Last Name:_______________First Name_________________Network-ID____________
Discussion Section:________Discussion TA Name:______________________________
Exam Room_________________________Seat Number____________

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. You may find the version of **This Exam Booklet at the top of page 2**. Mark the **version** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

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 13 ***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.**

This Exam Booklet is Version A. Mark the **A** circle in the **TEST FORM** box near the middle of your answer sheet. **DO THIS NOW!**

Exam Grading Policy—
The exam is worth a total of **xxx** 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.

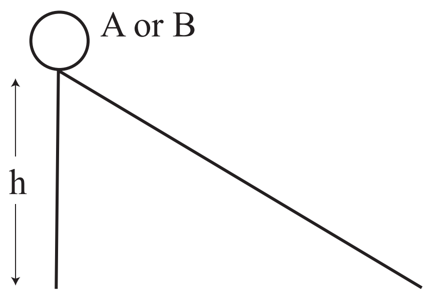
(a) If you mark only one answer and it is the correct answer, you earn **2** points.
(b) If you mark the wrong answer or neither answer, you earn **0** points.

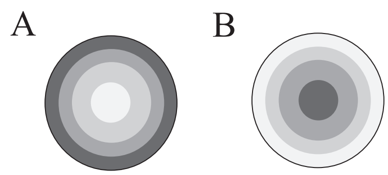
Unless told otherwise, you should assume that the acceleration of gravity near the surface of the earth is 9.8 m/s^2 *downward and ignore any effects due to air resistance.*

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

The next four questions refer to the same situation.

Two disks A and B have the same total mass and the same radius of their outer rim. However, the mass is distributed differently within the two disks, which makes disk A to have a larger moment of inertia than disk B ($I_A > I_B$). Both disks are initially at rest at the top of an inclined plane of height h (see the figure).





mass distributions in the disks

1. Assume that the two disks roll down the slope without slipping. When they reach the bottom of the slope, which disk, A or B, has a larger kinetic energy?

Mechanical energy is conserved.

a. A has more kinetic energy than B.
b. B has more kinetic energy than A.
c. Both have the same kinetic energy.

K at the bottom = Mgh, so A and B have the same kinetic energy.

2. Assume that the two disks roll down the slope without slipping. When they reach the bottom of the slope, which disk, A or B, has a larger translational speed?

a. A has a larger translational speed than B.
b. B has a larger translational speed than A.
c. Both have the same translational speed.

K = K_T + K_R must be the same. Larger K_T means faster translational speed v (since M is the same). Therefore, larger I implies smaller v. A is slower.

3. Now, assume some oil is applied to the slope, making it frictionless. Starting from rest at the top of the slope, which disk, A or B, has a larger kinetic energy when reaching the bottom of the slope?

Mechanical energy is conserved.

a. A has more kinetic energy than B.
b. B has more kinetic energy than A.
c. Both have the same kinetic energy.

K = U.

4. In the case of the frictionless surface (considered above), which disk, A or B, has a larger translational speed when the disks reach the bottom of the slope?

a. A has a larger translational speed than B.
b. B has a larger translational speed than A.
c. Both have the same translational speed.~~4, 3c, 3b, 3c, 3c~~

There is no rotation, so A and B have the same speed.

The following question is by itself.

5. The dimension of length is denoted as L, that of mass is M and that of time is T. What is the dimension of angular momentum?

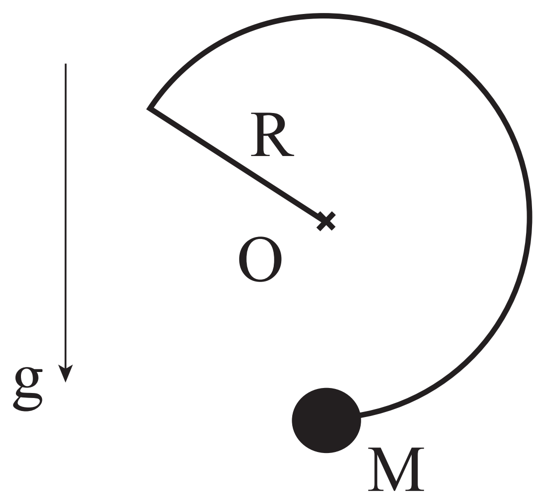
a. [angular momentum] = ML/T
b. [angular momentum] = $L/^2T$
c. [angular momentum] = ML^2/T
d. [angular momentum] = ML/T^2
e. [angular momentum] = L/T^2

times

Angular momentum = momentum x `arm length' = mass x speed x length = M (L/T) L

The next question refers to the following situation.

A balance toy is made of a massless wire attached to a ball of mass M = 0.2 kg (see figure). The radius of the wire is R = 0.12 m. The toy is stationary, balancing at its tip that is marked by the cross in the figure. The plane of the figure corresponds to the actual vertical plane. The arrow specifies the downward direction.



6 What is the torque around O (the cross mark)?

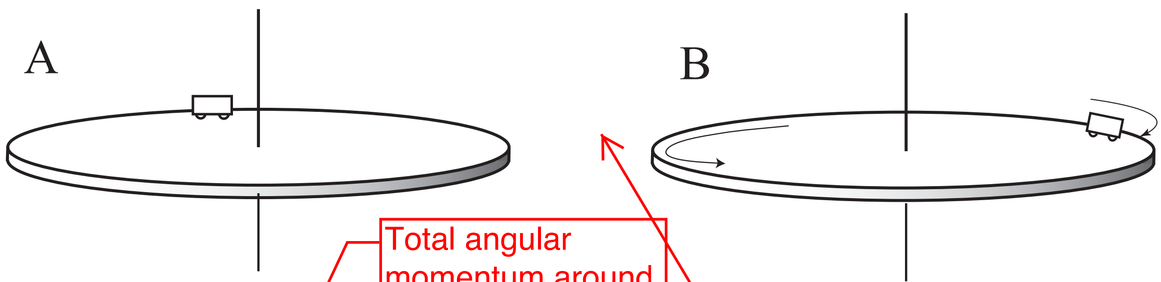
a. 0 N·m
b. 0.024 N·m
c. 0.12 N·m
d. 0.012 N·m
e. 0.0024 N·m

Torque around any point in the universe = 0, if \sum force = 0. Hence, 0!

~~*2, 6c, 6c*~~

The next question refers to the following situation.

A uniform turntable of mass M = 1.2 kg and radius R = 2 m can rotate freely around a vertical axis. A toy car of mass m = 0.4 kg is placed at the rim of the turntable.



Total angular momentum around the axle = 0.

7. Initially, the car and the turntable are at rest (A). Then, the toy car starts to move around the vertical axis along the rim of the turntable with an angular speed $\omega = 2.0$ rad/s (observed by a stationary observer) (B). What is the magnitude of the total angular momentum of the turntable and the toy car after the toy car starts to move?

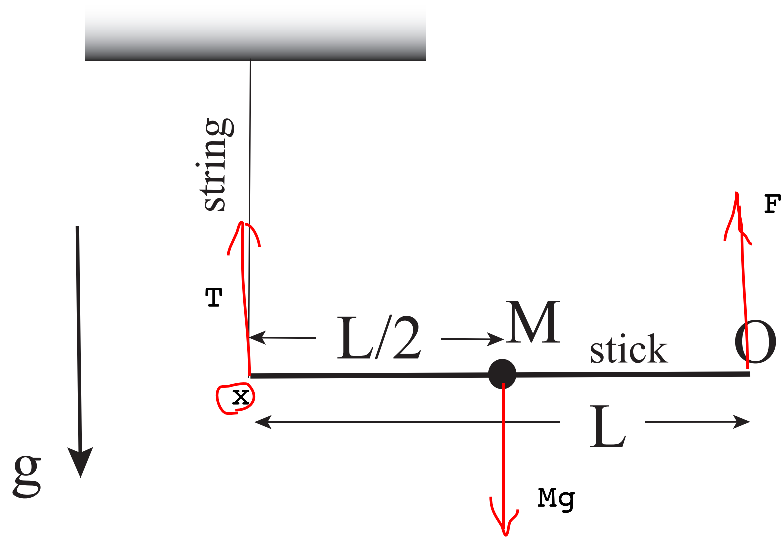
a. 8.0 kg·m^2/s
b. 0 kg·m^2/s
c. 4.8 kg·m^2/s
d. 3.2 kg·m^2/s
e. 1.2 kg·m^2/s

No external torque at all, so the total angular momentum is conserved.

~~*1, 6b*~~

The next two questions refer to the same situation.

A small ball of mass M = 2.6 kg is firmly attached at the center of a massless stick of length L = 2.2 m. Initially, one end of the stick is suspended from the ceiling via a massless string and the other end is attached to a hinge at point O (see figure). The stick is initially horizontal and at rest. Assume that the size of the ball is insignificantly small, i.e. zero.



8. What is the magnitude of the force acting on the stick from the hinge at point O?

a. 21.6 N
b. 12.7 N
c. 8.6 N
d. 15.4 N
e. 18.9 N

```
We must study the total torque around some point.
We wish to know F.  T is not known.  Therefore, x is
the best point. Around x
     +LF - Mg(L/2) = 0.   Therefore, F = Mg/2 = 2.6g/2
                                           = 12.74 N.
```

counterclockwise clockwise

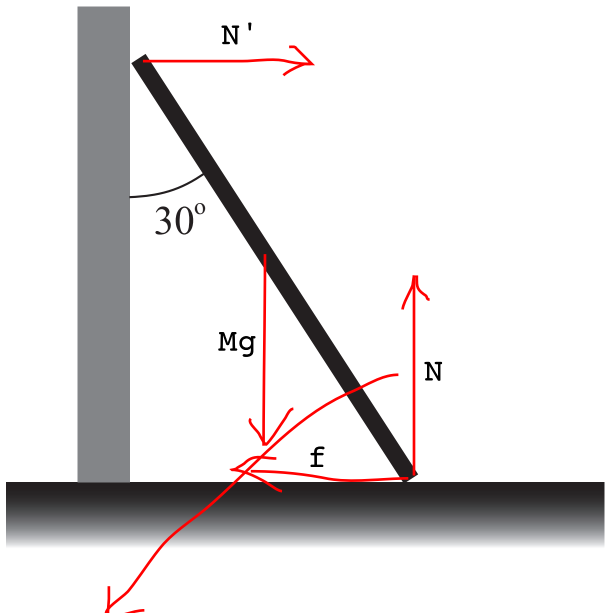
9. Just after the string is cut, what is the angular acceleration of the stick?

a. 11.8 rad/s^2
b. 8.91 rad/s^2
c. 5.28 rad/s^2
d. 9.81 rad/s^2
e. 6.43 rad/s^2
~~2, 6b, 6b~~

```
The rotation is around O.  Therefore, we must write down
the equation of rotational motion around O.
The moment of inertia around O is
     I = M(L/2)^2 = ML^2/4.
The torque around O due to force Mg is
     \tau = + Mg (L/2).
Therefore, the equation of rotational motion
     I \alpha = \tau
implies
     ML^2/4 \alpha = Mg (L/2).
That is,
     \alpha = 2g/L = 9.8/1.1 = 8.909 rad/s^2.
```

The next question refers to the following situation.

A ladder of length L = 7 m and mass M = 15 kg leans against a frictionless vertical wall. The ladder maintains an angle of 30° with the wall due to the friction force f with the (horizontal) ground. You may assume that the mass of the ladder is uniformly distributed along its length.



10. What is the normal force acting on the ladder from the ground?

a. 51.8 N
b. 92.2 N
c. 112.9 N
d. 127.4 N
e. 147.0 N

If you draw all the forces as above, N = Mg is obvious.

N = 15g = 15 x 9.8 = 147 N.

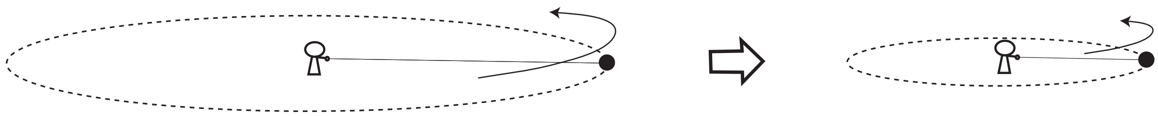
~~1, 6e~~

no torque, so no frictional work due to floor

The next two questions refer to the following situation.

A small ball of mass 10 kg is attached at one end of a massless string of length 10 m. A person holds the other end of the string. Initially, the ball is going around the person at a tangential speed of 1 m/s on a horizontal frictionless floor. Then, the person pulls in the string so that its length becomes 5 m as the ball continues to rotate.

Angular momentum is conserved



11. Which of the following statements applies to this simulation?

a. The rotational kinetic energy of the ball is conserved
b. The linear momentum of the ball is conserved
c. The angular momentum of the ball is conserved

12. What is the speed of the ball after the length of the string was shortened to 5 m?

a. 0.5 m/s
b. 1 m/s
c. 2 m/s
d. 4 m/s
e. 8 m/s

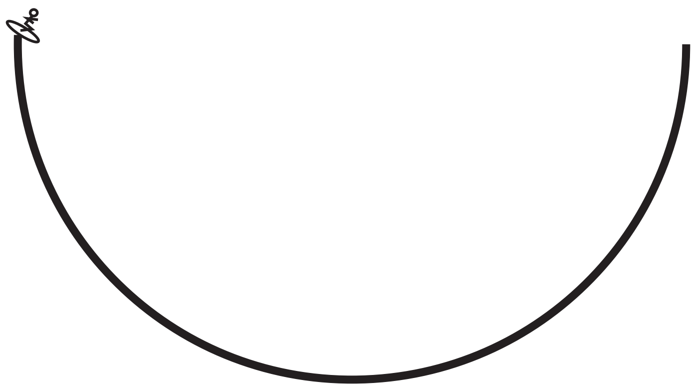
```
Angular momentum = arm's length x tangential speed.
This is conserved, so
     10 x 1 = 5 x v.
That is, v = 2 m/s.
```

times

~~2, 3c, 6c~~

The next three questions refer to the same situation.

Starting from a rest at the rim of a gigantic half-pipe, a snowboarder with a mass of 50 kg, rides down, experiencing a 20 m vertical drop. Neglect friction and air resistance.



Mechanical energy is conserved.

13. What is her speed after undergoing a 20 m vertical drop?

a. 25.4 m/s
b. 3.5 m/s
c. 14.2 m/s
d. 19.8 m/s
e. 0 m/s

```
K = (1/2)Mv^2 (final total mechanical energy),
U = Mgh (initial total mechanical energy)
so
Mgh = (1/2)Mv^2, or v = \sqrt{2gh}
                      = (40x9.8)^{1/2} = 19.8 m/s
```

14. Which is the following applies during this process?

a. The total momentum of the snowboarder is conserved.
b. The total kinetic energy of the snowboarder is conserved.
c. Neither of the above.

Total mechanical energy is conserved (K+U)

15. What is the work done on the snowboarder by the gravitational force of the Earth?

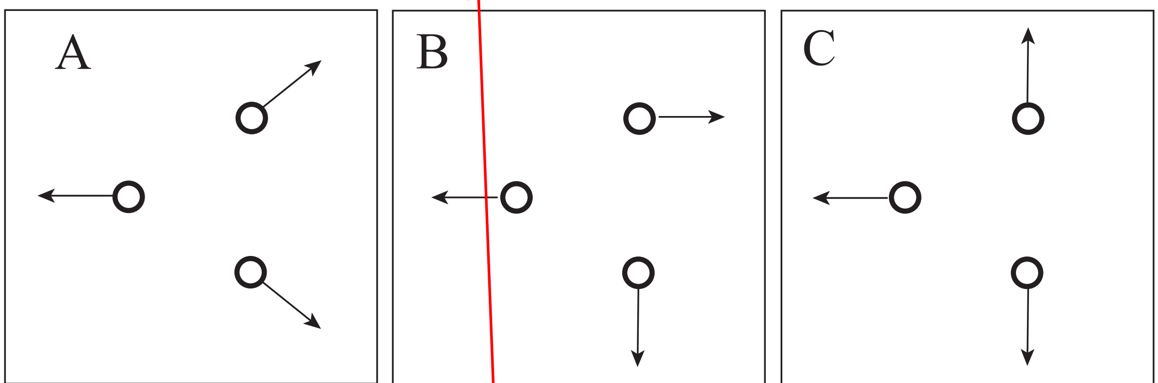
a. –9.8 kJ
b. –4.5 kJ
c. 0 kJ
d. 4.5 kJ
e. 9.8 kJ

Mgh = 50 x 20g = 9.8 kJ.
This is converted to the energy of the snowboarder, so the work-energy theorem tells us that someone did +9.8 kJ of work to the snowboarder. This was done by the Earth.

~~3, 6d, 3c, 6e~~

The next question refers to the following situation.

16. In a deep-vacuum gravitation-free environment, an asteroid explodes into three fragments of unequal masses. Which of the following drawings illustrates a plausible motion of the particles after the explosion, where the arrows indicate their velocities? (Assume that the center of mass of the asteroid is stationary when seen by the observer.)



a. Picture A
b. Picture B
c. Picture C

This implies that the total momentum = 0.
Therefore, the x and y components of the total momentum must be zero.

For B the y component of momentum is not conserved.
For C the x component of momentum is not conserved.
So, B and C are obviously impossible.
A can be realized.

~~1, 3a~~

The following three questions refer to the same situation.

The total momentum is zero.

At time t = 0, two skaters of different masses (M_1 = 50 kg and M_2 = 70 kg) are at rest on ice. Skater 1 pushes away skater 2 with a force of 100 N. Assume, there is no friction between the ice and the skaters.

No external force. so the total momentum is conserved.

17. What is the total momentum of the two skaters after 2 seconds?

a. 0 kg·m/s
b. 100 kg·m/s
c. 200 kg·m/s

18. After 2 seconds, what is the speed of skater 1?

There are many ways to solve this.

a. –2m/s
b. 0 m/s
c. 2 m/s
d. 4 m/s
e. 8 m/s

(1)100 N for 2 seconds, so the the momentum of skater 2 must be 200 Ns = 200 kg m/s, but the total momentum is zero so skater 1 must have the momentum with the same magnitude. 200/50 = 4 m/s.

(2)Action-reaction principle tells 100 N acts on skater 1 as well, so its momentum after 2 sec is 200 Ns. Hence, v = 200/50 = 4m/s

Newton's equation of motion

(3)100 = 50 a, so 2 m/s^2 is the acceleration. Hence, after 2 sec, the speed is 4 m/s.

v = v_0 + at

19. After 2 seconds, which statement correctly describes the relationship between the kinetic energies K_1 of skater 1 and K_2 of skater 2?

a. $K_1 > K_2$
b. $K_1 = K_2$
c. $K_1 < K_2$

Since the total momentum is zero, both skaters must have momenta with the same magnitude as we saw above.
K = P^2/2M, generally, so M_1 < M_2 implies K_1 > K_2.

The following question is by itself

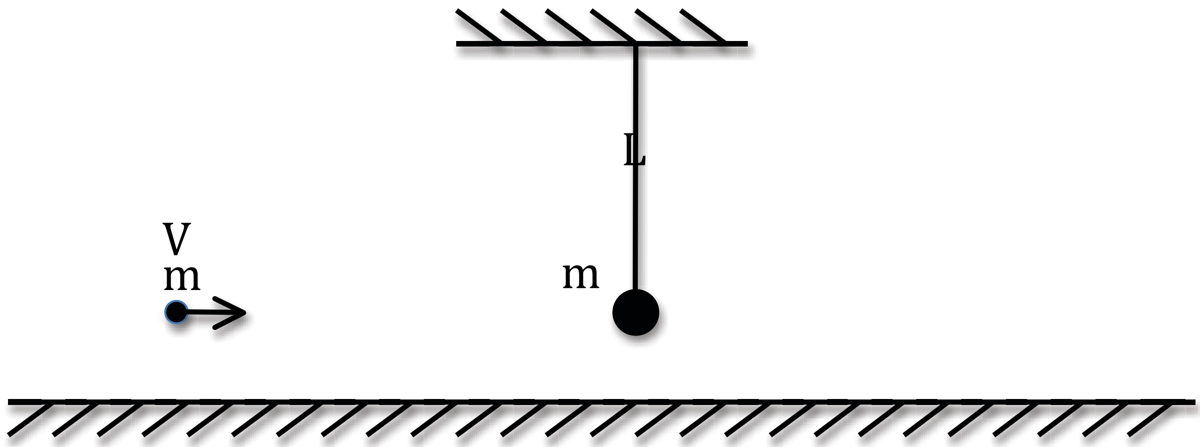
20. A car of m = 2,000 kg is moving at a speed of 20 m/s. The brakes are applied and the car comes to a complete stop after 60 m. What is the magnitude of the work done by friction slowing the car down?

a. 400 kJ
b. 0 kJ
c. 200 kJ ~~4, 3a, 6d, 3a, 3a~~

The kinetic energy is cancelled by the work the brakes do to the car.
The total kinetic energy is initially (1/2)2000 (20)^2 = 400 kJ. This must be the magnitude of the work done by the brakes.

The following three questions apply to the same situation.

A bullet of mass m_1 = 10 g moving parallel to the ground with the speed of 1000 m/s undergoes a completely inelastic collision with a pendulum of mass m_2 = 10 kg that was initially at rest in its vertical position. The string of the pendulum is length L = 1 m.



21. What is the work on the bullet during the collision?

a. –5 kJ
b. –2 kJ
c. 0 kJ
d. 2 kJ
e. 5 kJ

The initial kinetic energy is solely owned by the bullet:
(1/2)0.01x1000^2 = 5 kJ.
The final speed of the bullet is very small, so 5 kJ is lost due to the work. -5 kJ of work must have been done on the bullet.

22. What is the maximum height (measured from the lowest point of the pendulum) reached by the pendulum after the collision?

a. 0.01 m
b. 0.05 m
c. 0.1 m
d. 0.2 m
e. 0.5 m

The total momentum is conserved, which is P = 0.01 x 1000 = 10 kgm/s. Therefore, the total kinetic energy after collision is
K = P^2/2M = 10^2/2(10+0.01)= 5 J.
At the highest point this is totally converted to the potential energy U = Mgh, so h = 5/98 = 0.05 m.

23. What is the total work done by the string as the pendulum ascends to its maximum vertical rise?

a. 0 J
b. 10 J
c. 1.1 J

The tension is always perpendicular to the circular motion, so no work is done by the string.

~~3, 6a, 6b, 3a~~

The next question is by itself.

24. An object is rotating about a fixed axis. You attach some mass to the rotating object. The moment of inertia of the new object:

a. Increases the farther away from the axis of rotation the mass is attached.
b. Decreases the farther away from the axis of rotation the mass is attached.
c. Remains the same.

```
Recall I = \sum m r^2.
```

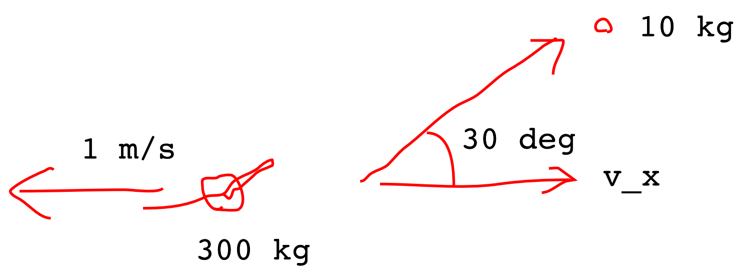
The next question is by itself.

25. A cannon of mass m_1 = 300 kg fires a metal ball of mass m =10 kg at a 30 degree angle with the horizon. The cannon recoils (from rest) with the speed of 1 m/s relative to the horizontal ground. What is the initial speed of the ball relative to the ground?

a. 23.9 m/s
b. 13.0 m/s
c. 34.6 m/s
d. 60.3 m/s
e. 49.8 m/s

```
The x component of the total momentum is conserved, so
300 x 1 = 10 v_x, the horizontal speed of the ball
is 30 m/s.  Therefore,
30/cos 30 = 34.64 m/s must be the speed of the cannon
ball.
```

~~2, 3a, 6c~~



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