Physics 218 – Comprehensive Exam

Spring 2018 (all UP sections)   April 27$^{\text{th}}$, 2018

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 5 short (A, B, C, D and E) and 5 long problems (1–5) on 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. 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 $\boxed{\text{final answer(s)}}$ and clearly indicate your work. Credit can be given **only** if your work is legible, clearly explained, and labelled.
8. Unless explicitly stated in the problem, all of the questions require you show your work and reasoning.
9. Have your TAMU ID ready when submitting your exam to the proctor.
10. For **any** numerical questions involving the acceleration due to gravity, instead of 9.8 m/s^2 take $\boldsymbol{g = 10}$ **m/s^2**.

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

Name: ______________________________ UIN: ______________________________
(printed legibly)

Signature: ______________________________ Section Number: ____________________

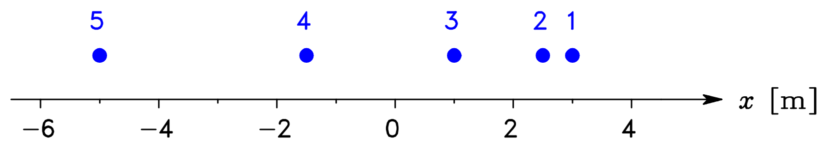
Instructor: (circle one)

Akimov	Dierker	Ko	Kocharovsky	Lyuksyutov
Mahapatra	Mioduszewski	Ross	Royston	Wu

Short Problems:

A) Below is a motion diagram of an object which started from rest at time $t_1 = 0$ from Position 1 moving along the x-direction with constant acceleration. The dots 1, 2, 3, ... show the position of the object, with equal time intervals Δt.

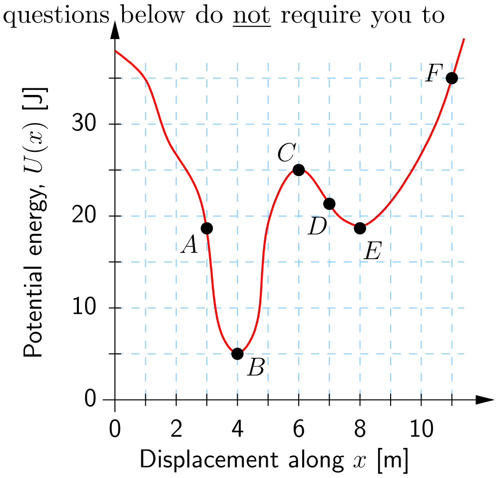
(a) Draw the v_x-t and the a_x-t graphs for this motion



(b) What are the directions (left/negative or right/positive) of $\vec{v}$ and $\vec{a}$ at Position 3?

LO	S	U
9.1		
9.2		
12.1		
12.2		
13.1		
13.2		

B) Consider the graph shown below, illustrating the potential energy for motion of a particle in the $\hat{\imath}$ direction. The horizontal axis shows the displacement in meters along the x axis. All of the questions below do not require you to explain your reasoning.



(a) Of the labeled points A through F, at which position does the particle experience the

i. largest positive x-component of force?

ii. largest negative x-component of force?

iii. largest magnitude x-component of force?

(b) For each of the labeled points, state whether it is a point of stable equilibrium, unstable equilibrium, or neither

	A	B	C	D	E	F
stable equilibrium	☐	☐	☐	☐	☐	☐
unstable equilibrium	☐	☐	☐	☐	☐	☐
not in equilibrium	☐	☐	☐	☐	☐	☐

(c) For each of the following starting points, the particle is released from rest. In each case, identify the minimum and maximum values of x the particle will reach. (Supply numerical answers, by reading from the graph.)

i. If it is released from rest at the point A?

ii. If it is released from rest at the point D?

iii. If it is released from rest at the point F?

LO	S	U
44.1		
44.2		
44.3		
42.1		
42.2		
42.3		
42.4		
42.5		
42.6		
43.1		
43.2		
43.3		

C) A box of mass m is attached to one end of a horizontal spring with spring constant k. The other end of the spring is attached to a wall. The block moves in simple harmonic motion on a horizontal frictionless surface. The mass and spring constant are unknown, but you observe that when the block is displaced $x = 3$ cm to the right of the equilibrium position, it has velocity $v_x = 8$ cm/s and acceleration $a_x = -12$ cm/s^2. Numerical answers are expected for all of the following.

(a) What are the angular frequency and time period of oscillation?

(b) What is the amplitude of oscillation?

(c) What is the magnitude of the maximum velocity during its motion?

(d) What is the magnitude of the maximum acceleration during its motion?

LO	S	U
3.1		
21.1		
25.1		
66.1		
66.2		
3.2		
40.1		
66.3		
66.4		
66.5		

D) A coconut, sitting in the middle of an ice-skating rink, explodes all of the sudden into two pieces of mass $m_1 = 0.4M$, and $m_2 = 0.6M$. Piece 2 goes flying off with velocity vector $\vec{v}_2 = (8 \text{ m/s})\hat{\imath}$.

(a) What is the velocity vector of piece 1?

(b) What is the velocity vector of piece 2 in the frame of piece 1?

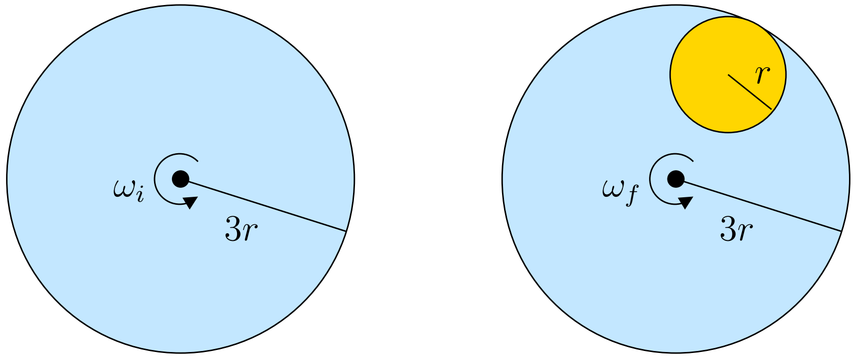
An ice-skater, flying by with velocity vector $\vec{v}_s = (10 \text{ m/s})\hat{\imath}$ witnesses the explosion.

(c) What is the velocity vector of piece 1 in the frame of the ice-skater?

(d) What is the velocity vector of piece 2 in the frame of the ice-skater?

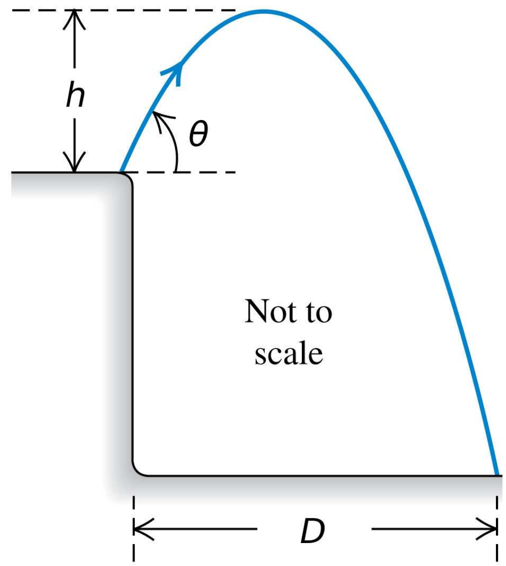
LO	S	U
48.1		
20.1		
20.2		
20.3		

E) A uniform disk of mass m and radius $3r$ is initially rotating about its center on a frictionless axle with angular velocity ω_i. A second uniform disk of the same mass m, but smaller radius of r, which is not rotating initially, is dropped straight down from above on top of the first disk so that their edges just touch as shown in the figure. The surfaces of the disks are covered with Velcro so that they stick together without slipping. What then is the final angular velocity of the system, ω_f, about the center of the larger disk?



LO	S	U
51.1		
51.2		
52.1		
53.1		
57.1		
57.2		
59.1		

Prob 1 From the edge of a city wall, a soldier launches a projectile at an angle θ above the horizontal. The projectile reaches a maximum height of h above the top of the city wall before it descends and finally lands on the leveled ground at a distance D from the city wall. In terms of θ, h, D, and the gravitational acceleration g, answer the following questions.



(a) Draw your coordinate system and label it clearly.

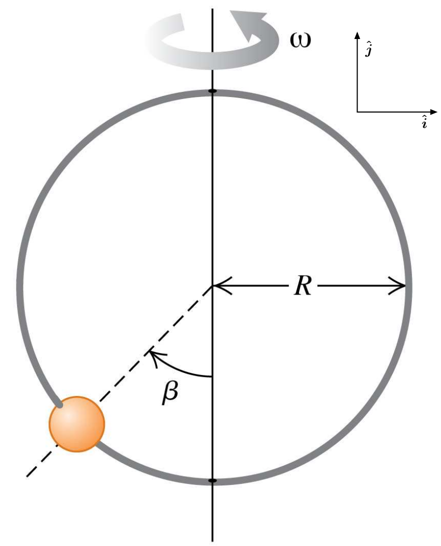
(b) What is the initial speed of the projectile?

(c) How long does it take for the projectile to reach the ground?

(d) What is the height of the city wall?

LO	S	U
9.3		
1.1		
3.3		
14.1		
15.1		
1.2		
3.4		
6.1		
14.2		
15.2		
6.2		
14.3		

Prob 2 A small bead of mass m can slide without friction on a circular hoop that is in a vertical plane and has a radius R. The hoop rotates at a constant angular velocity ω about a vertical axis through the diameter of the hoop. Our goal is to find the angle β, as shown, such that the bead is in vertical equilibrium. We break the problem into several steps.



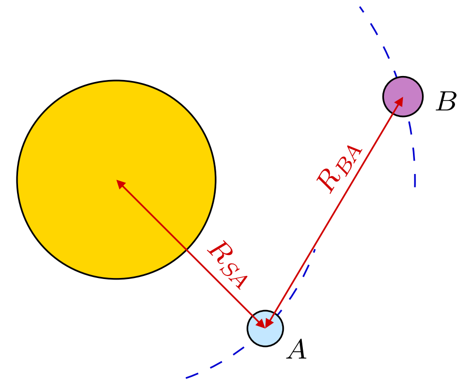
a) Assume the bead is in vertical equilibrium and does not slide along the hoop as the hoop rotates about the vertical axis. Why is the bead's acceleration still nonzero? What is the magnitude and direction of this acceleration? Express your answer for the magnitude in terms of R, β, and ω.

b) Draw a free body diagram for the bead. Decompose any forces not already along the $\hat{\imath}$ and $\hat{\jmath}$ axes into components along them.

c) Impose Newton's 2^{nd} Law and solve for β in terms of R, ω, and the acceleration due to gravity, g.

LO	S	U
16.1		
18.1		
18.2		
1.3		
23.1		
26.1		
4.1		
21.2		
21.3		

Prob 3 Consider two planets, A and B, orbiting a star of mass M.



(a) Draw on the figure all of the forces acting on planet A and all of the forces acting on planet B. Circle and connect with a line those forces forming action-reaction pairs.

(b) Suppose the star collapses to a sphere of half of its radius, but still has the same mass M. How would the gravitational potential energy of planets A and B change?

(c) Suppose that $M = 1000 m_B$ and that $R_{SA} = 10 R_{BA}$, where R_{SA} is the distance from the center of the star to the center of planet A, and R_{BA} is the distance from the center of planet B to the center of planet A. How does the contribution to A's potential energy from the star compare to that from planet B?

For the remainder of this problem we will ignore the gravitational effects of the planets on each other, and we assume planets A and B are in circular orbits of radii R_{SA} and R_{SB}, respectively, around the star with $R_{SA} < R_{SB}$. We also assume the planets have the same mass: $m_A = m_B = m$.

(d) Derive an expression for the speed of planet A in terms of R_{SA}, M and Newton's constant G.

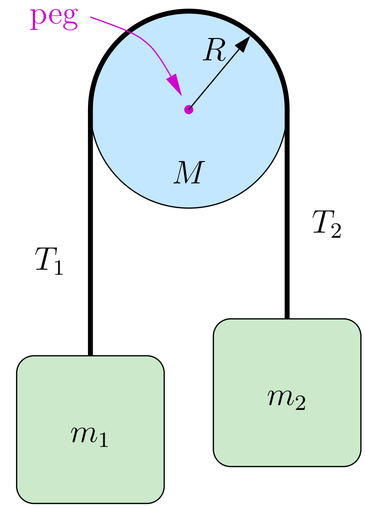
(e) Answer the following (you do <u>not</u> need to explain your reasoning):

i. Which planet has the greater kinetic energy?

ii. Which planet has the greater potential energy? (Note: if x and y are both negative, then x is greater than y if x is smaller in magnitude than y).

iii. Which planet has the greater total energy?

LO	S	U
22.1		
60.1		
60.2		
60.3		
60.4		
61.1		
61.2		
18.3		
21.4		
60.5		
34.1		
40.2		
61.3		



Prob 4 In the figure, two blocks, of mass m_1 and m_2, are connected by a massless cord that is wrapped around a uniform solid disk of mass M and radius R. The disk is supported by a peg and can rotate without friction about this fixed axis through its center and out of the page.

(a) Draw free body diagrams for each of the masses and the pulley (separately from the picture). In the case of the pulley clearly indicate where each of the forces acts.

(b) Suppose that $m_1 > m_2$ and the system is released from rest. Indicate the directions of the linear accelerations of the blocks, and the direction of the angular acceleration of the pulley on the figure. How are these three accelerations related?

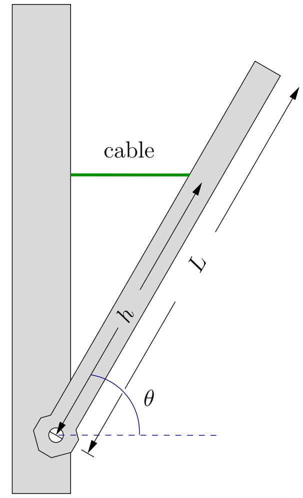
(c) Using Newton's 2$^{\text{nd}}$ Law (in linear form) for the blocks and (in rotational form) for the pulley, obtain three equations that could be solved to determine the tensions T_1, T_2, and the acceleration, a, in terms of the masses m_1, m_2, M, and the acceleration due to gravity, g.

(d) Solve for the acceleration.

LO	S	U
23.2		
23.3		
23.4		
24.1		
24.2		
24.3		
24.4		
26.2		
6.3		
6.4		
6.5		
21.5		
21.6		
51.3		
54.1		
54.2		
55.1		
4.2		

Prob 5 A uniform drawbridge (mass M and length L) must be held at an angle θ above the horizontal to allow ships to pass underneath. A cable is connected a distance h from the hinge where the bridge pivots (measured along the bridge) and pulls horizontally on the bridge to hold it in place.

(a) What is the tension in the cable?



(b) If the cable suddenly breaks, what is the magnitude of the angular acceleration of the drawbridge right after the cable breaks?

(c) What is the angular speed of the drawbridge as it becomes horizontal?

LO	S	U
2.1		
2.2		
3.5		
23.5		
24.5		
54.3		
54.4		
55.2		
51.4		
55.3		
3.6		
35.1		
38.1		
40.3		

Extra space: