Last Name:_______________First Name__________________Network-ID____________
Discussion Section:_________Discussion TA Name:________________________________

Instructions—
Turn off your cell phone and put it away.
You may not share your calculator. Please keep it on your 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*.

Before starting work, check to make sure that your test booklet is complete. You should have 14 ***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 107 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.

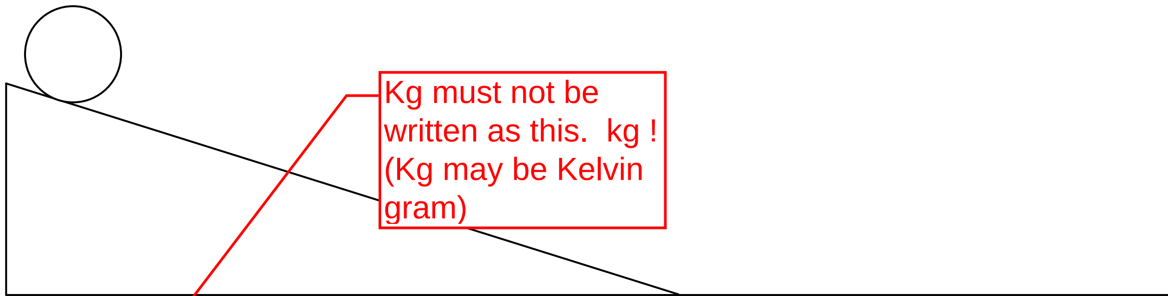
TF: *true-false questions, each worth 2 points.*
No partial credit.

(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 2 questions concern the same physical situation:

A solid, uniform disk of radius R = 0.10 m and mass 4 kg, starts from rest at a height of h = 2.0 m above a horizontal surface and rolls without slipping down an incline, as shown in the figure above. The length of the ramp is 5.0m.



1. What is the moment of inertia of the disk?

a. 0.04 Kg m^2
b. 0.01 Kg m^2
c. 0.02 Kg m^2

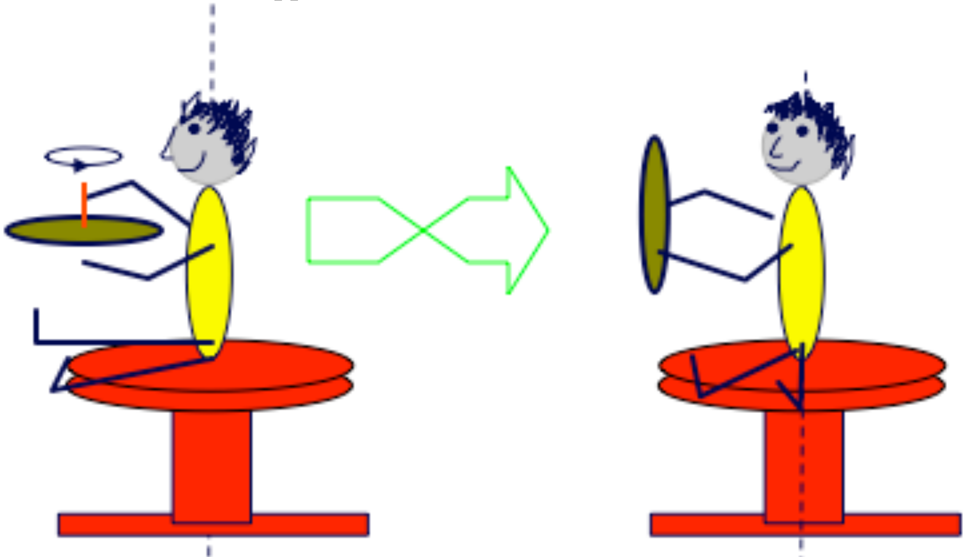
```
I = (1/2) mR^2 = 0.02 kgm^2
```

2. What is the ratio of translational kinetic energy to rotational kinetic energy when the disk reaches the bottom of the incline?

a. 1
b. 1.41
c. 2
d. 4
e. 8

```
K_T = (1/2) mv^2
K_R = (1/2)I omega^2 with omega = v/R (no slip)
    = (1/4) mR^2 \omega^2 = (1/4) mv^2.
Therefore,
     K_T/K_R = 2.
```

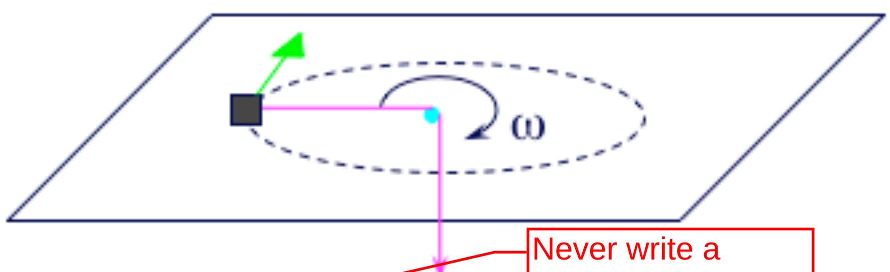
3. A student sits on a barstool holding a bike wheel. The wheel is initially spinning counterclockwise in the horizontal plane (as viewed from above). She now turns the bike wheel over. What happens?



a. She starts to spin counterclockwise.
b. She starts to spin clockwise.
c. She does not spin.

There is no external torque around the perpendicular axis (i.e., no z-component), so the angular momentum around this axis is conserved. Therefore, L_z > 0.

The following question pertains to the situation below.



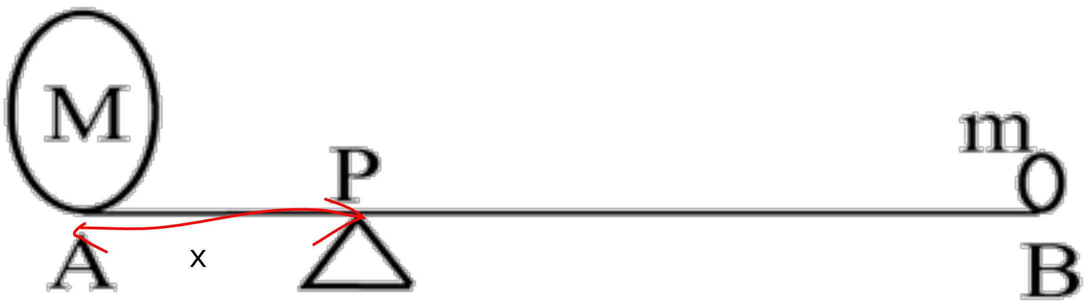
Never write a wrong unit.

4. A puck of mass 0.1 Kg slides in a circular path on a horizontal frictionless table at an angular velocity ω of 20 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 2. What happens to the angular velocity of rotation?

a. It decreases by a factor of four.
b. It decreases by a factor of two.
c. It does not change.
d. It increases by a factor of two.
e. It increases by a factor of four.

The angular momentum (around the perpendicular axis) must be conserved. L = I omega. But I changes from mr^2 to m(r/2)^2. That is, I -> I/4. Hence, omega must be quadrupled.

The following 3 questions pertain to the situation below.



There is a weightless bar of length 1 m. At one end A is a mass M = 30 kg and at the other end B is a mass m = 5 kg. The bar is at rest on the pivot P. (Note: Assume + is for counterclockwise rotation.)

5. What should be the distance between point A and the pivot point P to keep the system in equilibrium?

clockwise

a. 0.33 m
b. 0.28 m
c. 0.25 m
d. 0.14 m
e. 0.1 m

```
Let the distance be x.  The torque around P must vanish:
     Mx -m(1-x) = 0
or
     30x = 5(1 - x),
which implies 35 x= 5, or x = 1/7 m.
```

6. What is the torque around A due to mass m?

a. +98 N m
b. +49 N m
c. 0
d. –49 N m
e. –98 N m

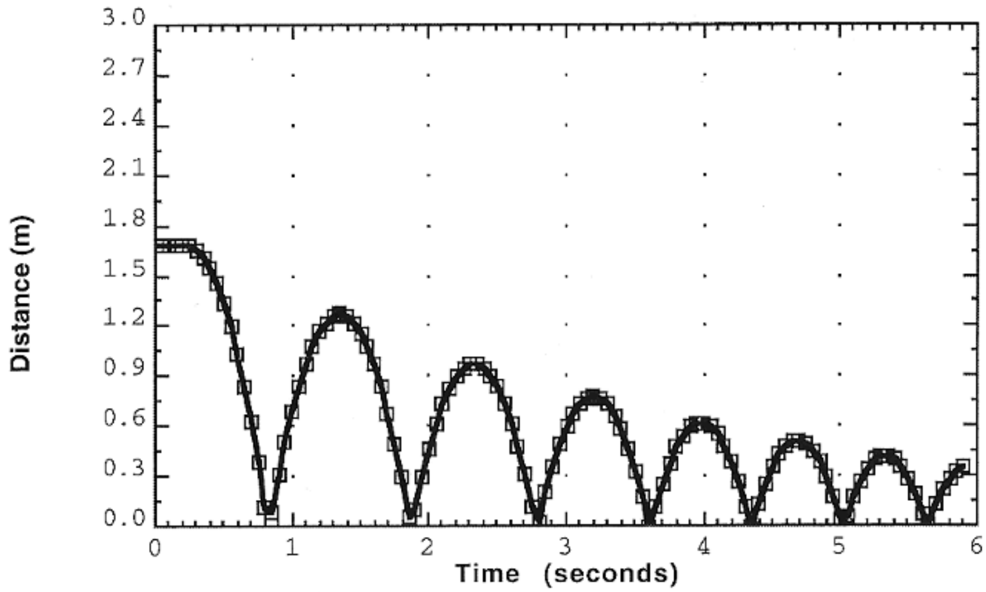
```
|Torque| = arm length x perp component of force
       = 1 times mg = 5 x 9.8 = 49 Nm.
It is clockwise, so the torque is -49 Nm.
```

7. What is the force exerted on the bar by the pivot in equilibrium?

a. 0 N
b. 245 N
c. 343 N

```
This is just force balance:
(M + m)g = 35 times 9.8 = 343 N.
```

A ball is dropped onto the floor and its distance vs. time graph looks like:



8. Approximately how much energy is lost after each bounce?

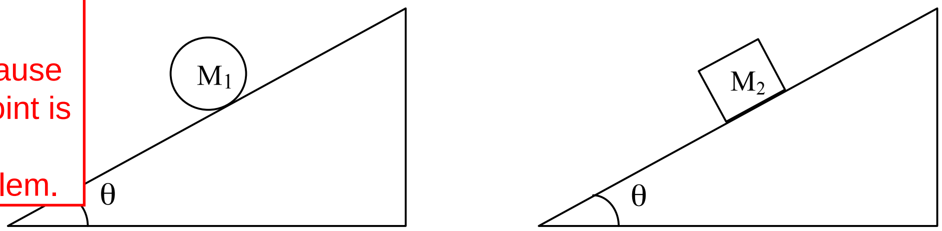
a. None
b. 10%
c. 25%
d. 75%
e. 100%

The max height h exhibits the total mechanical energy (mgh).
h changes as 1.6 -> 1.2 -> 0.9 -> ..., so about 1/4 lost at each bouncing.

This exam continues on the next page.

The following 3 questions concern the following physical situation:

This is not an answerable question, because the starting point is not given!
A sloppy problem.



9. A ball of mass M_1, and a block of mass M_2, where $M_1 > M_2$ of the same material are let go down an inclined plane. There is no friction. The order they reach the bottom is:

a. The ball first, then the block.
b. The block first, then the ball.
c. At the same time.

Since there is no friction, no rotation changes occur, so it is just a sliding block problem:
IF THEY ARE RELEASED AT THE SAME HEIGHT h, then their speeds at the bottom must be the same \sqrt{2gh} due to conservation of energy.
Therefore, IF THEY ARE RELEASED SIMULTANEOUSLY, c is the answer.

The same comment applies.

10. Friction is now added to the ramp for the ball so the ball rolls down the ramp. The ramp for the block remains frictionless. Which hits the bottom first?

a. The ball.
b. The block.
c. At the same time.

The block, because the total kinetic energy of the ball must not be more than that in case 9, and this energy must be partitioned to K_T and K_R, so its translational speed must be less than that of 9.

11. The same friction is now added to both the block and the ball, with the ball rolling down the ramp. Which hits the bottom first?

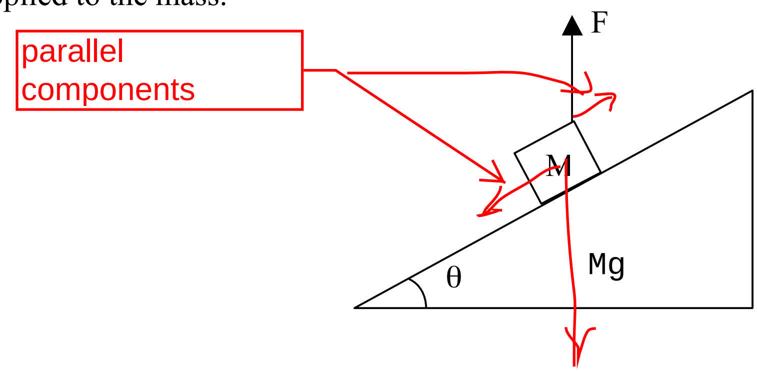
a. The ball first, then the block.
b. The square first, then the ball.
c. Not enough information is given.

If the friction is very large, the block will not move, but with an appropriate friction, the ball is slower.

This is actually the answer to all the above questions.

The following 2 questions concern related physical situations:

A block of mass M = 5.0 kg is on a frictionless incline which makes an angle θ=30° with the horizontal as shown in the figure. A constant, external vertical force F = 40 N is applied to the mass.



12. The mass starts at rest. What is the speed of the block after it has traveled a distance d = 0.2 m?

a. 0 m/s
b. 0.6 m/s
c. 0.9 m/s
d. 1.5 m/s
e. 5.0 m/s

This is a problem about the work-energy theorem.
The work is done by the force (component) parallel to the moving direction (obviously downward).
This is (Mg - F)sin \theta. Therefore,
W = (Mg -F)sin \theta \times d is the increase of the kinetic energy (1/2)M v^2.

v = \sqrt{2d(Mg-F)/2M} = \sqrt{0.2(5g-40)/5} = 0.566 m/s

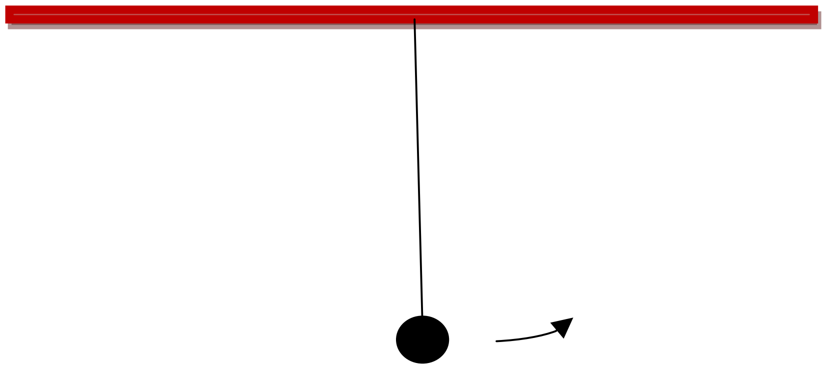
13. The block travels up the incline.

a. TRUE
b. FALSE

This exam continues on the next page.

The following 2 questions concern the physical situation shown directly below:

A pendulum consists of a mass m = 0.2 kg on the end of a string of length L = 0.3 m. At the moment the mass at its lowest point, it is observed that the speed of the mass is v = 2.2 m/s.



14. What can we say about the work done by the string, W_s?

a. $W_s > 0$
b. $W_s < 0$
c. $W_s = 0$

The tension in the string is always perpendicular to the direction of the motion (tangential!), so no work can be done.

15. At the moment the mass it at its lowest point, what is its angular velocity?

a. 2.2 rad/s
b. 5.6 rad/s
c. 7.3 rad/s
d. 9.8 rad/s
e. Not enough information is given.

omega = v/R = 2.2/0.3 = 7.333 rad/s

This exam continues on the next page.

Not answerable question, if you are a good student.

16. You and your friend are playing an egg toss game. You and your friend both catch the egg by bringing it to rest through the application of a constant (but not necessarily equal) force to the egg. When you catch the egg of mass m and initial velocity v, it does not break. When your friend catches an egg with the same mass and initial velocity, it is broken. What can we say about the force and impulse in these two cases?

a. Your friend applied a larger impulse to the egg than you did, while you and your friend both applied the same force to the egg.
b. Your friend applied a larger force on the egg than you did, while you and your friend both applied the same impulse to the egg.
c. Your friend applied the same force and impulse to the egg as you.

I can't answer this question, because whether an egg is broken or not is not solely determined by the force itself. You could apply the force with a sharp tool, for example. b is possible, but you cannot say so from the observation alone.

The next 2 questions concern the following situation:

ball?

A ball of mass 0.1 kg is traveling horizontally at 10 m/s towards a wall. The bat hits the wall and bounces off. It is observed that the ball is traveling at 8 m/s after it leaves the wall.

They should be dots.

What is the magnitude of the impulse delivered to the wall by the ball?

a. 0.2 N-s
b. 0.5 N-s
c. 1.0 N-s
d. 1.8 N-s
e. not enough information

|The momentum change| (= |impulse|) is
|0.1 x 10 - 0.1 x (-8)| = 1.8 Ns.

-, because the direction is reversed.

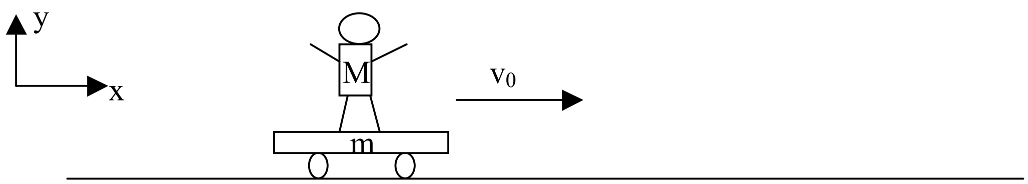
18. Mechanical energy is not conserved in this collision.

a. TRUE
b. FALSE

obvious.

The next 2 questions concern the following situation:

A man of mass M = 100 kg is standing atop a cart of mass m = 50 kg. The man and cart are moving in the positive x-direction at a speed of $v_0 = +1$ m/s as shown in the figure.



19. The man jumps off the cart. As soon as he leaves the cart, it is observed to be traveling at a speed $v_f = +4.0$ m/s. What is the velocity of the man after he leaves the cart?

If you think well, you must realize that this is not answerable, because we can only say about the horizontal component of his velocity. Let us find the `x-component.' The y-component can be anything (less than the speed of light).

a. –0.5 m/s
b. 3.6 m/s
c. –2.1 m/s
d. –4.3 m/s
e. 9.9 m/s

```
The x component of the total momentum must be conserved,
so, writing the x-component of the person's velocity
as V, we obtain
     (M+m)v_0 = MV + mv_f
or
     V = (150 - 200)/100 = - 0.5 m/s.
```

20. Due to momentum conservation, as the man jumps off the cart, the cart exerts no force on the man.

a. TRUE
b. FALSE

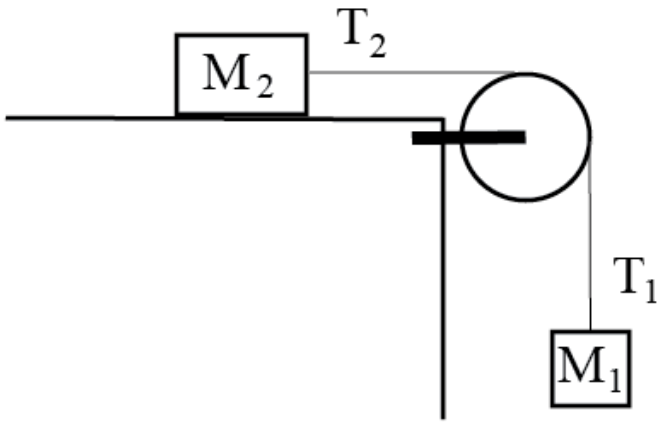
```
Momemtum conservation tells us nothing about internal
forces = forces within the system under consideration.

In the present case, the momentum of the person clearly
changes, so the cart must exert some force on the person.
```

This exam continues on the next page.

The following 2 questions concern the same physical situation:

There is a table whose top surface is frictionless and horizontal. A massive pulley is attached to its edge and two masses M_1 and M_2 are connected with a weightless string passing though the pulley as illustrated below. The block M_1 has mass 1.3 kg and $M_2 = 5$ kg. The string does not slip against the pulley whose radius R is 30 cm and whose moment of inertia is I= 1.2 kgm^2.



angular speed
omega = v/R

21. After mass M_1 has fallen a distance h, it is observed to be moving with v = 0.5 m/s. What is the distance h?

a. h = 0.193 m
b. h = 0.591 m
c. h = 0.844 m
d. h = 1.853 m
e. h = 6.722 m

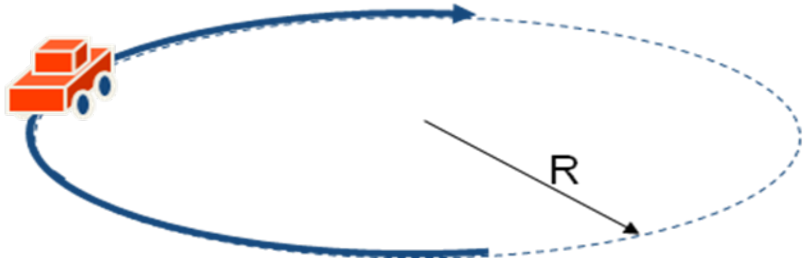
```
Conservation of energy tells us that M_1gh (the
potential energy decrease)must be equal to the
total kinetic energy K of the system.
     K = (1/2)M_1v^2 + (1/2)M_2v^2 + (1/2)I(v/R)^2
       = (1/2)(1.3 + 5 + 1.2/0.3^2)x 0.5^2
       = 2.454 J
     h = K/M_1 g = 0.1926 m.
```

22. What can we say about the magnitude of the tension in the string on either side of the pulley?

a. $T_1 > T_2$
b. $T_1 < T_2$
c. $T_1 = T_2$

```
Because, if \a denotes the angular acceleration in the
COUNTERCLOCKWISE direction,
     I \a = R(T_2 - T_1).
But we know \a < 0 (the actual motion is clockwise).
```

23. A car of mass M = 1000 kg is traveling in a circle of radius R = 225 m as shown in the figure. The road applies a frictional force of 2000 N towards the center of the circle on the car. What is the speed of the car?



a. 12.2 m/s
b. 21.2 m/s
c. 31.5 m/s
d. 33.8 m/s
e. 37.7 m/s

```
The centripetal force due to friction makes this rotation
possible:
     M v^2/R = centripetal force,
so
     v = \sqrt{2000 x 225/1000} = \sqrt{450} = 21.2 m/s.
```

24. A roller coaster car is traveling around a circular loop with a radius of 30 m. The speed of the roller coaster car is 10 m/s at the top of the loop and 30 m/s at the bottom of the loop. If it takes the roller coaster car 1.2 s to go from the top of the loop to the bottom of the loop, what is the average angular acceleration?

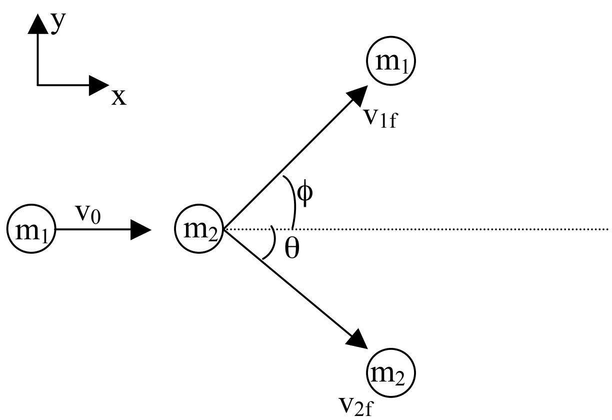
a. 0.56 rad/s^2
b. 1.42 rad/s^2
c. 16.2 rad/s^2

```
This is a pure kinematic question of
     omega = omega_0 + \a Delta t.
Here, omega_0 = 10/30 = 1/3 rad/s, omega = 30/30
= 1 rad/s, so
\a = (1- 1/3)/1.2 = 0.556 rad/s^2
```

This exam continues on the next page.

The next two problems concern the following situation.

A puck of mass $m_1 = 0.2$ kg is sliding on an ice table without friction. Its initial velocity is along the x-axis with $v_0 = 10$m/s as shown in the figure. The puck collides elastically with an identical puck, m_2, which is initially at rest. The pucks exit the collision as shown in the figure.



25. It is observed that, after the collision, the velocity components of puck 2 are $(v_{2fx}, v_{2fy}) = (8.6$ m/s, -3.5 m/s). What are the velocity components (v_{1fx}, v_{1fx}) of puck 1 after the collision?

a. (1.4 m/s, 3.5 m/s)
b. (4.4 m/s, 1.9 m/s)
c. (5.2 m/s, 4.4 m/s)

```
The total momentum is conserved:
initial momentum = m_1 (10, 0).
final momentum = m_2 (8.6, -3.5) + m_1(v_x, v_y).
Therefore,
x-component: 2 = 1.72 + 0.2v_x, v_x = 1.4 m/s.
No further calculation is needed. (but
y-component: 0 = -0.7 + 0.2 v_y, so v_y = 3.5 m/s.)
```

26. For the collision to instead be inelastic, puck 1 and puck 2 have to stick together after the collision.

a. TRUE
b. FALSE

```
`Inelastic' does not imply sticking.
```

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