

Last Name: \_\_\_\_\_ First Name \_\_\_\_\_ Network-ID \_\_\_\_\_  
Discussion Section: \_\_\_\_\_ Discussion TA Name: \_\_\_\_\_

*Instructions—*

**Turn off your cell phone and put it away.**

**Calculators may not be shared. Please keep your on your own desk.**

**This is a closed book exam. You have ninety (90) minutes to complete it.**

1. Use a #2 pencil; do **not** use a pen. Fill in completely (until there is no white space visible) the circle for each intended input – both on the identification side of your answer sheet and on the side on which you mark your answers. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner.
2. Print your last name in the **YOUR LAST NAME** boxes on your answer sheet and print the first letter of your first name in the **FIRST NAME INI** box. Mark (as described above) the corresponding circle below each of these letters.
3. Print your NetID in the **NETWORK ID** boxes, and then mark the corresponding circle below each of the letters or numerals. Note that there are different circles for the letter “I” and the numeral “1” and for the letter “O” and the numeral “0”. **Do not** mark the hyphen circle at the bottom of any of these columns.
4. **This Exam Booklet is Version A.** Mark the **A** circle in the **TEST FORM** box at the bottom of the front side of your answer sheet.
5. Stop **now** and double-check that you have bubbled-in all the information requested in 2 through 4 above and that your marks meet the criteria in 1 above. Check that you do not have more than one circle marked in any of the columns.
6. Do **not** write in or mark any of the circles in the STUDENT NUMBER or SECTION boxes.
7. On the **SECTION line**, print your **DISCUSSION SECTION**. (You need not fill in the COURSE or INSTRUCTOR lines.)
8. Sign (**DO NOT PRINT**) your name on the **STUDENT SIGNATURE line**.

*Before starting work, check to make sure that your test booklet is complete. You should have 10 **numbered pages** plus two Formula Sheets.*

*Academic Integrity—***Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including dismissal from the University.**

*Exam Grading Policy—*

The exam is worth a total of 113 points, and is composed of three types of questions:

**MC5:** *multiple-choice-five-answer questions, each worth 6 points.*

**Partial credit will be granted as follows.**

- (a) If you mark only one answer and it is the correct answer, you earn **6** points.
- (b) If you mark *two* answers, one of which is the correct answer, you earn **3** points.
- (c) If you mark *three* answers, one of which is the correct answer, you earn **2** points.
- (d) If you mark no answers, or more than *three*, you earn **0** points.

**MC3:** *multiple-choice-three-answer questions, each worth 3 points.*

**No partial credit.**

- (a) If you mark only one answer and it is the correct answer, you earn **3** points.
- (b) If you mark a wrong answer or no answers, you earn **0** points.

**TF:** *true-false questions, each worth 2 points.*

**No partial credit.**

- (a) If you mark only one answer and it is the correct answer, you earn **2** points.
- (b) If you mark the wrong answer or neither answer, you earn **0** points.

*Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is  $9.8 \text{ m/s}^2$  downward and ignore any effects due to air resistance.*

*Choose the closest number to the correct answer when a numerical answer is required.*

*The following 4 questions concern the same physical situation:*

A block of 10 kg rests on the (horizontal) floor. The coefficient of kinetic friction between the block and the floor is 0.1. You push horizontally on the block with a force  $F = 30$  N.

1. What is the work done on the block by the force  $F$  after the block has moved a distance  $d = 2$  m (in the same direction of the force on the floor).

- a. 20 J  
b. 30 J  
c. 40 J  
d. 50 J  
e. 60 J
- $W = F \times \text{displacement} = 30 \times 2 = 60 \text{ J.}$
- F and the displacement have the same direction**

2. What is the increase of the kinetic energy of the box after it has traveled a distance  $d = 2$  m?

- a. 20 J  
b. 30 J  
c. 40 J  
d. 50 J  
e. 60 J
- The friction force is  $\mu_s$  times (normal force)  
 $= \mu_s Mg = (0.1)(10)(9.8) = 9.8 \text{ N.}$   
 The work done by the block (by friction) is  $9.8 \times 2 = 19.6 \text{ J.}$   
 Therefore, the work-energy theorem tells us that  
 $\Delta E = 60 - 19.6 = 40.4 \text{ J.}$
- net work done to the box**

3. Suppose  $F$  is still 30 N but is now angled at 30 deg downward. Is the work done by  $F$  in moving the block through a distance  $d = 2$  m (on the floor) smaller or larger than the work done when  $F$  is horizontal?

- a. smaller.  
b. larger.  
c. the same.
- $W = F L \cos(30 \text{ deg}),$  so it is smaller.
- due to projection to the parallel direction**



4. Is total mechanical energy conserved in this system?

- a. yes.  
b. no.
- There is friction, so mechanical energy is dissipated.



*The following 3 questions concern the same physical situation:*

9. A 1.0 kg hammer moving at 3 m/s strikes an initially stationary 10 kg metal block head-on and bounces straight back at a speed of 0.5 m/s. What is the speed of the block after the collision?

- a. 0.11 m/s  
 b. 0.27 m/s  
 c. 0.35 m/s  
 d. 0.54 m/s  
 e. 0.99 m/s
- No external force in the horizontal direction  
 → horizontal momentum is conserved.  
 Initial total momentum = 1 times 3 kgm/s  
 Final total momentum = 1 times (-0.5) + 10v.  
 They are identical, so  $10v = 3.5$ .  
 Hence,  $v = 0.35$  m/s.

10. The collision is

a. elastic.  
 b. inelastic.  
 c. completely inelastic.

You can explicitly calculate energy loss, but if you recall that bigger object cannot carry large amount of energy, then the loss of the energy by the smaller object is fatal.

← This requires sticking.

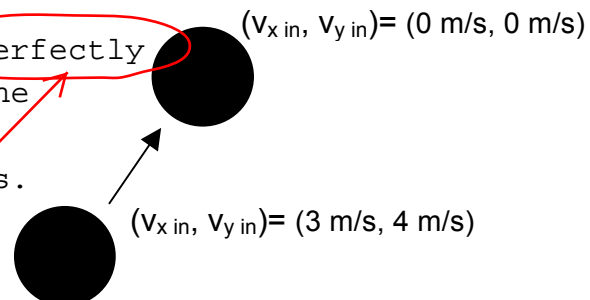
11. Suppose that after the collision the block is moving at 0.3 m/s, and that the hammer is in contact with the block for 0.01 s. What is the average force of the hammer on the block?

- a. 50 N  
 b. 100 N  
 c. 200 N  
 d. 300 N  
 e. 800 N
- Newton's second law:  $\Delta p / \Delta t = \text{Force}$ .  
 $\Delta p = p_{\text{final}} - p_{\text{initial}}$   
 $= 0.3 \times 10 - 0 = 3$  kgm/s  
 Therefore,  
 $F = 3 / 0.01 = 300$  N.

p is momentum

12. A hockey puck is moving across the ice with velocity ( $v_x = 3$  m/s,  $v_y = 4$  m/s) and has a head on, elastic collision with a second, identical puck with velocity ( $v_x = 0$ ,  $v_y = 0$ ), as in the figure. What is the speed of the second puck after the collision? Think before you calculate! This problem should involve minimal calculation.

- a. 0 m/s  
 b. 1 m/s  
 c. 2 m/s  
 d. 3 m/s  
 e. 5 m/s
- The momentum is perfectly transferred to the second puck, so the speed is 5 m/s.



If the particles run in the same direction, energy decreases; otherwise energy increases. Therefore, one particle must stop.

13. A comet, initially at rest, explodes into two parts of mass  $M/4$  and  $3M/4$ . If the more massive fragment has velocity ( $v_x = 0$ ,  $v_y = 50$  m/s), what is  $v_x$  for the smaller fragment?

- a. 0 m/s
- b. 25 m/s
- c. 50 m/s
- d. 100 m/s
- e. 150 m/s

Obviously, zero, since x and y components are conserved separately.

14. In the laboratory, when you dropped the basketball, the maximum height after each bounce off the floor slowly decreased. This was because:

- a. Mechanical energy was not conserved.
- b. Total energy was not conserved.
- c. Both (a) and (b).

15. A cart is allowed to roll down an incline without friction. The cart has both translational and rotational kinetic energy. The potential energy is defined to be zero at the top, becoming more negative as it rolls down. At the bottom of the incline, the cart's total kinetic energy is:

- a. zero
- b. positive
- c. negative

Initial total mechanical energy = 0.

Therefore, negative U means positive K.

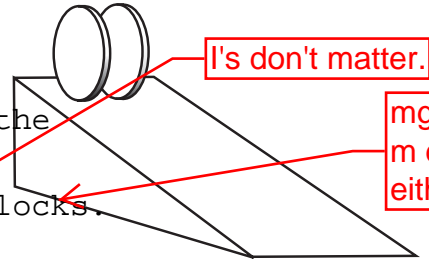
**This exam continues on the next page.**

*The following 2 questions concern related physical situations:*

There are two identically looking disks A and B. A and B have the same mass  $M_A = M_B$ , but the moment of inertia  $I_A$  of A around its symmetry axis is larger than that  $I_B$  of B. A and B are released gently from the same height on the incline as illustrated below.

16. Suppose the slope is frictionless. Which disk reaches the bottom of the incline first? (Note:  $M_A = M_B$ ,  $I_A > I_B$ )

- a. A.
  - b. B.
  - c. A and B simultaneously.
- This means rotation does not matter, and the problem is just the one for sliding blocks. A and B are the same.



I's don't matter.

$mgh = mv^2/2$ , so  $m$  does not matter, either.

17. Suppose instead that there is friction and the disks roll without slipping. Which disk reaches the bottom of the incline first? (Note:  $M_A = M_B$ ,  $I_A > I_B$ )

- a. A.
- b. B.
- c. A and B simultaneously.

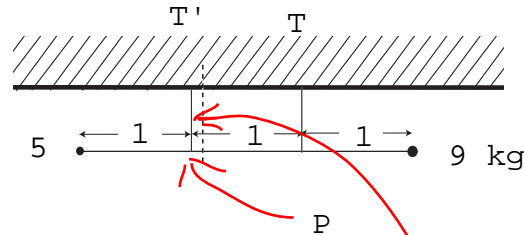
The point is: with friction the potential energy is distributed not only to the translational but also to the rotational kinetic energy. Thus, larger  $I/M$  implies slower translational motion.

To realize the same translational speed A requires more energy than B, so A cannot be faster than B; a larger portion of the potential energy must be converted into the rotational kinetic energy in case of A than B.

**This exam continues on the next page.**

*The following 2 questions concern related physical situations:*

There is a very light stick of length 3 m. At its one end is an almost point like mass of 5 kg, and at the other end of the stick is another almost point like mass of 9 kg. The stick with two masses is hung from the ceiling with two strings so that it is horizontal as illustrated below. (The dotted line segment in the figure is for the second question below.)



18. Find the tension  $T$  in the right string.

- a. 0 N
- b. 49 N
- c. 69 N
- d. 88 N
- e. 127 N

The torque around  $P$  is zero.

$$5g + T - 2 \text{ times } 9g = 0.$$

That is,

$$T = 13g = 127 \text{ N.}$$

clockwise

\d

19. If the position of the left string is moved slightly to the right (to the position designated by the dotted line in the figure above), what happens to  $T$ ?

- a.  $T$  increases.
- b.  $T$  does not change.
- c.  $T$  decreases.

Intuitively obvious.

[If you wish to be quaitative....]

The torque around the displaced  $P$  is zero.

$$5g(1+\d) + (1-\d)T - (2-\d)9g = 0$$

so for a very small  $\d$

$$T = (13g - 4g\d)/(1-\d) = 13g + 9g\d > 13g$$

]

approximately

20. A uniform disk of radius  $R$  and mass  $M$  has an angular momentum  $L$  initially around the symmetry axis of the disk. We wish to halve its angular momentum in  $t$  seconds.

What tangential constant force  $F$  should we apply to its rim?

- a.  $F = Lt/(2R)$
- b.  $F = L/(2Rt)$
- c.  $F = L/(2t)$
- d.  $F = L/(Rt)$
- e.  $F = Lt/R$

$$\Delta L / \Delta t = \text{torque} = FR$$

$$\text{Therefore, } F = \Delta L / (R \Delta t).$$

$$\Delta L = L/2, \Delta t = t.$$

That is,

$$F = L/2Rt.$$

Newton's second law (disguised)



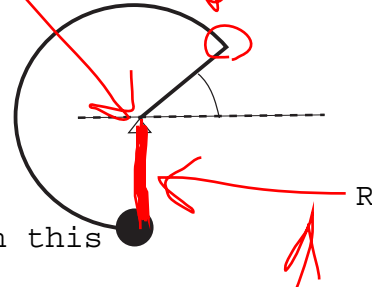


*The following 2 questions concern related physical situations:*

21. At one end of a massless wire with the partially circular shape shown in the figure is a mass  $M = 2 \text{ kg}$ . The other end is on a fulcrum  $O$ , and this balancing toy is stationary. That is, the mass is sitting vertically below the fulcrum  $O$ . What is the net torque around the corner  $A$ ? The angle  $\theta$  is  $\pi/6$  and  $R = 0.5 \text{ m}$ .

- a.  $-RMg$
- b.  $-RMg/2$
- c. 0
- d.  $RMg/2$
- e.  $RMg$

If there is force balance and if a rigid body is at rest, around any point in THE WORLD, the total torque due to the forces on this object is ZERO.



22. What is the moment of inertia of the balancing toy in the previous problem around an axis through  $O$  and perpendicular into the page?

- a. 0
- b.  $0.5 \text{ kg}\cdot\text{m}^2$
- c.  $1.0 \text{ kg}\cdot\text{m}^2$
- d.  $1.5 \text{ kg}\cdot\text{m}^2$
- e.  $2.5 \text{ kg}\cdot\text{m}^2$

$$I = MR^2 = 2(1/2)^2 = 1/2 \text{ kgm}^2.$$

$R$  is the length of the arm = the length of the vector connecting the point where the force acts and the point of interest (in our case  $O$ ).

23. At the rim of a rotating, uniform turntable of mass  $M$  is a girl of the same mass  $M$ . The girl is initially standing still (relative to the turntable) on its rim. She walks to the center of the turntable and stops (again relative to the turntable). The angular speed of the turntable

- a. increases.
- b. decreases.
- c. stays the same.

$$\text{Initial } I = (1/2)MR^2 + MR^2$$

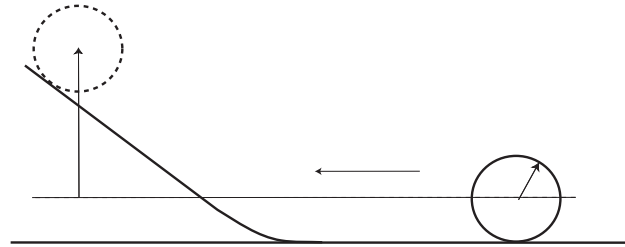
$$\text{Final } I = (1/2)MR^2 \rightarrow \text{no contribution from the girl}$$

The angular momentum  $L$  is conserved:  $L = I \omega$ .

Since  $I$  decreases,  $\omega$  must increase.

24. A uniform disk of radius  $R$  and mass  $M$  is moving across a horizontal floor toward an incline with a translational speed of  $v$  (see the illustration).

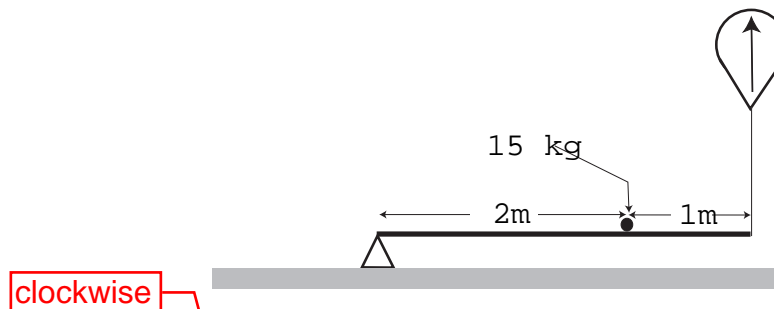
If the floor and the slope are perfectly frictionless, the disk slides without rolling. The largest vertical displacement of the center of mass of the disk is  $h$  as shown in the figure.



If instead the floor and the incline have friction, the disk rolls without slipping. What is the largest vertical displacement of the center of mass, if the translational speed of the disk on the floor is the same as before?

- a.  $0.5 h$  Frictionless: you need not worry about rotation.  
 b.  $0.67 h$  Transl kinetic energy =  $(1/2) M V^2$ , so  $Mgh$  agrees with this. That is,  $h_0 = V^2/2g$ .  
 c.  $0.75 h$   
 d.  $h$  With friction: we must also take the rotational kinetic energy into account:  $(1/2)I\omega^2 = (1/2)(MR^2/2)(V/R)^2 = MV^2/4$ . Therefore, the total initial mechanical energy  $MV^2/2 + MV^2/4 = (3/4)MV^2 = (3/2)h_0Mg$ . Thus,  $h = 3h_0/2$ .  
 e.  **$1.5 h$**

25. A massless rod of length 3 m is supported by a balloon that exerts an upward force  $F$  at one end and by a fulcrum at the other end as illustrated below. A mass  $M = 15 \text{ kg}$  is placed 1 m from the balloon end and 2 m from the fulcrum end, as shown in the figure. To maintain the rod horizontal, what force  $F$  is required?



- Torque balance  
 $-2 \times 15g + 3F = 0$   
 Therefore,  $F = 10g = 98 \text{ N}$ .  
 a. 33 N  
 b. 67 N  
 c. **98 N**  
 d. 131 N  
 e. 164 N