Name: **Solutions**

ID:

Physics 202

Midterm 1

1/31/2024

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

For questions 1 through 4 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **6** correct answers in this section and only the first **6** filled in answers will be graded. There is no partial credit.

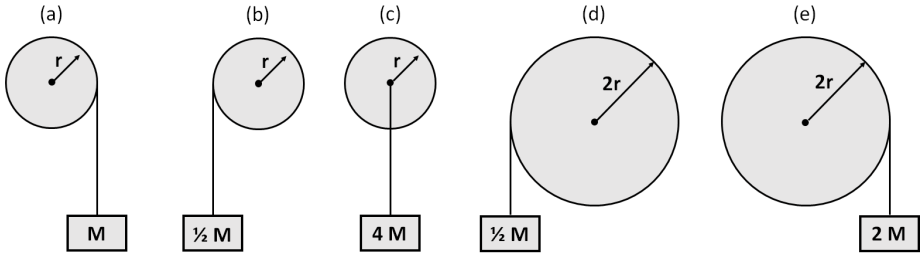
1. Mechanics sometimes use a piece of pipe to lengthen the handle of a wrench when trying to remove a very tight bolt. Which of the following statements are true regarding this situation?
   - □ (a) It increases the force exerted by the mechanic, without the need to apply a greater torque.
   - □ (b) It allows the mechanic to apply the same torque, with the same force.
   - ☒ (c) It increases the torque the mechanic can apply, without the need to exert a greater force.
   - □ (d) It allows the mechanic to exert the same force, while decreasing the torque.
   - □ (e) It reduces the lever arm.
   - ☒ (f) It lengthens the lever arm.
   - □ (g) The lever arm stays the same, but it changes the angle at which the force can be applied.

2. A disc is spinning clockwise when a **constant** counter-clockwise torque is applied to the disc. Which of the following statements are true about this situation?

   The moment immediately after the constant torque is applied, the...
   - □ (a) angular velocity of the disc is positive and the angular acceleration is positive.
   - □ (b) angular velocity of the disc is positive and the angular acceleration is negative.
   - □ (c) angular velocity of the disc is negative and the angular acceleration is negative
   - ☒ (d) angular velocity of the disc is negative and the angular acceleration is positive

   After a very long time the disc...
   - □ (e) will come to rest and stay at rest.
   - □ (f) will be rotating in the positive direction and slowing down.
   - ☒ (g) will be rotating in the positive direction and speeding up.

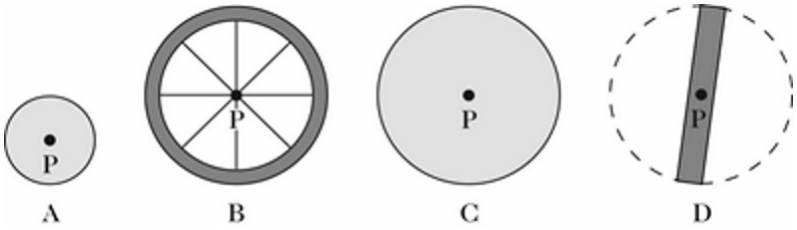
Massless strings are wrapped around several discs of equal mass. Boxes of varying masses are hung from the strings. If the discs are held static, answer the following questions:



3. Which disc experiences the most negative torque about an axis through its center from the hanging mass?
   - □ (a)
   - □ (b)
   - □ (c)
   - □ (d)
   - ☒ (e)

4. Which disc experiences the most positive torque about an axis through its center from the hanging mass?
   - □ (a)
   - □ (b)
   - □ (c)
   - ☒ (d)
   - □ (e)

5. (5 points) In the figure are scale drawings of four objects, each of the same mass and uniform thickness, each initially spinning at the same angular speed. An equal torque is applied to each object about an axis at point P. Which object will take the longest time to come to rest? Which object will take the least amount of time to come to rest? Explain your reasoning.



$\omega_f = \omega_i + \alpha \Delta t$ (0; same; ↑ ↓) $\Rightarrow$ a large α will bring the spinning objects to rest more quickly.

$\Sigma\tau = I\alpha$ (same; ↓ ↑) $\Rightarrow$ a small moment of inertia will give a large α for a given torque.

disc A $\Rightarrow$ most mass closest to axis $\Rightarrow$ smallest I $\Rightarrow$ largest α $\Rightarrow$ quickest to stop.

disc B $\Rightarrow$ most mass, furthest from axis $\Rightarrow$ largest I $\Rightarrow$ smallest α $\Rightarrow$ longest to stop.

Rubric:

1 pt - correct answers
4 pts - reasoning that includes discussion of 2nd law for rotation, moment of inertia, and kinematics

6. (13 points) Amy the ant is on a disc, 7.0 cm from the center. Starting from rest at t = 0 seconds, the disc spins with an angular acceleration of +4.0 rad/sec².

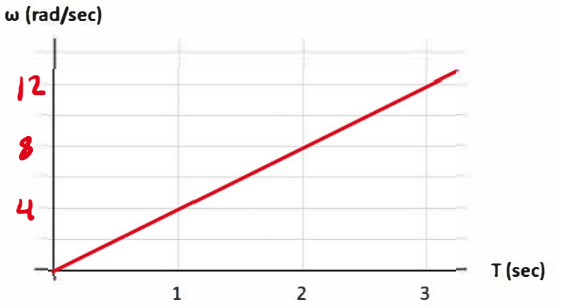
(a) What is Amy's **angular speed** at t = 3.0 seconds?

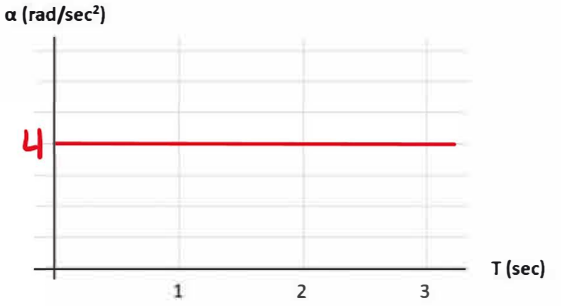
(b) What is Amy's **tangential acceleration** at t = 3.0 seconds?

(c) What is Amy's **radial acceleration** at t = 3.0 seconds?

(d) Through how many radians has Amy traveled during this time?

(e) Using the provided graphs, draw graphical representations of the angular position, angular velocity, and angular acceleration as a function of time for Amy.





a) $\omega_f = \omega_i + \alpha \Delta t$

$\omega_f = \alpha \Delta t = (4 \frac{rad}{s^2})(3.0s)$

$\omega_f = 12 \frac{rad}{s}$

b) $a_t = \alpha r = (4.0 \frac{rad}{s^2})(0.07\,m) = 0.28 \frac{m}{s^2} = a_t$

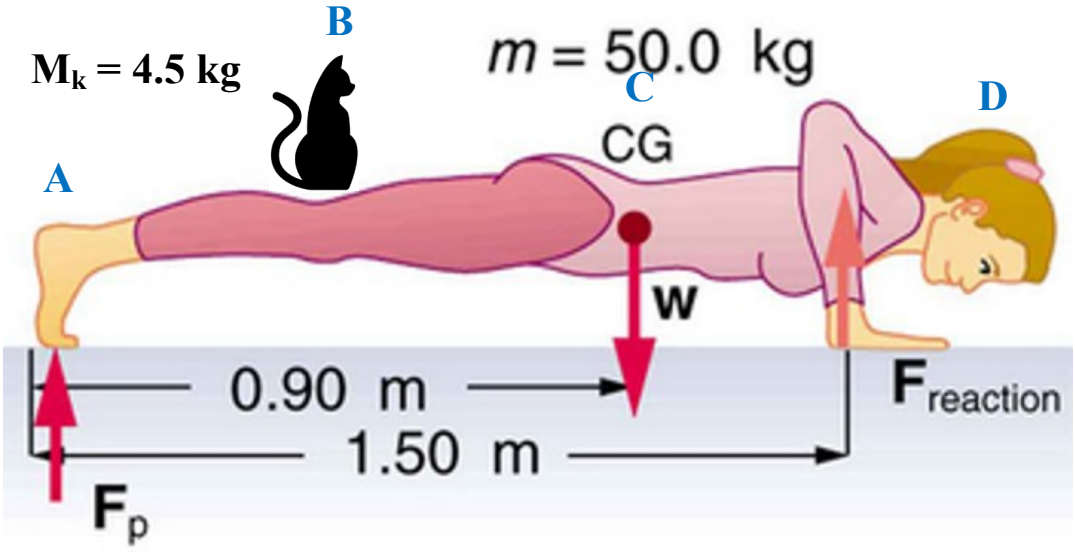
c) $a_r = \frac{v_t^2}{r} = \omega^2 r$

$= (12 \frac{rad}{s})^2 (0.07\,m) = 10.08 \frac{m}{s}$

d) $\Delta\theta = \omega_i \Delta t + \frac{1}{2} \alpha \Delta t^2$

$\Delta\theta = \frac{1}{2}(4\,rad/s^2)(3s)^2 = 18\,rad$

7. (12 points) A women is performing a static exercise called a plank with her 4.5-kg kitty on the back of her body.

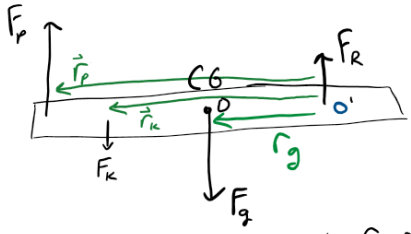


(a) At which location A, B, C, or D, would the kitty increase the force $\mathbf{F_p}$ on her toes the most? Explain your reasoning through a discussion of the torques about a reference axis of your choosing.

(b) If the kitty is at point B, halfway between $\mathbf{F_p}$ and her center of gravity (CG), find the magnitude of the force $\mathbf{F_P}$ acting on her toes?

(c) Assuming the kitty is still at point B, find the magnitude of the force on her hands $\mathbf{F_{reaction}}$.

e-FBD



(a) Location A

use axis o at CG. $\Sigma\tau_o = \tau_R + \tau_K - \tau_p = I_o\alpha_o$

τ_p has to balance $\tau_R + \tau_K$

w/ τ_R = constant, τ_p is max when τ_K is max.

τ_K has largest lever arm at A & thus largest value

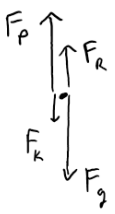
b/c $r = 0$

(b) $\Sigma\tau_{O'} = \tau_p - \tau_K - \tau_g + \cancel{\tau_R}^{\,0} = \cancel{I_{O'}\alpha_{O'}}^{\,0}$

$|\vec{r}_p||\vec{F}_p|\cancel{\sin\theta_p}^{\,1} - |\vec{r}_K||\vec{F}_K|\cancel{\sin\theta_K}^{\,1} - |\vec{r}_g||\vec{F}_g|\cancel{\sin\theta_g}^{\,1} = 0, \quad |\vec{F}_K| = M_K g$

$$F_p = \frac{r_K M_K g + r_g M_p g}{r_p} = 227\,N$$

(c) FBD



$\Sigma F_y = F_p + F_R - F_K - F_g = \cancel{M_p a_y}^{\,0}$

$F_R = M_K g + M_p g - F_p = 307\,N$

Rubric

Part (a) - 2 pts	Part (b) - 7 pts
1 pt - correct answer	1.5 pt - extended FBD
1 pt - correct reasoning	1 pt - 2nd law equation
	1 pt - torque equation
	3 pt - application of 2nd law
	0.5 pt - correct answer and units

Part (c) - 3 pts

2.5 pt - application of sum of forces or toques with new axis

0.5 pt - correct answer and units