as it falls.

| LO | S | U |
| ---: | ---: | ---: |
| 9.3 |  |  |
| 9.4 |  |  |
| 23.2 |  |  |
| 23.3 |  |  |
| 24.3 |  |  |
| 24.4 |  |  |
| 26.1 |  |  |
| 51.5 |  |  |
| 51.6 |  |  |
| 53.2 |  |  |
| 54.5 |  |  |
| 55.3 |  |  |
| 16.3 |  |  |
| 4.2 |  |  |
| 21.3 |  |  |
| 22.1 |  |  |

Ans: $\qquad$

Extra space:

Extra space (continued):

