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 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).

W = F \times displacement = 30 x 2 = 60 J.

F and the displacement have the same direction

a. 20 J
b. 30 J
c. 40 J
d. 50 J
e. 60 J

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

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 N.
The work done by the block (by friction) is
9.8 x 2 = 19.6 J.
Therefore, the work-energy theorem tells us that
Delta E = 60 - 19.6 = 40.4 J.

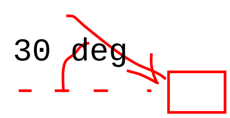
net work done to the box

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?

due to projection to the parallel direction

W = F L cos(30 deg), so it is smaller.

a. smaller.
b. larger.
c. the same.



4. Is total mechanical energy conserved in this system?

There is friction, so mechanical energy is dissipated.

a. yes.
b. no.

5. A 7.2 kg bowling ball is suspended from a 3 m long wire to make a pendulum. The pendulum is pulled to one side, to a height h above its lowest point, and released from rest. What is the speed v of the ball when it reaches its lowest point?

a. $v = 0$
b. $v = mgh$
c. $v^2 = 2gh$

```
The initial energy = potential energy mgh.
The final energy = (1/2)mv^2.
The mechanical energy is conserved, so
     v^2 = 2gh.
```

The following 3 questions concern the same physical situation:

6. Two 80 kg skiers, A and B, race on a pair of trails down a mountain. Both trails drop a vertical distance of 100 m. Skier A chooses a trail that zigzags back and forth and has a total length of 1000 m. Skier B chooses a trail that heads straight down the steepest part of the mountain and has a total length of 250 m. Ignoring friction and air resistance, which skier is moving faster at the bottom of the mountain?

a. A
b. B
c. A and B have the same speed.

```
The initial potential energy is totally
converted into kinetic energy, so v^2 = 2gh.
The same.
```

7. Which skier will get to the bottom first?

a. A
b. B
c. A and B get to the bottom at the same time.

```
Intuitively, the shorter path: B.  (This is answerable
without calculation, only if we assume that
          the slope is more or less constant.
          Not a very good question.)
```

8. The skier is hauled back to the top of the mountain by a tow rope. The tow rope operates at a speed of 1 m/s up a frictionless tow track of length 400 m, up a height of 100 m. What is the average power required to lift skier A?

a. 175 W
b. 196 W
c. 229 W
d. 344 W
e. Not enough information given.

```
Power = Work/time.
The work needed is the same as the final potential
energy = mgh = (100)(80)(9.8) J.  The time needed
          = 400/1 = 400 s.
          Therefore, Power = 8000 x 9.8/400 = 20 x 9.8
           = 196 W.
```

Use your calculator sparingly.

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.
```

p is momentum

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?

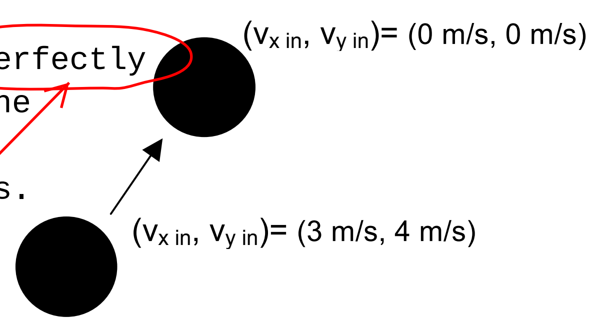
a. 50 N
b. 100 N
c. 200 N
d. 300 N
e. 800 N

```
Newton's second law: Delta p/Delta t = Force.
     Delta p = p_{final} - p_{initial}
             = 0.3 x 10 - 0 = 3 kgm/s
Therefore,
     F = 3/0.01 = 300 N.
```

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:

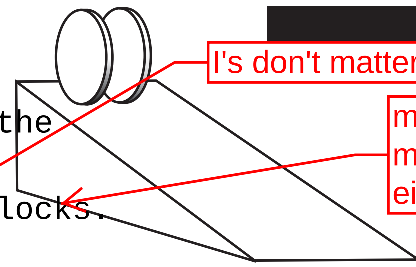
There are two identically looking disks A and B. A and B have the same mass $M_A = M_B$, but the moment of inertia I_A of A around its symmetry axis is larger than that I_B of B. A and B are released gently from the same height on the incline as illustrated below.

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.

[redacted]



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: $M_A = M_B$, $I_A > I_B$)

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.

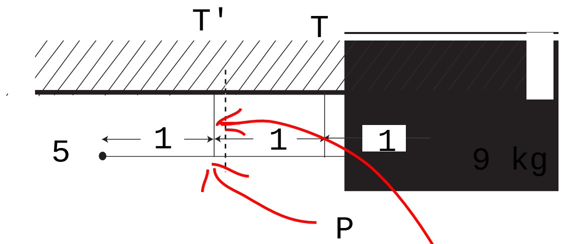
a. A.
b. B.
c. A and B simultaneously.

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.

clockwise

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

```
The torque around P is zero.
     5g + T - 2 times 9g = 0.
That is,
     T = 13g = 127 N.
```

\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 quatitative....
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
]
```

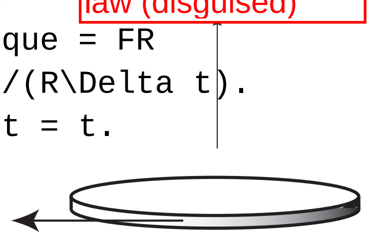
approximately

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?

Newton's second law (disguised)

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

```
\Delta L/\Delta t = torque = FR
Therefore, F = \Delta L/(R\Delta t).
\Delta L = L/2, \Delta t = t.
That is,
     F = L/2Rt.
```

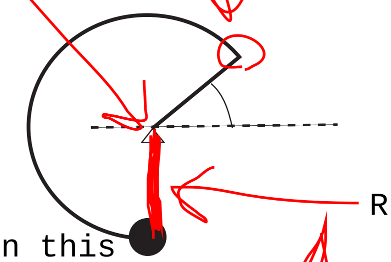


The following 2 questions concern related physical situations:

21. At one end of a massless wire with the partially circular shape shown in the figure is a mass M = 2 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 θ is π/6 and R = 0.5 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 kg·m^2
c. 1.0 kg·m^2
d. 1.5 kg·m^2
e. 2.5 kg·m^2

```
I = MR^2 = 2(1/2)^2 = 1/2 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).

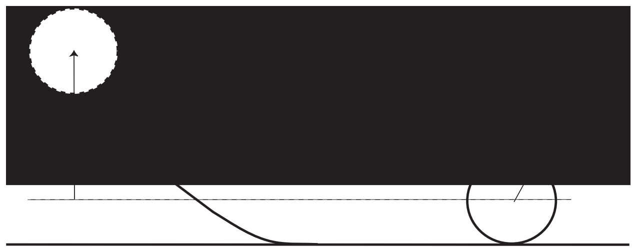
23. At the rim of a rotating, uniform turntable of mass M is a girl of the same mass M. The girl is initially standing still (relative to the turntable) on its rim. She walks to the center of the turntable and stops (again relative to the turntable). The angular speed of the turntable

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

```
Initial I = (1/2)MR^2 + MR^2
Final I = (1/2)MR^2     no contribution from the girl
The angular momentum L is conserved: L = I \omega.
Sinnce 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).

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



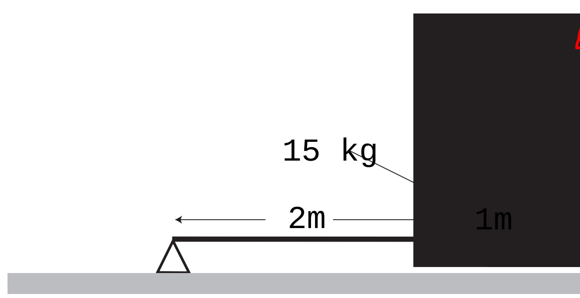
No slip V = R omega

<u>If instead the floor and the incline have friction</u>, 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
b. 0.67 h
c. 0.75 h
d. h
e. 1.5 h

Frictionless: you need not worry about rotation.
Transl kinetic energy = (1/2) M V^2, so Mgh agrees with this. That is, h_0 = V^2/2g.
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.

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 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?



clockwise

Torque balance
-2\times 15g + 3F = 0
Therefore, F = 10g = 98 N.

a. 33 N
b. 67 N
c. 98 N
d. 131 N
e. 164 N

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