1.

Two ladybugs are standing on a rotating disk that is spinning counterclockwise, as shown in the figure above. Assume that friction in the bearings of the axle is negligible.

(a)

i. Is the angular speed of ladybug A greater than, less than, or the same as the angular speed of ladybug B?

   ____ Greater     ____ Less     X The same

Briefly justify your answer.

Rigid body has uniform angular speed rotational disk (bugs at rest on the disk)
ii. Is the linear speed of ladybug A greater than, less than, or the same as the linear speed of ladybug B?

- [ ] Greater    [ ] Less    [ ] The same

Briefly justify your answer.

\[ v = \boxed{\omega} \cdot r \]

\[ \overline{W \text{ the same}} \]

\[ r_A > r_B \implies v_A > r_B \]
(b) Ladybug A begins walking in a circular path in the direction of the disk’s rotation. Does the magnitude of the angular momentum of the disk alone (not the ladybugs-disk system) increase, decrease, or stay the same? 

___ Increase  
___ Decrease  
___ Stay the same

Briefly explain your reasoning.

\[ L_0 = L_f \]

\[ I_d \omega_0 = I_b \omega_0 = I_d f + I_b \omega_f \]

(c) In a different scenario, a single ladybug is standing near the edge of the disk at a distance of 0.9R from the center, where R is the radius of the disk, as shown in Figure 1 below. The rotational inertia of the ladybug-disk system is \( I_1 \), and the disk completes one rotation in 2.5 s. The ladybug then walks toward the center of the disk to a distance of 0.1R from the center and comes to a stop relative to the disk, as shown in Figure 2. Now the rotational inertia of the system is \( I_2 \), and the disk completes one rotation every 2.0 s.

\[ I = m r^2 \]

\[ I_1 = I_b + I_d \]

\[ I_2 = m_b (0.1R)^2 + I_d \]
i. Derive an equation for $I_2$ in terms of $I_1$.

$$I_1 \omega_1 = I_2 \omega_2$$

$$\frac{I_2}{I_1} = \frac{\omega_1}{\omega_2} = \frac{\frac{2\pi}{T_1}}{\frac{2\pi}{T_2}} = \frac{T_2}{T_1} = \frac{T_2}{\frac{2\pi}{4}} = \frac{T_2}{\frac{T_1}{2.5}} = \frac{4}{5}$$

$$I_1 \cdot \frac{I_2}{I_1} = \frac{4}{5} \cdot I_1$$

$$I_2 = \frac{4}{5} I_1$$
ii. While the ladybug is walking toward the center of the disk, does it exert a **torque** on the disk?

___ Yes  ___ No

Briefly explain your reasoning.

*Force is exerted along the radius,*

\[ \tau = F \cdot l \cdot \sin \theta, \quad \theta = 0, \quad \tau = 0. \]
### Scenario

A long rod of length $L$ and negligible mass supports a box of mass $M$. The left end of each rod is held in place by a frictionless pin about which it can freely rotate. In each case, a vertical force is holding the rods and the weights at rest. The rods are marked at half-meter intervals.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$F_g \cdot \frac{1}{4} L = F_p \cdot L$</td>
</tr>
<tr>
<td>B</td>
<td>$F \cdot \frac{1}{2} L = F_g \cdot L$</td>
</tr>
<tr>
<td>C</td>
<td>$F = \frac{3}{4} F_g$</td>
</tr>
<tr>
<td>D</td>
<td>$F_F \cdot \frac{1}{4} L = F_g \cdot \frac{1}{2} L$</td>
</tr>
<tr>
<td>E</td>
<td>$F_F = 2 F_g$</td>
</tr>
</tbody>
</table>
Data Analysis

Rank the magnitude of the vertical force \( F \) applied to the rods to keep the rod horizontal.

Greatest Force \( F_B = F, C, D, E, A \) Smallest Force \( F \)

Explain your ranking.

Since each system is at rest, we know the sum of all three forces on each system and the sum of all three torques on each system is also zero. The torque caused by the force at the pivot is zero, so the torque from the gravitational force must equal the torque from the force \( F \).

In each case, \( F(x) = mg(d) \) where \( x \) is the distance from the finger to the pivot and \( d \) is the distance from the box to the pivot. The closer the box is to the pivot, the less torque is required to hold it up.
Argumentation
In which cases is the force from the pin up? Down? Zero? Justify your answers.

Force from pin is up in case(s): A, C, D, E

Force from pin is down in case(s): B, F

Force from pin is zero in case(s): None
Explain in a short paragraph with reference to the picture above why it is easier to hang a shopping bag from the crook of your elbow than to carry it suspended from your hand with your arm at a 90-degree angle.

Assuming that the elbow is the pivot point, when someone is holding the bags with their hand, there is a torque around the pivot point equal to the magnitude of the gravitational force exerted on the bag, times the length of the forearm. When the grocery bag is held at the elbow, no torque is created because there is a not a perpendicular distance between the pivot point and the force of gravity of the grocery bag.
8.5 Skills for Analyzing Situations Using Equilibrium Conditions (1 of 6)

- When you hold a ball in your hand, your bicep muscle tenses and pulls up on your forearm in front of the elbow joint.
- When you push down with your hand on a desk, your triceps muscle tenses and pulls up on a protrusion of the forearm behind the elbow joint.
- The equations of equilibrium allow you to estimate these muscle tension forces.
8.5 Skills for Analyzing Situations Using Equilibrium Conditions (2 of 6)

- Sketch and translate
  - Construct a labeled sketch of the situation. Include coordinate axes and choose an axis of rotation.
  - Choose a system for analysis.