Name:_____ ID:_____

Physics 202 Ecampus

Midterm Exam 1

1/19/2022

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, 1 page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

For questions 1 through 3 **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 **8** correct answers in this section and only the first **8** filled in answers will be graded. There is no partial credit.

1. Alexa the ant is riding on a spinning disc near the edge. The center of mass of the disk is not moving but it is spinning clockwise about it's center. The angular acceleration of the disc is constant and positive. Which of the following statements are true?

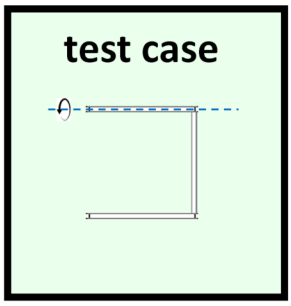
   x (a) Alexa is slowing down
   □ (b) Alexa is speeding up
   □ (c) Alexa is traveling at a constant speed
   □ (d) Alexa's tangential acceleration is decreasing
   x (e) Alexa's tangential acceleration is constant
   x (f) Alexa's radial acceleration is decreasing
   □ (g) Alexa's radial acceleration is constant

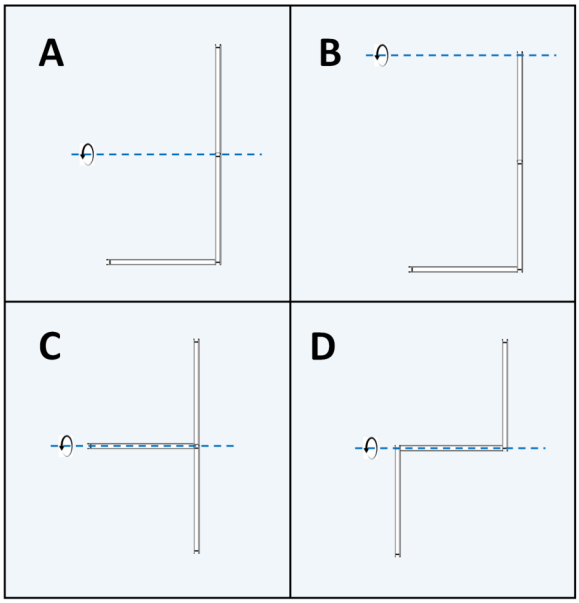
2. A system has an angular acceleration about the center of mass of -2 rad/s^2 and the system's center of mass has an acceleration of 0 m/s^2. Which of the following statements are true?

   □ (a) The net torque on the system is zero.
   x (b) The net torque on the system is non-zero.
   x (c) The net force on the system is zero.
   □ (d) The net force on the system is non-zero.
   □ (e) The velocity of the center of mass of the system must be zero.
   □ (f) The velocity of the center of mass of the system must be non-zero.
   x (g) Not enough information is provided to determine the system's center of mass velocity.

3. Three identical rods are put together to form various shapes. These shapes then have a reference axis about which there is a moment of inertia. Which of the following have a greater moment of inertia about their reference axis than the test case?

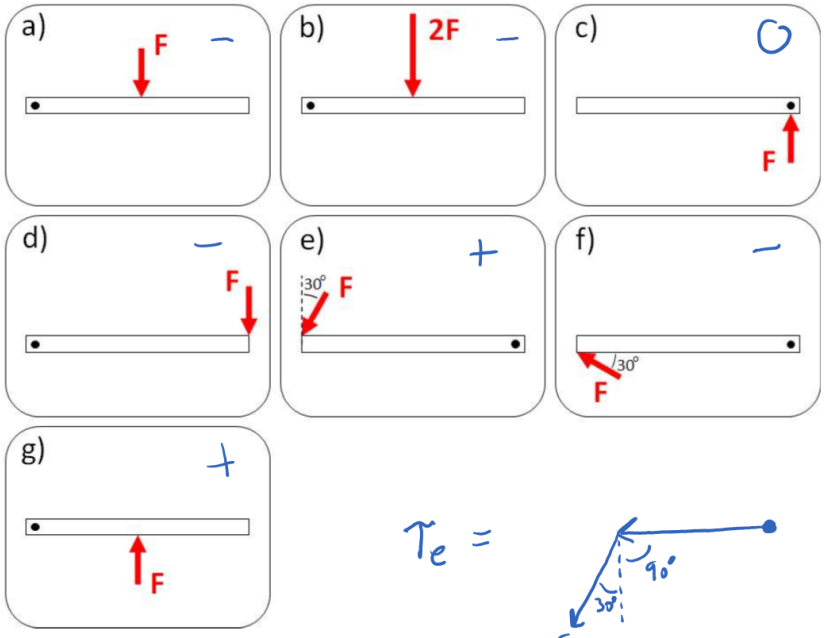
   x (a)
   x (b)
   □ (c)
   □ (d)





4. (5 points) Rank the pictured torques on a solid beam from most negative to most positive. The black dot in the beam is a fixed pivot axis which is located at the very end of the beam (notice that c, e, and f have different pivots!). You may assume that forces are either applied at the end or the center of the beam. Angles that appear to be 90 degrees, are 90 degrees. If torques are equal in magnitude, please indicate this. If any of the torques are zero, please indicate this.

An example ranking (**which is not correct**), would be: a < b = c < d < e = f < g.



$\tau_c = 0$

if beam length = L

$\tau_a = -\frac{1}{2} FL$

$\tau_b = -(2F)(\frac{1}{2}L)$

$= -FL$

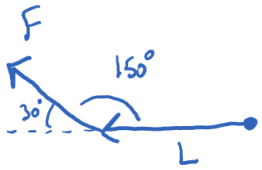
$\tau_d = -FL$

$\tau_e =$

$= FL \sin(120°)$

$= \frac{\sqrt{3}}{2} FL$

$\tau_f \Rightarrow$



$= -FL \sin(150°)$

$= -\frac{1}{2} FL$

$\tau_g = F(\frac{1}{2}L) = \frac{1}{2} FL$

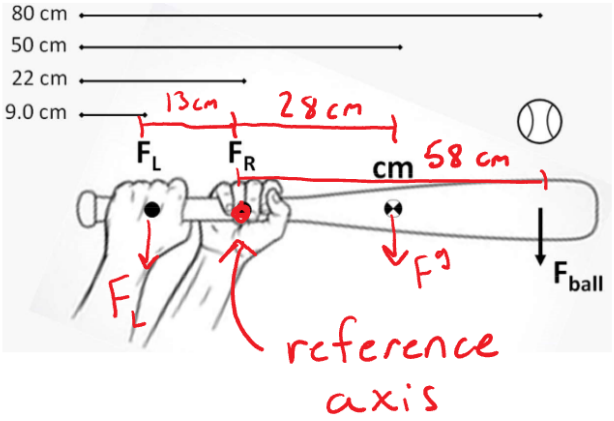
$\tau_b = \tau_d < \tau_a = \tau_f < \tau_c < \tau_g < \tau_e$

$\tau_c = 0$

0.5 identifies Tc = 0 2.0 High level torque sign - Correctly identifies positive and negative torques 1.0 Mid level torque sign - most of torques signs are identified correctly.	1.5 High level mathematical model - Identifies that Tb = Td and Ta = Tf 1.0 Mid level mathematical model - Identifies that Tb = Td or Ta = Tf , or both with an incorrect equality assigned.	1.5 High level torque magnitude - ranking is correct 1.0 Mid-high level torque magnitude - ranking of torque magnitudes is mostly or completely correct

5. (8 points) Viewed from the side as shown, a person holds a 0.94 kg wood bat with their left hand 9.0 cm from the left end of the bat, and their right hand 22 cm from the left end of the bat. The center of mass of the baseball bat is 50 cm from the left end of the bat. A ball, falling vertically, bounces 80 cm from the left end of the bat. During the bounce, the ball exerts an average force of 29 N on the bat. During the collision, the baseball bat is held still and without rotation by the person's hands. Find the average force exerted by the person's left hand during the ball's bounce on the bat.

because we don't know F_L or F_R, we want to remove one of them from our torque analysis ⇒ reference axis is chosen to be at F_R



$|\tau| = |\vec{F}||\vec{r}|\sin\theta$ ← 90° for all angles here

$\tau_{net} = I\alpha$ ($\alpha = 0°$)

$\Rightarrow 0 = |F_L||r_L| - |F^g||r_g| - |F_{ball}||r_{ball}|$

$|F_L|$ must be CCW to balance; $|F^g||r_g|$ ↑ CW; $|F_{ball}||r_{ball}|$ ↑ CW

$0 = |F_L|(0.13\,m) - (0.94\,kg)(9.8\,m/s^2)(0.28\,m) - (29\,N)(.58\,m)$

$F_L = 149\,N$ downwards

2.0	Problem setup - Mathematical model for torque is stated and/or used, or other relevant information is shown, or a partial problem setup is shown

5.0	High level torque analysis - reference axis is chosen, mathematical model is used appropriately,
3.5	Mid level torque analysis - Mathematical model for torque is used appropriately, but torque analysis is incomplete
2.0	Low level torque analysis - mathematical model for torque is applied inappropriately to a torque analysis
1.0	Low level torque analysis - mathematical model for torque is applied inappropriately

1.0	Correct final answer magnitude, units, and direction (149 N downwards)
0.5	Correct final answer magnitude. May be missing units or direction

6. (10 points) The figure below shows the angular velocity for a system graphed as a function of time.

   (a) What is the angular acceleration (in rad/s²) of the system at t = 3 seconds?
   (b) What is the change in angular position (in radians) of the system between 0 and 2 seconds?
   (c) Carefully draw a scaled graph of the angular acceleration as a function of time on the provided graph. Clearly label sections of your graph as quadratic, linear, or constant.
   (d) Carefully draw a scaled graph of the angular position as a function of time on the provided graph. The initial angular position is 3 rad. Clearly label sections of your graph as quadratic, linear, or constant.

(a) α = SLOPE OF ω vs t @ t = 3 SEC

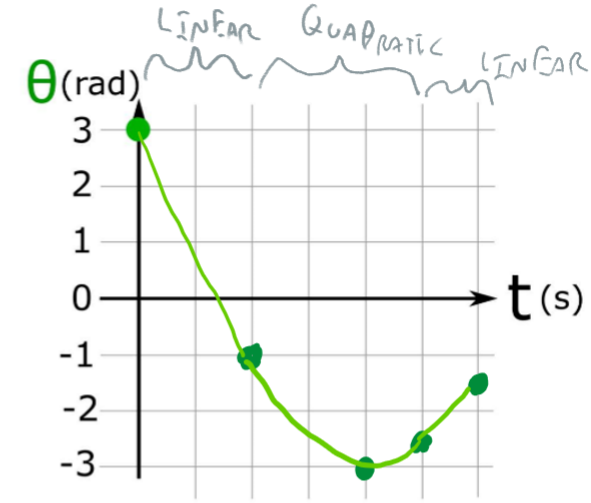
$$\frac{3\ \text{RAD/S}}{3\ \text{SEC}}$$

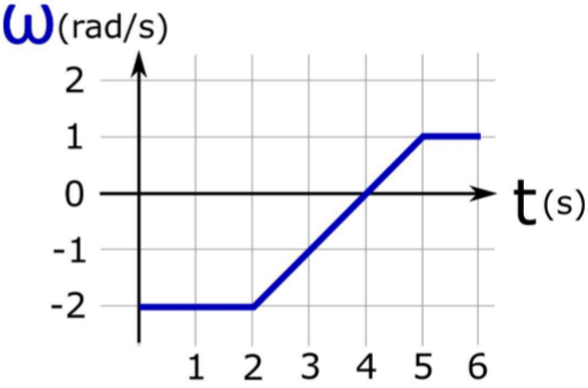
$$\boxed{\alpha = 1\ \frac{\text{RAD}}{\text{S}^2}} \quad @\ t = 3\ \text{SEC}$$

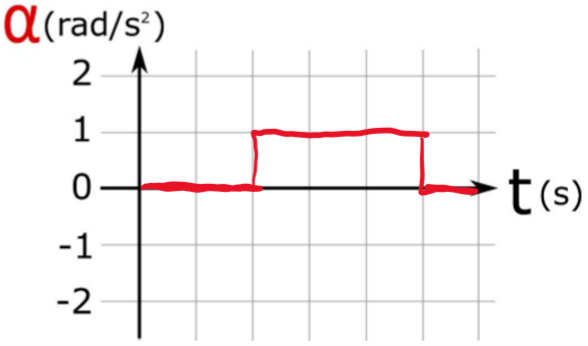
(b) $\Delta\theta_{0-2}$ = AREA OF ω vs t FROM 0–2 SEC

$$(2\ \text{SEC})\left(-2\ \frac{\text{RAD}}{\text{S}}\right)$$

$$\boxed{\Delta\theta_{0-2} = -4\ \text{RAD}}$$







Question 6 Rubric

Question part	Points	Description
(a)	1.5 pts	High Level Graphical Analysis: Correct answer with correct work shown.
(a)	1.0 pt	Mid Level Graphical Analysis: Correct magnitude with correct work shown. OR Incorrect answer with correct work shown.
(a)	0.5 pt	Low Level Graphical Analysis: Correct answer with no work shown. OR Incorrect answer with incorrect work shown.
(b)	1.5 pt	High Level Graphical Analysis: Correct answer with correct work shown.
(b)	1.0 pt	Mid Level Graphical Analysis: Correct magnitude with correct work shown. OR Incorrect answer with correct work shown.
(b)	0.5 pt	Low Level Graphical Analysis: Correct answer with no work shown. OR Incorrect answer with incorrect work shown.
(c)	3.0 pt	High Level Graphical Analysis: Correct shape and scale.
(c)	2.0 pt	Mid Level Graphical Analysis: Correct shape but not scale. Or 2 of the three segments correct.
(c)	1.0 pt	Low Level Graphical Analysis: 1 of the three segments correct.
(d)	4.0 pt	High Level Graphical Analysis: Correct shape and scale.
(d)	3.5 pt	Mid-High Level Graphical Analysis: Mostly correct but challenging to determine which is linear/quadratic.
(d)	2.5 pt	Mid Level Graphical Analysis: 2 of the 4 segments correct.
(d)	1.5 pt	Low Level Graphical Analysis: 1 of the 4 segments correct. OR None correct but overall change in angular position is negative.

7. (12 points) An engineer designs a system to increase the rotational speed of a flywheel (large disk). The flywheel has a 70.0 cm radius and a moment of inertia equal to 5.40 kg·m². In one experiment, the flywheel begins (t = 0 s) from rest, and a 80.0 N·m torque is applied to it.

(a) What is the angular acceleration of the flywheel during the time it speeds up.
(b) What is the angular velocity of the flywheel, in rpm (revolutions per minute), at Δt = 10 s?
(c) What is the speed of a point on the outside edge of the flywheel at Δt = 10 s?
(d) How far has a point on the outside edge of the flywheel traveled in the first 10 s?
(e) What is the translational (linear) acceleration vector for a point on the outside edge of the flywheel at Δt = 10 s?

Rubric

Part (a)
- 0.5 pt - Newton's 2nd law for rotation equation
- 1.0 pt - application
- 0.5 pt - correct answer + units

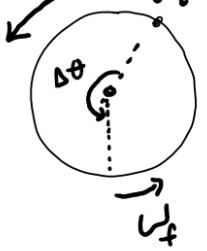
Part (b)
- 1.0 pt - physical representation
- 1.0 pt - knowns and unknowns, problem orientation
- 0.5 pt - kinematic equation (ii)
- 0.5 pt - application
- 0.5 pt - correct answer
- 0.5 pt - correctly converted answer

Part (c)
- 0.5 pt - v = ωr equation
- 0.5 pt - application
- 0.5 pt - correct answer and units

Part (d)
- 0.5 pt - kinematic equation (i) or (iii)
- 0.5 pt - s = Δθr equation
- 1.0 pt - application
- 0.5 pt - correct answer and units

Part (e)
- 0.5 pt - vector quantity
- 0.5 pt - $a_r = v^2/r$ equation
- 0.5 pt - $a_t = \alpha r$ equation
- 0.5 pt - application

$\Sigma\tau, \alpha$ $\quad \omega_i = 0$ $\quad$ (a) $\Sigma\tau = I\alpha \Rightarrow \alpha = \frac{\Sigma\tau}{I} = 14.8\ N\cdot m$



(b)

K	uk
α	ω_f ?
ω_i	Δθ
Δt	

eqs (i) $\Delta\theta = \omega_i \Delta t + \frac{1}{2}\alpha\Delta t^2$
(ii) $\omega_f = \omega_i + \alpha\Delta t$
(iii) $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

(ii) $\omega_f = \cancel{\omega_i^{0}} + \alpha\Delta t$

$\omega_f = \frac{\Sigma\tau}{I}\Delta t = 148.1\ \frac{rad}{s}$

$(148.1\ \frac{rad}{s})(\frac{1\ rev}{2\pi\ rad})(\frac{60\ s}{1\ min}) = 1415\ rpm$

(c) $v_t = \omega r = 103.7\ m/s$

(d) (i) $\Delta\theta = \cancel{\omega_i^{0}}\Delta t + \frac{1}{2}\alpha\Delta t^2$

$\Delta\theta = \frac{1}{2}\left(\frac{\Sigma\tau}{I}\right)\Delta t^2$

$s = \Delta\theta\, r = \frac{r}{2}\left(\frac{\Sigma\tau}{I}\right)\Delta t^2 = 518.5\ m$

(e) $\vec{a} = \langle a_r, a_t, a_z\rangle = \langle \frac{v^2}{r}, \alpha r, 0\rangle = \langle \omega^2 r, \alpha r, 0\rangle$

$\vec{a} = \langle 15{,}451, 10.4, 0\rangle\ m/s^2$