Name:______________________________	ID:______________________________

Physics 202

Midterm Exam 1

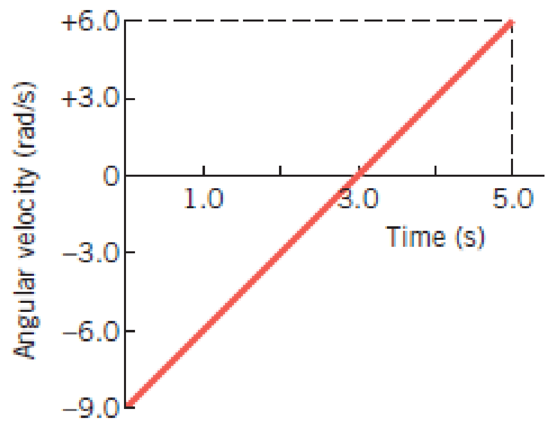
1/24/2018

** Note **
The answer boxes are for the final number or yes/no type answers. You must still explain your reasoning outside of the box

Collaboration is not allowed. Allowed on your desk are: up to 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.

$$I_{Hoop} = mR^2 \quad I_{Disk} = \frac{1}{2}mR^2 \quad I_{Sphere} = \frac{2}{5}mR^2 \quad I_{rod} = \frac{1}{3}mR^2$$

1. (8 points) The figure shows the angular velocity of an object as a function of time. Explain your reasoning and/or show your work for the following questions regarding this situation.



(a) Is the angular acceleration constant as a function of time?

$\alpha = \frac{\Delta \omega}{\Delta t}$ ~ slope, which is constant.

answer (a)

yes

(b) What is the angular acceleration at 3 s?

Slope @ 3s

answer (b)

$3 \frac{rad}{s^2}$

(c) If the object's initial angle is zero radians, what is its final angle after 5 s?

$\Delta\theta$ is equal to area under curve

$A_{0\to3s} = -13.5\ rad$, $A_{3\to5s} = +6$

answer (c)

$\Delta\theta = \theta_f = -7.5\ rad$

(d) What is the object's minimum rotational rate and what time does it occur?

answer (d)

$\omega_{min} = 0 \frac{rad}{s}$ @ $t = 3s$

Rubric
(a), (b), (c), (d)
+ 0.5pt - answer
+1.5pt - Reasoning/work

For questions 2 through 7 circle all correct answers, a given problem may have more than one correct answer. Each correctly circled answer will receive two points. There are **7** correct answers in this section and only the first **7** circled answers will be graded. There is no partial credit.

2. A rock is placed on a disk that is spinning at a constant 12 rpm. The linear acceleration of the rock is

[F] (a) directed perpendicular to the line joining the mass and the center of rotation.
[F] (b) independent of the position of the mass on the turntable.
[T] (c) greater the farther the mass is from the center.
[F] (d) greater the closer the mass is to the center.
[F] (e) zero.

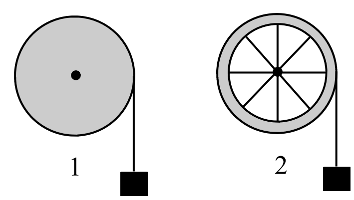
3. A merry-go-round is rotating clock-wise and slowing down. Which of the following statements are true regarding this situation?

[T] (a) The angular velocity of the wheel is negative.
[F] (b) The angular acceleration of the wheel is negative.
[F] (c) The net torque on the wheel is zero.
[F] (d) The wheel is in dynamic equilibrium.
[T] (e) The change in position of the wheel would be a negative angle.

4. A dumbbell-shaped object is composed of two equal masses, ***m***, connected by a rod of negligible mass and length ***r***. If $\mathbf{I_1}$ is the moment of inertia of this object with respect to an axis passing through the center of the rod and perpendicular to it and $\mathbf{I_2}$ is the moment of inertia with respect to an axis parallel to the first axis but passing through one of the masses, it follows that

[F] (a) $\mathbf{I_1} = \mathbf{I_2}$.
[F] (b) $\mathbf{I_1} > \mathbf{I_2}$.
[T] (c) $\mathbf{I_1} < \mathbf{I_2}$.

Questions 5 through 7 refer to the following situation. A solid cylinder and a cylindrical shell have the same mass, same radius, and turn on frictionless, horizontal axles. (The cylindrical shell has lightweight spokes connecting the shell to the axle.) A rope is wrapped around each cylinder and tied to a block of mass ***m***. The blocks have the same mass and are held the same height above the ground as shown below. Both blocks are released simultaneously. Consider the time from right after the block is released to right before it hits the ground. The ropes do not slip. Which of the following statements are true regarding this situation. (There is one correct answer per question)

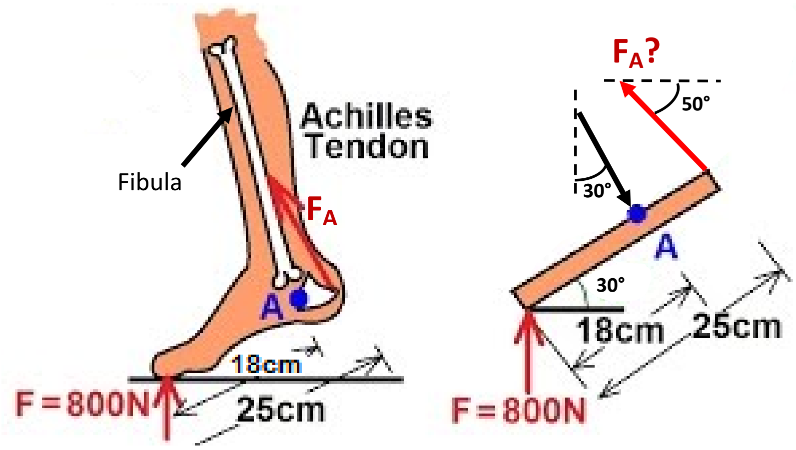


5. [T] (a) The block connected to wheel 1 will reach the ground first.
[F] (b) The block connected to wheel 2 will reach the ground first.
[F] (c) Both blocks reach the ground at the same time.

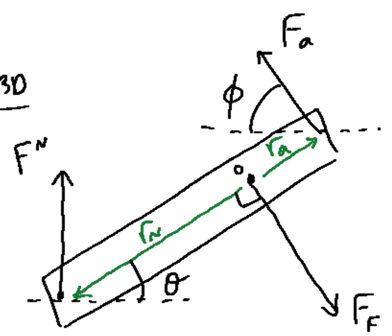
6. [F] (a) The tension in both ropes is equal to mg.
[F] (b) The tension in both ropes is greater than mg.
[T] (c) The tension in both ropes is less than mg.

7. [F] (a) The torque applied by the rope in both cases is equal.
[T] (b) The torque from the rope in case 2 is greater than in case 1.
[F] (c) The torque from the rope in case 1 is greater than in case 2.

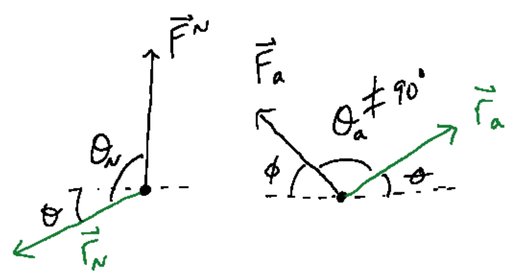
8. (10 points) In order for you to stand in equilibrium on your toes, your Achilles tendon must lift with a large force. The diagram shows the foot with the Fibula bone and the Achilles tendon. The normal force from the ground is 800N. The Fibula pushes on the foot at point A. Determine the magnitude of the force from the Achilles tendon (F_A) during this action.



e-FBD



Vector Ops



Angles

$\theta_N = 90 + \theta$

$\theta_a = 180 - \theta - \phi$

b/c $r_F = 0$

$$\Sigma \tau_o \Rightarrow \tau_a + \tau_F^{\,0} + (-\tau_N) = I\alpha^{\,0}$$

$$|\vec{r}_a||\vec{F}_a|\sin(180-\theta-\phi) - |\vec{r}_N||\vec{F}^N|\sin(90+\theta) = 0$$

$$F_a = \frac{r_N F^N \sin(90+\theta)}{r_a \sin(180-\theta-\phi)} = 1809\,N$$

Rubric

+1 pt – e FBD

+1 pt – Vector ops

+2 pts – finding θ_N + θ_a

+1.5 pt – $\Sigma \tau = I\alpha$ eq.

+2 pts – $\tau = rF\sin\theta$

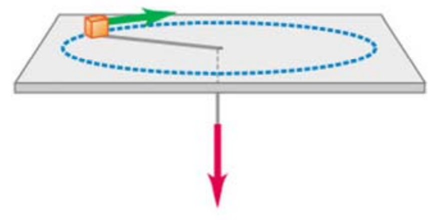
+2 pt – application + algebra

+0.5 pt – answer + units

answer

1809 N

9. (10 points) A small block on a frictionless horizontal table is attached to a light string that is thread through a hole in the center of the table. The 200 g block is originally rotating at a rate of 30 rpm, 40 cm from the hole. The string is then pulled from below and the radius of the circle the block rotates around is decreased by 25%. (a) Is the angular momentum of the block conserved? Why or why not? (b) What is the new angular speed in rpm? (c) Is the rotational kinetic energy of the block conserved? Show your work or explain why or why not.



(a) Yes, w/ $\vec{F}_{string}$ // to the moment arm $\vec{r}_s$, $\Sigma \tau_{ext} = 0$ + w/ $\Sigma \tau_{ext} \Delta t = \Delta L$

$\Delta L = 0$

Point Particle

(b) $L_i = L_f \Rightarrow I_i \omega_i = I_f \omega_f$, $r_f = 0.75\, r_i$

So $m r_i^2 \omega_i = m (0.75\, r_i)^2 \omega_f$

$$\omega_f = \frac{\omega_i}{(0.75)^2} = \frac{16}{9}\omega_i = 53.\bar{3}\ \text{rpm}$$

(c) w/ $\vec{F}_s$ // to $\Delta \vec{r}_{string}$ the work is positive + thus K.E. increases + is Not Conserved

alternatively $\Delta K_{rot} = \frac{1}{2}\left(I_f \omega_f^2 - I_i \omega_i^2\right)$

$$= \frac{1}{2}\left(M r_f^2 \omega_f^2 - M r_i^2 \omega_i^2\right) = 0.123\ \text{J} \neq 0$$

Rubric

(a)

+ 0.5pt – answer
+ 1pt – reasoning

(b)

+ 1.5pt – $L_i = L_f$
+ 1.5pt – $L = I\omega$
+ 1pt – $I = mr^2$
+ 1pt – $r_f = 0.75 r_i$
+ 1pt – Algebra
+ 0.5pt – Answer + units

(c)

+ 0.5pt – Answer
+ 1.5pt – reasoning

answer (a)	answer (b)	answer (c)
Yes	$53.\bar{3}$ rpm	Not Conserved

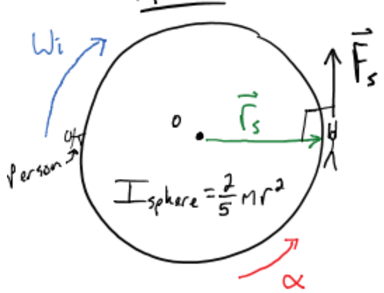
10. (12 points) Superman, foolishly attempting to turn back time, applies a constant force tangent to the Earth at the equator. He mistakenly believes that if he changes the direction the Earth rotates, the clocks will somehow run backwards. He should have taken physics.
M_E=5.97x10^{24} kg, R_E=6.37x10^6 m.

(a) If it takes him 2 mins to stop the rotation of the Earth, how much force did he apply?

(b) If he continues pushing with that same force, the Earth begins rotating in the opposite direction. How long will it take for some people to feel weightless?

(c) Where on the Earth will people first start feeling weightless?

(a) Top View



Kinematics

K	UK	eq's
$\omega_i = -7.272\times10^{-5}\frac{rad}{s}$	$\Delta\theta$	(i) $\Delta\theta = \omega_i\Delta t + \frac{1}{2}\alpha\Delta t^2$
$\Delta t = 120s$	α	(ii) $\omega_f = \omega_i + \alpha\Delta t$
$\omega_f = 0\ \frac{rad}{s}$		(iii) $\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$

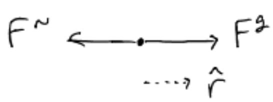
$$\omega_i = -\frac{2\pi}{T} = \frac{-2\pi \text{ rads}}{86{,}400s}$$

from eq (ii) $\quad \alpha = -\frac{\omega_i}{\Delta t} = 6.06\times10^{-7}\frac{rad}{s^2}$

Now Torque $\quad \Sigma\tau_o \Rightarrow |\vec{r}_s||\vec{F}_s|\sin\theta_s = \underbrace{\frac{2}{5}M_E r_E^2}_{I}\alpha$

$$F_s = \frac{2}{5}M_E r_E\alpha = 9.22\times10^{24}N$$

(b) FBD (Person on Earth)



$\Sigma F_r \Rightarrow M_p g - F^N = m_p\frac{v^2}{r}$, Apparent Weightless $F^N \to 0$

So, $\frac{v^2}{r_E} = g$, w/ $v = \omega r$, $\omega_f = \sqrt{\frac{g}{r_E}}$

Starting from Rest $\quad$ eq (ii) $\quad \omega_f = \cancel{\omega_i}^{\,0} + \alpha\Delta t$

$$\Delta t = \frac{1}{\alpha}\sqrt{\frac{g}{r_E}} = 2047s \approx 34min$$

(c) @ Equator where a_r is largest.

Rubric on back

answer (a)	answer (b)	answer (c)
$9.22\times10^{24}N$	2047s	@ Equator

extra space if needed

#10 Rubric

Rubric

+2pts - Physical Rep. (Kin + e-FBD)

(a)

+1pt - converting ω_i to SI

+1pt - K + UK

+1pt - Kin eq. (ii)

+1.5pt - $\Sigma\tau$ eq.

+0.5pt - I_{sphere}

+0.5pt - algebra

+0.5pt - answer w/ units

(b)

+1pt - ΣF

+0.5pt - $F^N \to 0$

+0.5pt - $\omega_f = \sqrt{\frac{g}{r}}$

+0.5pt - eq (ii)

+0.5pt - Answer + units

(c)

+1pt - Answer

Scores:

Problems

1	2-7	8	9	10

Exam Total