# Physics 218 - Comprehensive Exam <br> Spring 2017 (all sections) April $28^{\text {th }}, 2017$ 

> 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 120 minutes ( 2.0 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 9 numbered (five 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 page has 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 so the graders know to look at it!
5. You may use any type of handheld calculator. However, you must show your work. If you don't show how you integrated or how you took the derivative or how you solved a quadratic of system of equations, etc., you will not get credit.
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. All of the questions require you show your work and reasoning.
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 |

Name:
(printed legibly)

Signature:
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Section Number: $\qquad$

## Short Problems:

A. A car is going around a circular racetrack of radius $R=100 \mathrm{~m}$ with a speed given as $v(t)=\left(3.0 \mathrm{~m} / \mathrm{s}^{2}\right) t+2.0 \mathrm{~m} / \mathrm{s}$.
(a) Find the acceleration of the car in the direction of its velocity.
(b) Find the acceleration of the car in the direction perpendicular to its velocity at $t=1.0 \mathrm{~s}$.

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B. A block of mass $m=2.0 \mathrm{~kg}$ is sliding down an inclined plane. There is friction between the block and the surface of the incline.
(a) What is the work done by the normal force as the block moves 2.0 m along the plane?
(b) What is the work done by gravity as the block moves 0.50 m in the vertical direction?

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C. Two objects, $A$ and $B$, are sliding freely along the frictionless surface of ice rink and collide with each other.
(a) If the collision is elastic, what quantities are conserved in the collision?
(b) If both objects have the same mass but opposite velocities, and when they collide they stick together, what kind of collision would you say it is? Explain why.

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D. An object is subjected to a single force whose potential is shown in the diagram at the right. From the diagram, estimate the answer to the following questions:
(a) Indicate whether the following $x$ positions are equilibrium points and, if so, whether they are stable or unstable equilibrium points. Indicate (with a $\sqrt{ }$ or $\times$ ) only one column per row.

| $x$ position | not an equilibrium <br> point | an equilibrium point |  |
| :---: | :---: | :---: | :---: |
|  |  | stable | unstable |
| 6 m |  |  |  |
| 10 m |  |  |  |
| 17 m |  |  |  |


(b) If the object has a total mechanical energy of 3 J and is initially at a position of $x=10 \mathrm{~m}$, estimate the maximun and minimum $x$ positions this object can reach.

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E. An object is subjected to a single force and oscillating along the $x$-axis in simple harmonic motion around a stable equilibrium point.
(a) Is the force on the object restorative or not? That is: if we move the object slightly off its equilibrium position, will the force try to bring the object back to equilibrium (restorative) or farther away?
(b) The differential equation representing the movement is $\frac{d^{2} x}{d t^{2}}=-\frac{3 B^{2}}{C} x$, where $B$ and $C$ are positive constants. What is the angular frequency of the oscillation in terms of $B$ and $C$ ?
$\omega=$
(c) Write the generic equation for position as a function of time. Indicate in your equation which parameter represents the amplitude and which the phase (or phase offset) of the oscillatory movement.
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Prob 1 Newton's Law and kinematics: One end of a narrow rigid rod of mass $m=3.0 \mathrm{~kg}$ and length $L=1.0 \mathrm{~m}$ is attached to the axle of a motor and is originally at rest. At time $t=0$, the motor turns on and exerts a constant torque $\tau=10 \mathrm{Nm}$ on the rod.
(a) What is the moment of inertia of the rod with respect to the motor axle?
(b) What is the angular acceleration of the rod?
(c) What is the angular velocity of the rod at time $t=2.0 \mathrm{~s}$ ?
(d) What is the rotational kinetic energy of the rod at time $t=2.0 \mathrm{~s}$ ?
(e) Is the angular momentum of the rod conserved or not? Explain why.

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Prob 2 Statics: A person of mass 75 kg is at rest in a horizontal position ready to do a pushup as shown in the figure.

(a) Draw a free-body diagram for the person.
(b) If the normal force from the floor on the persons hands is a total of 450 N , what is the magnitude of the total normal force on his feet?
(c) If the persons hands and feet are 1.5 m apart, where is the persons center of mass relative to his hands?
(d) After completing the pushup, the person's body is at rest at an angle of $20^{\circ}$ with respect to the ground. Assume the position of the person's center of mass with respect to his body doesn't change, and that his arms and feet are perpendicular to the floor. What is the normal force that the floor exerts on the person's hands in this position?


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Prob 3 Bullet and Pendulum: A bullet of mass $m$ and velocity $v$ hits a block of mass $M$, which is suspended in the equilibrium position of a pendulum of length $L$ as shown in part (a) of the figure to the right. Assume the pendulum to be ideal (i.e. the strings have no mass, the block is a point-like object and there is no friction). At time $t=0$, the bullet has penetrated the block and is stuck in it. As a result, the block and bullet move to the right with a velocity $v^{\prime}$.

(a)

(b)
(a) Is the mechanical energy of the bullet and block conserved during the bullet's penetration of the block (and before the block and bullet have move significantly to the right)? Explain why or why not.
(b) Express $v^{\prime}$ in terms of the given quantities.
(c) When the pendulum reaches maximum angle of rotation, the block has been raised by height $h$. Express $h$ in terms of the given quantities.

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Prob 4 Rotation of Rigid Bodies: A hollow spherical shell of mass $M$ and radius $R$ sits on a platform and rotates about a frictionless horizontal axle. A massless cord passes around the equator of the shell, over a cylindrical massless pulley, and is attached to a small crate of mass $m$. There is no friction on the pulleys axle and the cord does not slip on the pulley or the sphere. The system is initially at rest and then released.

m
(a) Draw the free-body diagrams for the sphere and crate.
(b) Find the angular acceleration of the sphere in terms of $m, M$ and $R$.
(c) Suppose $R=1.5 \mathrm{~m}$ and the tension in the string is $T=3.0 \mathrm{~N}$. What is the angular momentum of the sphere after a time of 20 s ?

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Prob 5 Satellite Motion: A satellite of mass 700 kg is in an approximately circular orbit around Earth, at a height of 2500 km above the Earth's surface. The mass of the Earth is $M_{E}=5.97 \times 10^{24} \mathrm{~kg}$, and its radius is $R_{E}=6,380 \mathrm{~km}$. The universal constant of gravity is $G=6.67 \times 10^{-11} \mathrm{Nm}^{2} / \mathrm{kg}^{2}$.
(a) Calculate the acceleration of the satellite.
(b) Calculate the period of the satellite's motion.
(c) Calculate the potential energy of the satellite (taking its value to be zero at infinite distance).
(d) What is the total mechanical energy of the satellite?
(e) How do you know from the mechanical energy whether the satellite is gravitationally bound to the Earth or not?

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## Extra Space:

