Last Name:_____First Name_____ID_____
Discussion Section:_____Discussion TA Name:_____

Instructions—
Turn off your cell phone and put it away.

!!!!!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!!!!!

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*.

Before starting work, check to make sure that your test booklet is complete. You should have 12 **numbered pages** *plus three 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 108 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.*

The following 5 questions concern the same physical situation:

A small block of mass 0.2 kg starts from rest at position O on the frictionless slide shown in the figure. When the block passes the point A, its speed is 1.3 m/s.
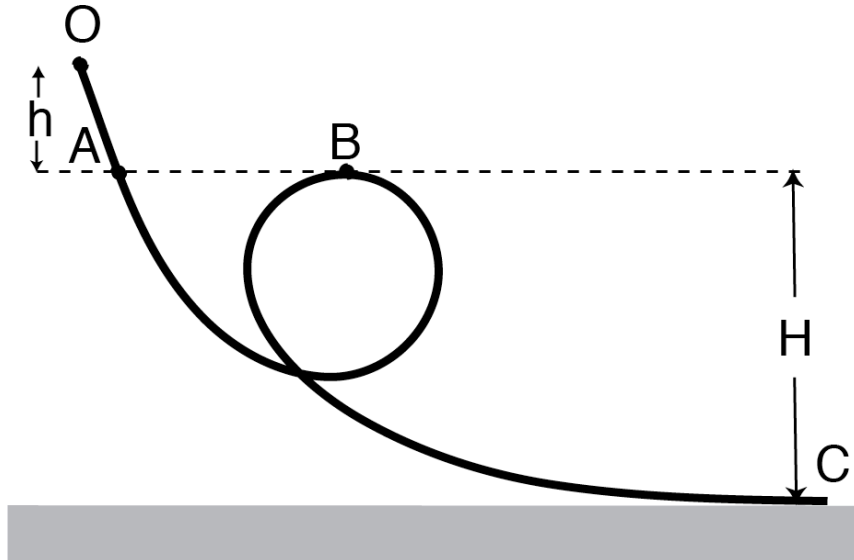
1. What is the difference in height, h, of point O and point A?

a. 0.086 m
b. 0.097 m
c. 0.11 m
d. 0.12 m
e. 0.13 m

```
This is a conservation-of-energy problem.
Initial potential energy relative to A = mgh
The kinetic energy at A = (1/2)mv^2.
Conservation of energy impies
       mgh= (1/2)mv^2,
so h = v^2/2g = 1.3^2/19.6 = 0.08622 m.
```

2. The block passes the point B, which is at the same height as point A. What is the kinetic energy of the block at point B?

a. 0.08 J
b. 0.11 J
c. 0.14 J
d. 0.17 J
e. 0.20 J

```
Since the height of B is the same as that of A,
there is no potential energy change.  Since
mechanical energy is conserved, the kinetic energy
at A and that at B must be identical.
       (1/2)m v^2 = 0.1(1.3)^2 = 0.169 J.
```

The next 3 questions pertain to the previous page.

3. What is the magnitude of the acceleration of the block at point B? The circular portion has a radius of 0.1 m.

a. 8.8 m/s^2
b. 9.8 m/s^2
c. 11.8 m/s^2
d. 13.9 m/s^2
e. 16.9 m/s^2

```
In this case the tangential speed does not change
at the top.  Therefore, we have only to pay
attention to the centripetal acceleration:
     v^2/r = 1.3^2/0.1 = 16.9 m/s^2
is the acceleration.
```

4. What is the direction of the acceleration of the block at point B

a. upward
b. horizontal
c. downward

```
This is a centripetal acceleration; the center of
the circle is directly below B.
```

5. What is the speed of the block when it reaches point C? Assume the height H of point B (and also of point A) from point C is 3h.

a. 1.5 m/s
b. 2.6 m/s
c. 3.7 m/s
d. 4.8 m/s
e. 5.9 m/s

```
The height difference between O ad C is 4h, so
the speed at C must be 2 times the speed at A,
2.6 m/s.  See the following formulas, if you
are not sure.

      At A v = \sqrt{2gh}.
      At C v' = \sqrt{2g(4h)} = 2v.
```

The following 2 questions concern the same physical situation:

There are two small space ships A and B of the same mass of 5000 kg. The initial velocity of each of these ships is V=0. A space walker of total mass 120 kg jumps from space ship A to B. Her speed relative to space ship B is 5 m/s before landing on B.
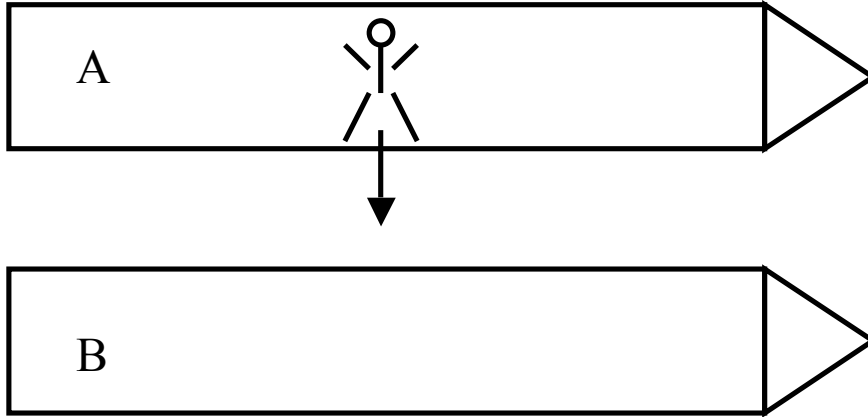
6. What is the magnitude of the impulse she imparts to spaceship A when she jumps?

a. 200 Ns
b. 300 Ns
c. 400 Ns
d. 500 Ns
e. 600 Ns

```
The momentum of A + the astronaut = 0, initially.
Since there is no external force, this momentum must be
conserved.
The momentum of the astronaut after leaving A is
126 times 5 = 600 kgm/s or 600 Ns.
The magnitude of the momentum of A must be the
same. (As vectors the astronaut's momentum and the
spaceship A momentum must be opposite with the same
magnitudes.)
```

7. Now, she jumps back to spaceship A from spaceship B with speed 5 m/s relative to spaceship B. What happens to the total kinetic energy of the two spaceships plus the space walker?

a. The total energy increases.
b. The total energy decreases.
c. No sufficient information is given to answer this question.

```
Obviously: initially nothing is moving, but
after the above exercise, things are still moving.
```

The following 2 questions concern the same physical situation:

There is an incline with a 35 degree slope. The slope is rough. You pull a block of mass 3.0 kg upward along the slope, for a distance of 5 m, at a constant speed of 2.2 m/s. You have to exert a force of 20 N parallel to the slope, as shown in the figure.

F

35°
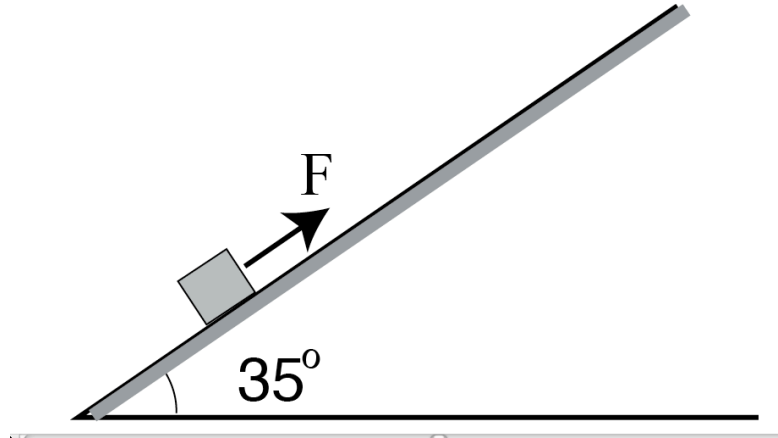
8. What is the magnitude of the work done by friction on the block?

a. 4.3 J
b. 7.3 J
c. 15.7 J
d. 20.5 J
e. 40.6 J

```
We use the work-energy theorem.
The work done by the force F is 20 times 5= 100 J.
The problem statement is a bit tricky: the constant
speed must be interpreted that the block is already moving
at 2.2 m/s. Therefore, the actual mechanical energy
increase is mgh = 3(9.8)(5 sin(35 deg)) = 84.3 J.
Thus, 100 - 84.3 = 15.7 J has been `wasted.' This must be
due to negative work done by friction.
```

9. When you stop pulling the block, it continues up the slope. What is the magnitude of the work done on the block between the time you stop pulling and the time the block comes to a stop?

a. 4.3 J
b. 7.3 J
c. 15.2 J
d. 30.5 J
e. 85.3 J

```
This is the kinetic energy (1/2)mv^2 = (1/2)3(2.2)^2
= 7.26 J that is still maintained by the block when
pushing is over.
```

The following 2 questions concern the same physical situation:

There is a merry-go-round of radius 3 m, which completes one rotation every 2.5 seconds at a constant angular velocity. You are standing on the edge of the merry-go-round.

10. What is your acceleration?

a. 10.9 m/s^2 outward
b. 10.9 m/s^2 tangent to the edge
c. 10.9 m/s^2 inward
d. 18.9 m/s^2 outward
e. 18.9 m/s^2 inward

```
omega = 2 pi/2.5 = 2.513 rad/s.
Therefore, the centripetal acceleration is
omega^2 R = 2.513^2 x 3 = 18.9496 m/s^2
towards the center (inward).
```

11. You jump upwards (no horizontal force is applied) and return to the same height 0.4 seconds later. You will

a. land inside the merry-go-round.
b. land again on the edge.
c. land off the merry-go-round.

```
If you jump, there is no centripetal force to keep you
in a circle, so you go strait to the outside of the
merry-go-round.
```

The following 3 questions concern the same physical situation.

Two dry ice pucks slide on a horizontal, frictionless surface. Puck A moves at $\theta = 120$ degrees to Puck B, as shown in the figure. Puck B moves in the negative y direction. The pucks collide near the point marked X in the diagram. After the collision Puck A and Puck B are moving in the negative y and positive x directions, respectively. The initial speed of Puck A is 3 m/s and the initial speed of Puck B is 6 m/s. All the pucks have equal mass of 1 kg.
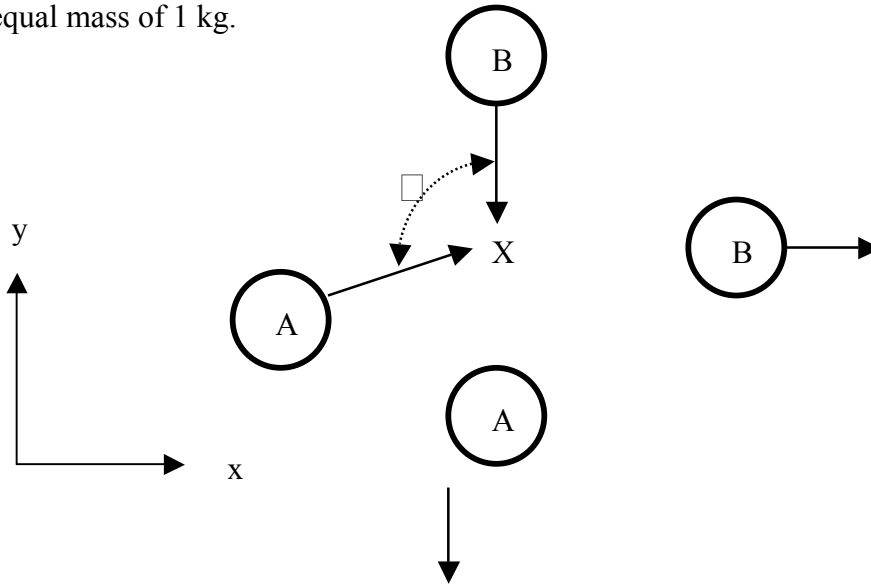
12. What is the final speed of puck B?

   a. 2.6 m/s
   b. 3.9 m/s
   c. 4.2 m/s
   d. 5.1 m/s
   e. 9.8 m/s

```
This is a momentum conservation problem.
Let us use the component-wise
representation of the vectors.

The initial total momentum
     1(3cos30, 3sin30) + 1(0,-6) = (3\sqrt{3}/2. -4.5).
The final total momentum
     (0,v) + (u,0), so u = 3\sqrt{3}/2 = 2.598 m/s.
```

13. What is the final speed of puck A?

   a. 2.2 m/s
   b. 3.9 m/s
   c. 4.2 m/s
   d. 4.5 m/s
   e. 5.4 m/s

```
v = -4.5 m/s.
```

14. How much mechanical energy was lost in the collision?

   a. none, energy is conserved.
   b. 9.0 J
   c. 19 J
   d. 27 J
   e. 45 J

```
The initial kinetic energy = (1/2)(3^2 + 6^2) = 22.5 J
The final kinetic energy = (1/2)(2.6^2 + 4.5^2) = 13.5 J
Hence, 9 J is lost.
```

The following 2 questions concern the same physical situation.

Consider a block attached by a massless rope to a massive pulley. The block has a mass of 3 kg, and the pulley has a moment of inertia $I = 0.01$ kg m^2 and radius 0.1 m. The block starts from rest. When the block has fallen 2 m the pulley is rotating at 8.0 revolutions per second.
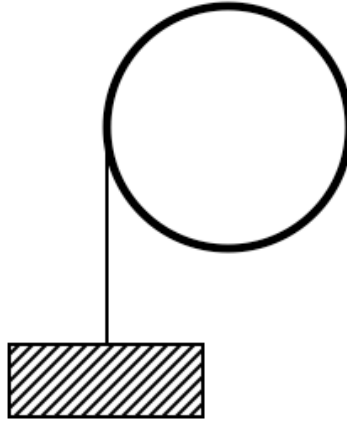
15. How fast is the block falling?

a. 1.0 m/s
b. 2.0 m/s
c. 5.0 m/s

```
The angular speed of the pulley is 2 pi times 8 = 16 pi
rad/s.  R = 0.1, so v = 1.6 pi = 5.026 m/s.
```

16. What is the rotational kinetic energy of the pulley?

a. 12.6 J
b. 13.5 J
c. 19.8 J

```
K = (1/2)I  omega^2, so
K = (1/2)(0.01)(16 pi)^2 = 12.633 J
```

The following 3 questions concern the same physical situation.

use the calculator sparingly!

Consider a flywheel that, starting from rest, is spun up with constant angular acceleration = 5.0 rad/s^2.

17. How many *revolutions* does the flywheel go through before it reaches its final speed of 3000 revolutions per minute?

a. 30.5
b. 511
c. 1571
d. 8137
e. 12496

```
Use omega^2 = omega_0^2 + 2 alpha Delta theta.
omega = 3000 rpm = 3000(2 pi)/60 = 100 pi = 314 rad/s.
Delta theta = 2 pi times (R revolutions) rad.
```

use the calculator sparingly!

```
        (10^2 pi)^2 = 0 + 2(5.0)(2 pi R).
    Therefore,
        R = 10^4 pi^2/(20 pi) = 500 pi = 1570.79 revolutions.
```

18. If the answer to the previous questions were R revolutions, and the final speed were doubled, what would the new answer be?

a. R/2
b. 2 R
c. 4 R

```
This implies R is proportional to omega^2 R, so the
new answer must be 4R.
```

19. How long does the flywheel take to spin up?
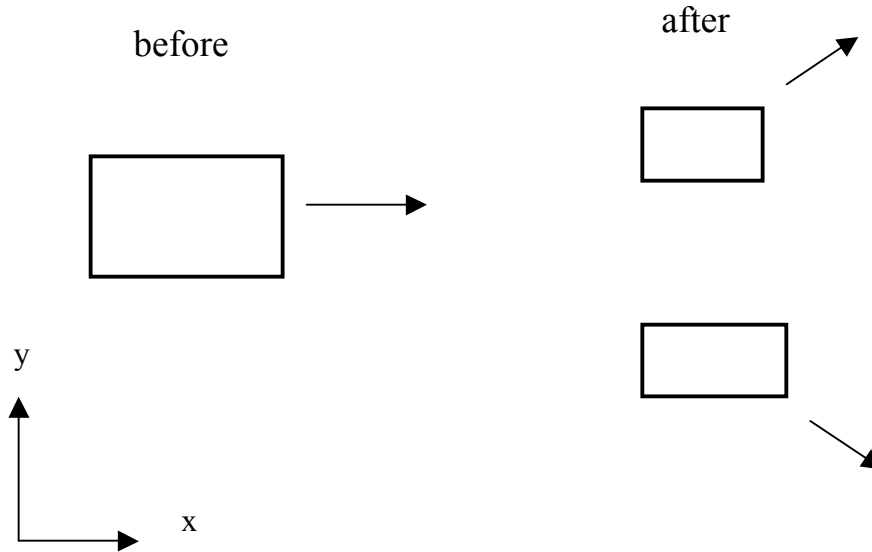
a. 5.0 s
b. 63 s
c. 128 s

```
Constant acceleration motion, so
omega = alpha times Delta t.
    so Delta t = omega/alpha = 314/5 = 62.8 s.
```

The following 3 problems concern the same physical situation.

A block of mass 7 kg explodes into two blocks, one of mass 3 kg and the other of mass 4 kg, as shown in the Figure. Before the explosion the block has a momentum of 6 kg m/s in the +x direction.

after

before

y

x

20. What is the x component of the velocity of the center of mass after the explosion?

a. 0.86 m/s
b. 3.2 m/s
c. 7.7 m/s

```
Since momentum is conserved, the CM velocity is
invariant: the total initial momentum = 6 kgm/s
= mv.
        v = p/m = 6/7 = 0.857 m/s.
```

21. What is the y component of the center of mass velocity after the explosion?

a. -0.4 m/s
b. 0.0 m/s
c. +1.3 m/s

```
There is no y component initially, so zero forever!
```

22. Shortly after the explosion, the 4 kg block is at y = +3.0m and the 3 kg block is at y = +8.0 m. Both have x = +10m. What is the y-coordinate of the center of mass?

a. 0 m
b. 3.0 m
c. 5.1 m

```
x is irrelevant.

The y coordinate of the CM is the weighted average of
the y positions:
      (4 times 3 + 3 times 8)/7 = 36/7 = 5.14 m.
```

23. You grasp the end of a spring that is attached to the wall and is initially in its resting position. You pull it out until it is extended 0.1 m from its resting position, then push it in until it is compressed by 0.1 m from its resting position. Finally, you return the spring to its resting position. The spring constant is k = 20 N/m. The total work W done by the spring on your hand is

a. $W < 0$

b. $W = 0$

c. $W > 0$

```
The total energy is conserved, and the
spring goes from a state to the same
state.  Therefore, the net work done by
you must be zero.
```

This is out of the range of HE2 this time.

24. A block is allowed to slide down a ramp of length L until it reaches the bottom. The coefficient of kinetic friction between the block and the ramp is $_k > 0$. The experiment is repeated with the ramp at an angle of 30 deg and 45 deg to the horizontal. In which case does friction do the most work?

a. 30 deg

b. 45 deg

c. it does the same amount of work in both cases.

```
The work done by a force is larger if the force is large under
the condition of the same displacement (in the direction of the
force). The friction is larger if the normal force is larger.
Therefore, the less steep slope requires the more work.
```

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