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 mechanical pencil or 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*.

9. **At the end of the exam, turn in your exam booklet and scantron.** You must write your **name on the exam booklet**, and **your seat number** on the **scantron.** Submit both before you leave the room,

Before starting work, check to make sure that your test booklet is complete. You should have 12 ***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 **106** 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.

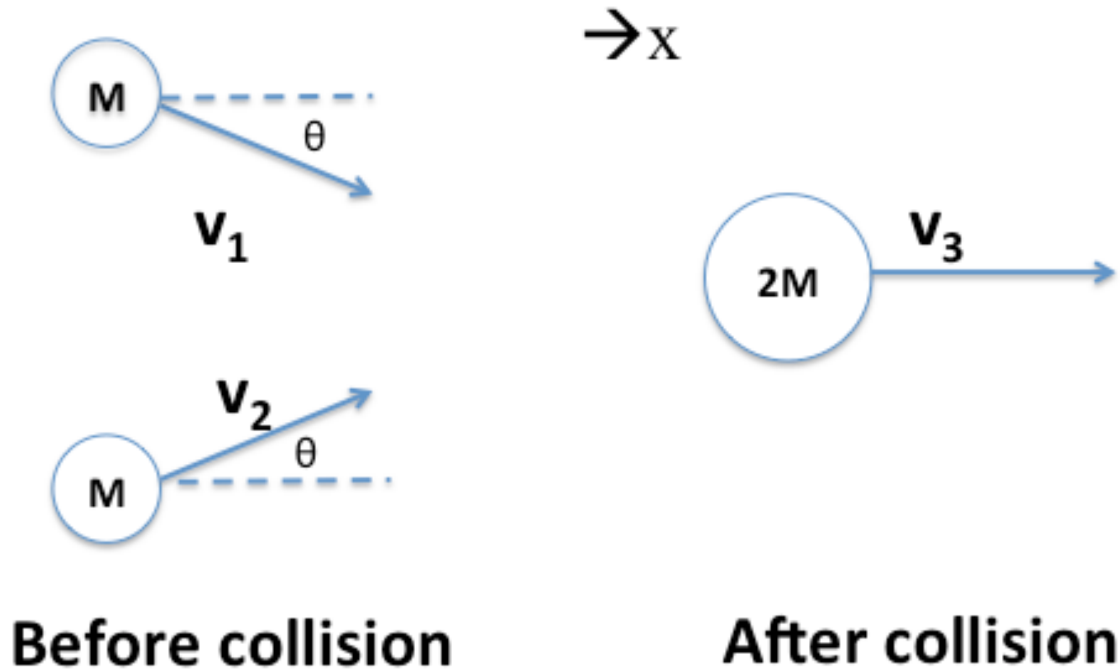
(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is 9.8 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 3 questions concern the same physical situation:

Two objects of mass M (= 1 kg) each travel with identical speed ($|v_1| = |v_2| = 3$ m/s) making an angle of □ relative to the x-axis. After they collide with each other, they travel as one object of mass 2M and with a velocity v_3 ($|v_3| = 2$ m/s) in the horizontal direction.



1. Is the collision elastic or inelastic?

a. elastic.
b. inelastic.

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The energy carried by the y-component movement is totally
lost.
```

2. How much kinetic energy is lost during the collision?

a. 2.5 J
b. 5 J
c. 10 J
d. 15 J
e. 20 J

```
E_init = (1/2)(1)3^2 x 2 = 9 J,
E_finite = (1/2)(2) 2^2 = 4 J.

Delta E = E_final - E_init = 4 - 9 = -5 J.
That is, 5 J lost.
```

3. What is the value for angle □?

a. 0.50 radians
b. 0.84 radians
c. 1.37 radians
d. 1.51 radians
e. 1.60 radians

```
The x-component of the total momentum is conserved:
     2 M v_1 cos \theta = 2M v_3,
that is,
     cos \theta = v_3/v_1 = 2/3.
Therefore, \theta = Arccos 2/3 = 48.2 deg
     = (48.2/180) pi = 0.841 radians.
```

The next 2 questions concern the following situation:

You have two balls of identical mass (m = 0.1 kg) but made of different materials. Let's call one the happy ball and the other the sad ball. When the happy ball is dropped and hits the floor at a speed of 2 m/s, it bounces back with the same speed. In contrast, the sad ball, when it is dropped and hits the floor at a speed of 2 m/s, it sticks to the floor without bouncing.

\+

+0.2

-0.2

4. What is the magnitude of the impulse delivered to the floor by the happy ball?

a. 0 kg m/s
b. 0.05 kg m/s
c. 0.1 kg m/s
d. 0.2 g m/s
e. 0.4 kg m/s

Impulse = Delta p = 0.1 times 2 - (-0.1 times 2)
= 0.4 kg m/s.

5. Which of the two balls delivers a higher magnitude impulse to the floor?

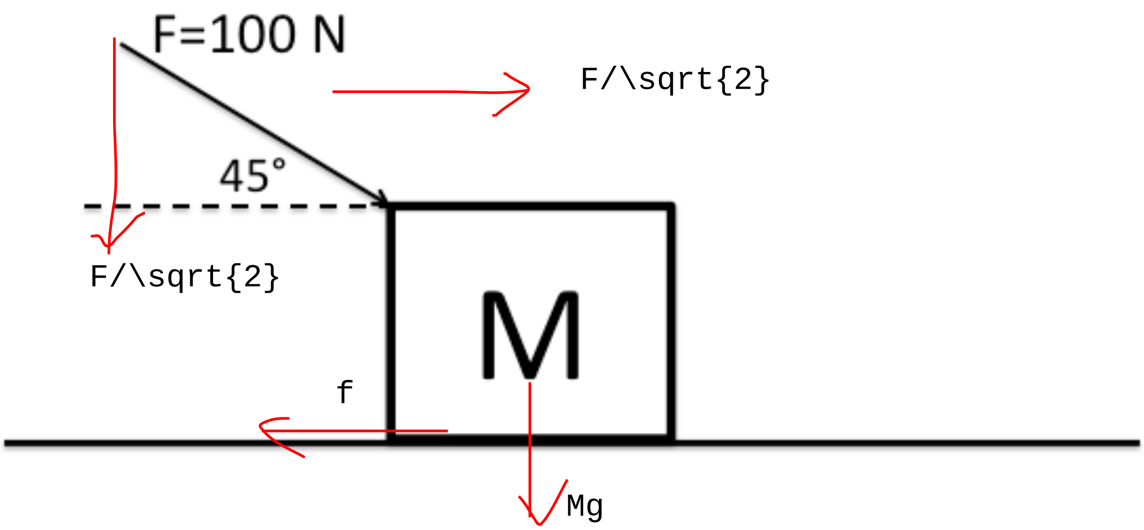
a. The happy ball.
b. The sad ball.

The magnitude of the momentum change of the sad ball is smaller than that of the happy ball.

This exam continues on the next page.

The following three questions pertain to the situation below.

A student is pushing a box of mass M (= 5 kg) by applying a force F (= 100 N) on a horizontal floor. The kinetic coefficient of friction between the box and the floor is 0.2. The box starts from rest and moves to the right over a distance of 2 m.



6. How much work is done by the student to the box?

a. 0 J
b. −141 J
c. 141 J
d. −94 J
e. 94 J

Work done by the student to the box is F projected on the floor times the displacement length = 100\cos(45 deg) times 2 = 100\sqrt{2} = 141.4 J.

7. What can you say about the work done by the normal force exerted by the floor?

a. It is zero.
b. It is positive.
c. It is negative.

The projection of the normal force onto the floor is, by definition, zero. Therefore, no work is done by the normal force.

8. What is the work done by all of the forces acting on the box combined?

a. 0 J
b. −141 J
c. 141 J
d. −94 J
e. 94 J

A negative work is done by the friction force f. The normal force is Mg + F sin (45 deg), so

f = \mu (Mg + F/\sqrt{2}).

Therefore, the magnitude of the negative work is

0.2(5 x 9.8 + 50\sqrt{2}) x 2 = 47.88 J.

Therefore, the energy gained by the box is

141.4 - 47.88 = 93.51 J

The following three questions pertain to the situation below.

Kaushiki throws a ball straight up from an initial height of 1 m. The initial speed of the ball is 5 m/s. Ignore friction due to air for this problem. The mass of the ball is 0. 3 kg.

9. What is the maximum height reached by the ball?

a. 2.28 m
b. 3.56 m
c. 4.73 m
d. 5.88 m
e. 6.97 m

```
The initial kinetic energy is (1/2)m v^2.
The final potential energy is mgh, where h is the
max height (measured from the initial height 1 m).
The conservation of mechanical energy
     mgh = (1/2)mv^2  so h = v^2/2g.
Thus, h = 5^2/(19.6) = 1.276 m.  The actual height
is 2.276 m.
```

10. When the ball falls down back to the height of 1 m, what is the speed of the ball?

a. 0 m/s
b. 10 m/s
c. 5 m/s

```
The kinetic energy must be conserved, so the speed must
be the same: 5 m/s.
```

11. What is the kinetic energy of the ball immediately before it hits the ground?

a. 3.5 J
b. 6.7 J
c. 9.3 J
d. 11.1 J
e. 12.9 J

```
The initial mechanical energy is the kinetic energy
due to 5 m/s velocity, and the potential energy due
to its (relative) height 1m:
E_init = [(1/2)5^2 + 9.8](0.3) = 6.69 J
The conservation of mechanical energy implies that
E_init must be the final kinetic energy.
```

This exam continues on the next page.

The following 2 questions pertain to the situation below.

Fred (75 kg) and Jane (50 kg) are at rest on skates facing each other. Jane then pushes Fred with a constant force F = 45 N for a time □t. Jane then moves at a speed of 1.35 m/s.

12. What can you say about Fred's motion after the push?

a. He moves at the same speed as Jane's and in the opposite direction.
b. He moves at a speed higher than Jane's and in the opposite direction.
c. He moves at a speed lower than Jane's and in the opposite direction.

The total momentum is conserved: Momentum_fred + Momentum_jane = 0.
75 \times |v_fred| = 50 \times 1.35.

13. What is the duration of push, □t?

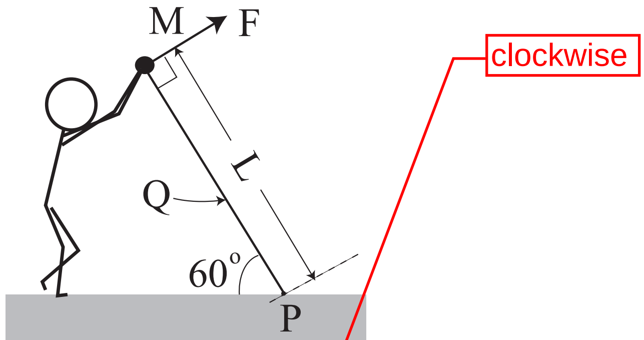
a. 0.5 s
b. 1 s
c. 1.5 s
d. 2 s
e. 3 s

The momentum of Jane is initially zero. Her final momentum is 50 times 1.35 = 67.5 kg m/s. This must be due to the impulse exerted on Jane by Fred (due to Action-Reaction): the force is 45 N, so 67.5/45 = 1.5 s is the duration of the force.

This exam continues on the next page.

The following 3 questions concern related physical situations:

At one end of a light bar of length L is fixed a small ball of mass M. The other end of the bar is fixed to the ground at point P but can rotate freely around the point. A person supports the end of the bar where the ball is fixed with a force F that is perpendicular to the bar as noted in the figure. Initially, the bar makes an angle of 60 degrees with the horizontal ground as illustrated below. You may ignore the mass of the bar.



14. To keep the bar stationary as shown in the figure, what force must the person exert? Give its magnitude. Here, g is the acceleration of gravity.

a. Mg/4
b. Mg/2
c. Mg

```
The total torque around P must be zero.
The torque due to F is -FL.  The torque due to gravity on the
ball = MgL sin(30deg).  Hence, MgL/2 = FL, or F = Mg/2.
```

15. The bar with the small ball is stationary. What is the total torque acting on the bar around its mid point Q?

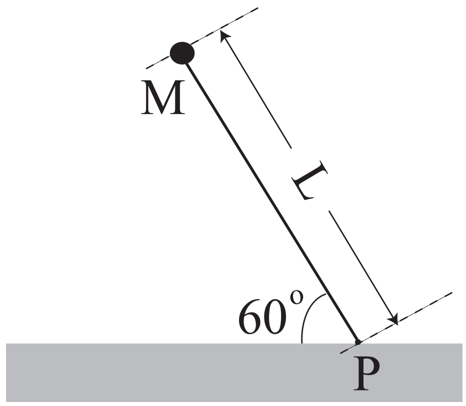
a. Nonzero and clockwise around Q (seen from you).
b. Zero.
c. Nonzero and counterclockwise around Q (seen from you).

```
Stationary, so the total torque around P must be zero. Since the
total force is also zero, so the total torque around any point is zero.
```

This problem continues on the next page.

This problem continues from the previous page.

Now, the person stops holding the bar (of length L), so the force F is gone and the bar with the small ball (of mass M) starts to rotate around P. The situation immediately after the force is removed is illustrated below. You may ignore the size of the ball.



16. What is the magnitude of the angular acceleration α of the bar around point P immediately after the force F is gone?

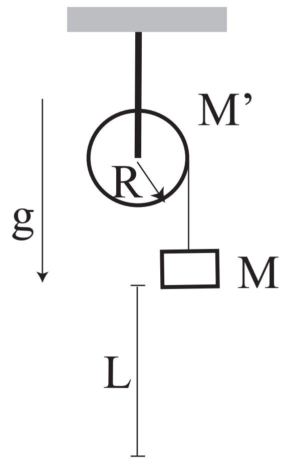
a. $\alpha = g/2$
b. $\alpha = 3g/4$
c. $\alpha = g/4$
d. $\alpha = g/2L$
e. $\alpha = 3g/4L$

```
The equation of motion reads I\alpha = \tau.
I = ML^2.  \tau = MgL/2.
Therefore, \alpha = \tau/I = MgL/2ML^2 = g/2L.
```

This exam continues on the next page.

The following question pertains to the situation below.

A disk of radius R and mass M’ is used as a frictionless pulley. There is a block of mass M with a massless string wound around it. Suppose M = M’. Initially, the system is stationary. Then, the mass is gently released, and it goes down by length L vertically as described in the figure below.



17. What can you say about the relation between the rotation kinetic energy of the pulley, K_{pulley} and the translational energy of the block, K_{block} after the block has dropped by a distance of L?

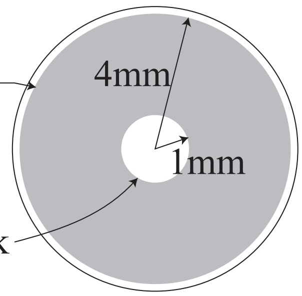
a. $K_{pulley}=K_{block}/4$
b. $K_{pulley}=K_{block}/2$
c. $K_{pulley}=K_{block}$
d. $K_{pulley}=2K_{block}$
e. $K_{pulley}=4K_{block}$

```
K_p = (1/2) I omega^2. where T = (1/2)MR^2,
V = R omega.  Therefore,
     K_p = (1/2)(1/2)MR^2(V/R)^2 = MV^2/4.
K_b = (1/2) MV^2.
Therefore, K_p = K_b/2.
```

This exam continues on the next page.

The following 3 questions concern related physical situations:

You have invented a new recording device that uses a disk of radius 4.1 mm, similar to a DVD or CD (see figure). The outermost track is with radius 4 mm and the innermost track is with radius 1 mm. The reading speed (linear speed) is kept constant irrespective of the position on the disk by adjusting the angular velocity depending on which track is being read. The angular velocity of the disk when the outermost track is being read is 241 rad/s.



18. For the outermost track, what is the linear reading speed? (The linear reading speed is the constant tangential speed which is maintained while playing the disk.)

a. 0.96 m/s
b. 1.08 m/s
c. 1.15 m/s
d. 1.52 m/s
e. 1.97 m/s

V = R omega = 0.004 x 241 = 0.964 m/s.

19. What should be the angular velocity of the disk when the innermost track of radius 1 mm is being read to maintain the linear reading speed (tangential speed) of the track?

a. 52 rad/s
b. 109 rad/s
c. 243 rad/s
d. 823 rad/s
e. 961 rad/s

The linear speed must be the same (just as the CD or DVD). Therefore, R omega = constant. To read the innermost track, the disk must rotate faster: 4 x 241 = 964 rad/s.

20. After a recording is over, the disk must be stopped. The reading ends at the outermost track. What is the magnitude α of the uniform angular acceleration required to stop the disk rotating at 241 rad/s after 12 full rotations? (Pay attention to the units!)

a. $\alpha = 243$ rad/s
b. $\alpha = 243$ rad/s^2
c. $\alpha = 382$ rad/s
d. $\alpha = 382$ rad/s^2
e. $\alpha = 451$ rad/s

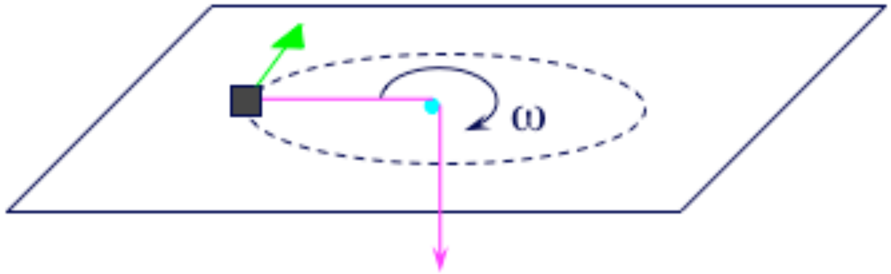
Use omega^2 = omega_0^2 + 2 alpha \Delta \theta.
omega_0 = 241, \Delta \theta = 12 times 2\pi,
omega = 0. Therefore,
alpha = -omega_0^2/2\Delta \theta
= - 241^2/48\pi = 385.2 rad/s^2.

21. Two uniform objects of the same mass start to roll down an inclined plane without slip from the same height. One is a solid cylinder and the other is a hollow cylinder. Which gets to the bottom first?

a. Solid cylinder
b. Hollow cylinder
c. They arrive at the same time.

```
The hollow cylinder rotates more slowly
than the solid cylinder. Therefore,
the solid cylinder is faster.
```

The following question pertains to the situation below.



22. A puck of mass 0.2 kg slides in a circular path on a horizontal frictionless table at an angular speed □ of 10 rad/s. It is held at a constant radius of 1 meter by a string threaded through a frictionless hole at the center of the table. Then, you pull on the string such that the radius decreases by a factor of 3. What happens to the angular speed of rotation?

a. It decreases by a factor of nine.
b. It decreases by a factor of three.
c. It does not change.
d. It increases by a factor of three.
e. It increases by a factor of nine.

```
The angular momentum is conserved:
L = I omega; I = mr^2.  Therefore,
if r -> r/3, omega -> 9omega.
```

Check to make sure you bubbled in all your answers.
Did you bubble in your name, exam version and network-ID?