

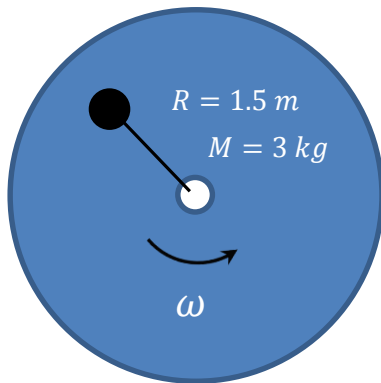
Name: _____ DISC: _____ Score: _____ / 20

Instructions:

- Do your own work.
- Answer the questions below in the space provided.
- Make sure you show all your work and any equations that you use.
- Please place a box around your answers.
- Remember to give the correct units with all numerical answers

Q1	Q2	Q3	Q4
10	10	5	5

1. Consider a block tied to a string which rotates with constant speed on a frictionless surface as shown in the diagram.



R (disk-to-block)	M (block)	I	ω
1.5 m	3 kg	MR^2	25 rad/s

Table 1: Properties of the System

Figure 1: Top View of Rotating Block

- a. There are external torques acting on this system?

- i. No, the table is frictionless.
ii. Yes, the string has tension pulling on the block.

External
Torques (2 pts):

- b. Like translational momentum, angular momentum is a conserved quantity. In your own words, explain the conditions under which angular momentum is conserved.

Explanation of
Conservation (3
pts):

Just like linear momentum is conserved in the absence of external forces, angular momentum is conserved in the absence of external torques. (Lecture 16, p. 4)

- c. Remember, angular momentum is $L = I\omega$. What is the angular momentum of the block?

$$L = I\omega = MR^2\omega = (3 \text{ kg})(1.5 \text{ m})^2 \left(25 \frac{\text{rad}}{\text{s}}\right) = 168.75 \text{ kg m}^2/\text{s} \text{ (Lecture 16, p. 18)}$$

Angular
Momentum (2
pts):

- d. You pull on the string, reducing the radius of the rotation by $R/4$. Calculate the new rotational velocity ω_{new} .

New speed (3
pts):

Because there are no external torques, angular momentum must be conserved. Thus,

$$L_i = L_f.$$

We also remember that the mass of the object is not changing, but the radius does. Thus, I changes. The new moment of inertia,

$$I_{new} = \frac{1}{16} I_{old}$$

because the radius is reduced by $1/4$. Since $L = I\omega$ and angular momentum is conserved, if I is smaller by $1/16$, ω_{new} must be 16ω . Thus

$$\omega_{new} = 400 \text{ rad/s}$$

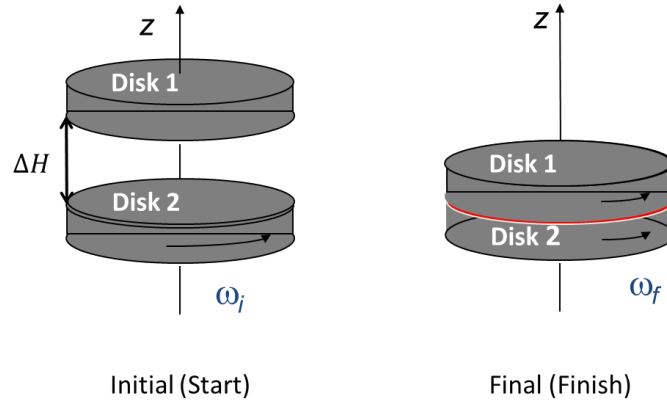
(Lecture 16, p. 18)

Overall this problem went very well. Most of the errors I found in my group were pretty strange, random errors.

- 1) Arithmetic errors: 1 pt each
- 2) Complete misunderstanding of conservation of angular momentum: -3 pts.
- 3) Use your best judgement for partial understanding of angular momentum—feel free to ask if you have any questions.

2. Consider the system of two disks as shown in the diagram. The important parameters are given in the table:

DISK	MASS	RADIUS	MOMENT OF	INITIAL ω
1	50 kg	0.5 m	$\frac{1}{2}MR^2$	0 rad/s
2	25 kg	0.5 m	$\frac{1}{2}MR^2$	30 rad/s



- a. Disk 1 is initially stationary and Disk 2 is initially rotating as shown in the *Initial* diagram. Disk 1 suddenly falls resulting in the situation in the *Final* diagram. Explain in your own words what you expect to happen.

Explanation (3 pts):

Because there are no external torques in this system angular momentum must be conserved. Once the second disk is dropped on top of the first, the moment of inertia of the rotating system will change. Because the mass will increase, the moment of inertia will increase. This increase in moment of inertia will cause a change in the angular frequency of the rotating disk system. Because angular momentum is conserved, since the moment of inertia went increased proportionally to the increase in the mass, the rotational speed must decrease by the same amount. (Lecture 16, pp. 6-7)

- b. Calculate the angular momentum for the *Initial* system:

Angular Momentum (2 pts):

$$L = I\omega = \frac{1}{2}MR^2\omega = \frac{1}{2}(25 \text{ kg})(0.5 \text{ m})^2 \left(30 \frac{\text{rad}}{\text{s}}\right) = 93.75 \text{ kg m}^2/\text{s}$$

- c. What is the final angular momentum of the system?

Angular Momentum (2 pts):

Because of conservation of momentum $L_i = L_f = 93.75 \text{ kg m}^2/\text{s}$

- d. Find the final rotational speed (ω_f) of the system of disks in the *Final* diagram.

Final speed (3
pts):

To calculate the final rotational speed we need to figure out how the moment of inertia changes:

$$\frac{I_f}{I_i} = \frac{\frac{1}{2}(M_1 + M_2)R^2}{\frac{1}{2}M_2R^2} = \frac{M_1 + M_2}{M_2} = \frac{50 + 25}{25} = 3$$

In other words, the final moment of inertia I_f is three times larger than the initial moment of inertia. Therefore, to conserve angular momentum, the angular speed must be reduced by a factor of 3. So,

$$\omega_f = \frac{\omega_i}{3} = \frac{30 \frac{\text{rad}}{\text{s}}}{3} = 10 \frac{\text{rad}}{\text{s}}.$$

Again, this problem went well if students did understand conservation of angular momentum, not well if they didn't. Most errors again were very random.

- 1) Part C—Didn't conserve angular momentum -2 pts.
- 2) Arithmetic errors -1 pt each
- 3) Substitution errors -1 pt each.