Last Name:________________ First Name ________________ ID ________________

Discussion Section:________ Discussion TA Name:__________________________

Instructions—
Please turn off your cell phone and put it away.
Calculators may not be shared. Please keep yours on your own desk.
This is a closed book exam. You have ninety (90) minutes to complete it.

1. Use a #2 pencil. Do not use a mechanical pencil or pen. Darken each circle completely, but stay within the boundary. If you decide to change an answer, erase vigorously; the scanner sometimes registers incompletely erased marks as intended answers; this can adversely affect your grade. Light marks or marks extending outside the circle may be read improperly by the scanner. Be especially careful that your mark covers the center of its circle.

2. Print your **NETWORK ID** in the designated spaces at the right side of the answer sheet, starting in the left most column, then **mark the corresponding circle** below each character. If there is a letter "o" in your NetID, be sure to mark the "o" circle and not the circle for the digit zero. If and only if there is a hyphen "-" in your NetID, mark the hyphen circle at the bottom of the column. When you have finished marking the circles corresponding to your NetID, check particularly that you have not marked two circles in any one of the columns.

3. Print **YOUR LAST NAME** in the designated spaces at the left side of the answer sheet, then mark the corresponding circle below each letter. Do the same for your **FIRST NAME INITIAL**.

4. **You may find the version of this Exam Booklet at the top of the next page.** Mark the version circle in the TEST FORM box at the bottom right on your answer sheet. **DO THIS NOW!**

5. Print your UIN# in the **STUDENT NUMBER** designated spaces and mark the corresponding circles. You need not write in or mark the circles in the SECTION box

6. Sign your name (**DO NOT PRINT**) on the **STUDENT SIGNATURE** line.

7. On the **SECTION** line, print your **DISCUSSION SECTION**. You need not fill in the COURSE or INSTRUCTOR lines.

Before starting work, check to make sure that your test booklet is complete. In addition to these instructions, you should have 8 numbered pages plus one (1) Formula Sheet.

Academic Integrity: **Giving assistance to or receiving assistance from another student or using unauthorized materials during a University Examination can be grounds for disciplinary action, up to and including expulsion.**

This Exam Booklet is Version A. Mark the **A** circle in the TEST FORM box at the bottom right on your answer sheet. **DO THIS NOW!**

Exam Grading Policy—

The exam is worth a total of **102** points, composed of two types of questions.

MC5: *multiple-choice-five-answer questions, each worth 6 points.*
Partial credit will be granted as follows.

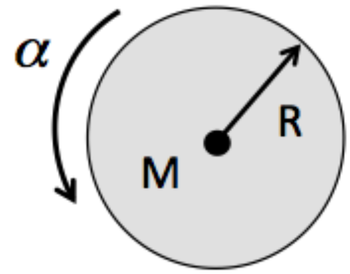
A) If you mark only one answer and it is the correct answer,
you earn **6** points.
B) If you mark two answers, one of which is the correct answer,
you earn **3** points.
C) If you mark three answers, one of which is the correct answer,
you earn **2** points.
D) If you mark no answers, or more than three, you earn 0 points.

MC3: *multiple-choice-three-answer questions, each worth 3 points*.
No partial credit.

A) If you mark only one answer and it is the correct answer,
you earn 3 points.
B) If you mark a wrong answer or no answers, you earn 0 points.

The next three questions pertain to the situation described below.

A wheel is made from a solid cylinder of mass M = 4.1 kg and radius R = 1.6 m. It can rotate without friction around a central axis (out of the page). The wheel is initially at rest and at $t = 0$ a constant torque τ is applied around the axis, causing the wheel to rotate with an angular acceleration α = 3.8 rad/s^2.



1) What is the magnitude of the applied torque?

a. τ = 0.36 N-m
b. τ = 0.72 N-m
c. τ = 19.94 N-m
d. τ = 2.76 N-m
e. τ = 39.88 N-m

2) How many revolutions N has the wheel made after 31 seconds?

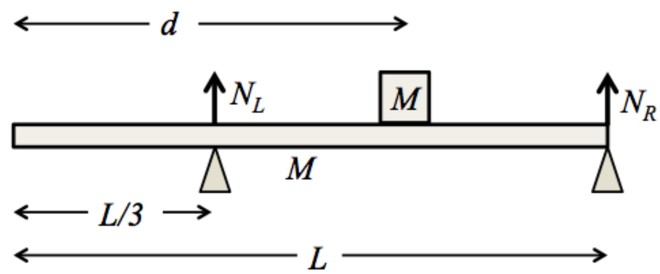
a. $N = 581.2$
b. $N = 1162.4$
c. $N = 1825.9$
d. $N = 3651.8$
e. $N = 290.6$

3) Suppose the answer to the above problem is N. If the same wheel is restarted from rest and the magnitude of the applied torque is halved, how many turns would the wheel make in twice the time?

a. $N/2$
b. $2N$
c. N

The next three questions pertain to the situation described below.

A beam of mass $M = 5.8\ kg$ and length $L = 4.47\ m$ rests on two supports as shown. The support on the left exerts an upward normal force N_L and is located a distance $L/3$ from the left end of the beam. The support on the right exerts an upward normal force N_R and is located at the right end of the beam. A box that has the same mass M as the beam is located a distance d from the left end of the beam.



4) If the box were located at the right side of the beam (i.e. $d = L$), how would N_L compare to N_R ?

a. $N_L = N_R$
b. $N_L > N_R$
c. $N_L < N_R$

5) What is the value of d for which N_R is zero?

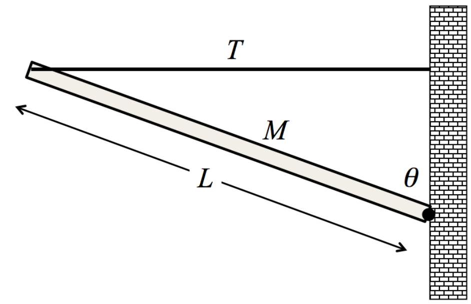
a. $d = 1.12\ m$
b. $d = 0.74\ m$
c. $d = 0.83\ m$
d. $d = 0.89\ m$
e. $d = 0.99\ m$

6) If the box is located halfway between the supports (i.e. $d = 2L/3$), what is the value of N_R?

a. $N_R = 56.9\ N$
b. $N_R = 28.45\ N$
c. $N_R = 18.97\ N$
d. $N_R = 42.67\ N$
e. $N_R = 37.93\ N$

The next four questions pertain to the situation described below.

A beam of mass $M = 3.1$ kg and length $L = 4.1$ m is attached to a vertical wall by a hinge at its lower end and a horizontal massless wire at its top end, as shown in the diagram. The angle between the wall and the beam is $\theta = 67$.



7) What is the tension in the wire ?

a. $T = 6.5$ N
b. $T = 35.8$ N
c. $T = 12.9$ N
d. $T = 11.88$ N
e. $T = 71.6$ N

8) If the attachment point of the wire on the wall were moved upward by half a meter, but M, L and θ were the same as in the above question, how would the tension in the wire change? (Note that a longer wire is required to move the attachment point this way.)

a. It would increase.
b. It would stay the same.
c. It would decrease.

9) Now suppose the wire breaks and the beam starts to rotate around the hinge. What is α_0, the magnitude of the angular acceleration of the beam about the hinge immediately after the wire breaks?

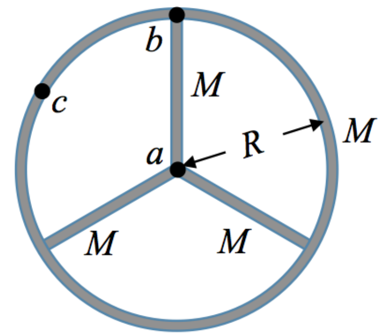
a. $\alpha_0 = 1.47$ rad/s^2
b. $\alpha_0 = 3.3$ rad/s^2
c. $\alpha_0 = 1.2$ rad/s^2
d. $\alpha_0 = 2.2$ rad/s^2
e. $\alpha_0 = 2.39$ rad/s^2

10) If the beam were shorter, but M and θ were the same as above, how would the answer to the above question change ?

a. The magnitude of α_0 would be smaller.
b. The magnitude of α_0 would be the same.
c. The magnitude of α_0 would be bigger.

The next three questions pertain to the situation described below.

A wheel is made by combining a hoop of radius R and mass M with three spokes, each a thin rod of length R and mass M.



11) What is the moment of inertia of the wheel for rotations around an axis through its center and perpendicular to the page, labeled a in the diagram?

a. $I_a = 3MR^2$
b. $I_a = 2MR^2$
c. $I_a = 4MR^2$
d. $I_a = MR^2$
e. $I_a = 6MR^2$

12) Suppose the answer to the above question is I_a. What is the moment of inertia of the wheel for rotations around the axis labeled b in the diagram? (The b axis is perpendicular to the page and passes through the rim of the wheel at the end of one of the spokes).

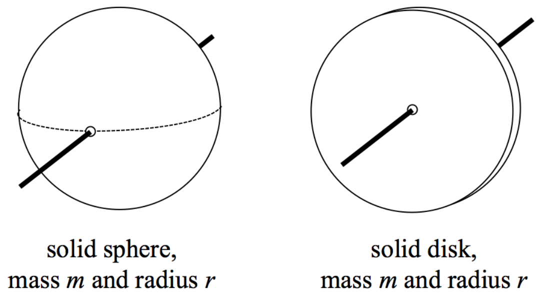
a. $I_b = I_a + MR^2$
b. $I_b = I_a + 3MR^2$
c. $I_b = I_a + 4MR^2$

13) The c axis is perpendicular to the page and passes through the rim of the wheel halfway between two spokes, as shown in the diagram. The moment of inertia for rotations around the c axis is I_c. How does I_c compare to I_b?

a. $I_c > I_b$
b. $I_c = I_b$
c. $I_c < I_b$

The next four questions pertain to the situation described below.

A solid sphere of mass m and radius r is mounted on an axle that passes through the center of the sphere. A solid disk, also of mass m and radius r, is mounted on a second axle which passes through the center of the disk and is perpendicular to the face of the disk.



14) If both objects are spinning around their axles with the same angular velocity ω_0, what is the ratio of their angular momentum L_{sphere}/L_{disk}?

a. $L_{sphere}/L_{disk} = 2/5$
b. $L_{sphere}/L_{disk} = 3/5$
c. $L_{sphere}/L_{disk} = 3/4$
d. $L_{sphere}/L_{disk} = 4/5$
e. $L_{sphere}/L_{disk} = 5/3$

15) How does the ratio of the kinetic energy of the objects compare to the ratio of the angular momentum of the objects ?

a. $K_{sphere}/K_{disk} = L_{sphere}/L_{disk}$
b. $K_{sphere}/K_{disk} < L_{sphere}/L_{disk}$
c. $K_{sphere}/K_{disk} > L_{sphere}/L_{disk}$

16) Now suppose the solid sphere is released so that it rolls without slipping along a horizontal floor. What is the ratio of its translational kinetic energy to its total kinetic energy?

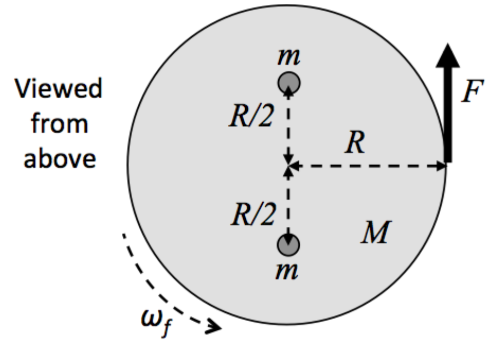
a. $K_{trans}/K_{total} = 3/5$
b. $K_{trans}/K_{total} = 1/5$
c. $K_{trans}/K_{total} = 3/4$
d. $K_{trans}/K_{total} = 2/5$
e. $K_{trans}/K_{total} = 5/7$

17) Now suppose that both objects roll without slipping along a horizontal floor. If they move with the same speed, which one has the bigger total kinetic energy?

a. The solid sphere has the bigger total kinetic energy.
b. The disk has the bigger total kinetic energy.
c. The disk and the solid sphere have the same total kinetic energy.

The next three questions pertain to the situation described below.

A playground ride consists of a uniform disk of mass $M = 41$ kg and radius $R = 1.6$ m that can rotate in the horizontal plane around a frictionless axle through its center. Two children, each having mass m, are sitting on opposite sides of the disk, halfway between the center and the edge. The combined moment of inertia of the ride and the children in this configuration is $I_{initial} = 92.16$ kg-m^2. Treat the children as point masses.



18) What is the mass of each child?

a. $m = 72$ kg
b. $m = 15.5$ kg
c. $m = 7.75$ kg
d. $m = 62$ kg
e. $m = 31$ kg

19) Once the disk reaches its final angular velocity the parent stops pushing and steps away from the ride. One child now crawls to the center of the disk, and the other child crawls out to the edge of the disk. The final combined moment of inertia of the disk and the children in this new configuration is I_{final}. How does I_{final} compare to $I_{initial}$?

a. $I_{final} < I_{initial}$
b. $I_{final} > I_{initial}$
c. $I_{final} = I_{initial}$

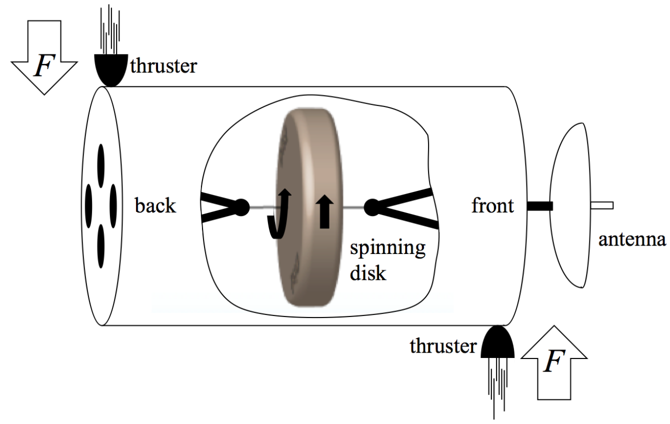
20) As the children crawl to their new positions on the disk, which of the following statements best describes the system composed of the disk and the children ?

a. Both the kinetic energy and the angular momentum of the system are conserved.
b. The kinetic energy of the system is conserved but the angular momentum is not.
c. The angular momentum of the system is conserved but the kinetic energy is not.

The next three questions pertain to the situation described below.

A space probe is motionless in interstellar space. It contains a massive disk rotating rapidly around the central axis of the probe. The direction of rotation of the disk, as indicated by the black arrows in the diagram, is counter-clockwise as viewed from the back of the probe.

At time t = 0 a pair of small identical thrusters begin firing, pushing down on the back side of the probe and up on the front side of the probe. The forces provided by the two thrusters are always equal in magnitude and opposite in direction.



21) While the thrusters are firing, at the instant shown in the diagram, which of the following statements is true?

a. The net force on the space probe *is not zero*, and the net torque on the space probe about an axis perpendicular to the page through the center of the disk *is also not zero*.
b. The net force on the space probe *is zero*, but the net torque on the space probe about an axis perpendicular to the page through the center of the disk *is not zero*.
c. The net force on the space probe *is not zero*, but the net torque on the space probe about an axis perpendicular to the page through the center of the disk *is zero*.

22) After the thrusters have been firing for several minutes, the probe has rotated by approximately 90 degrees. As a result, the antenna at the front of the probe (which was initially pointing towards the right side of the page) is now pointing

a. into the page.
b. towards the top of the page.
c. towards the bottom of the page.
d. out of the page.
e. towards the left side of the page.

23) If the angular velocity of the disk had been increased by a factor of 4 before the thrusters began firing, the time required to achieve a 90 degree rotation would have

a. increased by a factor of 16.
b. increased by a factor of 4.
c. increased by a factor of 2.

Phys 211 Formula Sheet

Kinematics
$\mathbf{v} = \mathbf{v}_0 + \mathbf{a}t$

$\mathbf{r} = \mathbf{r}_0 + \mathbf{v}_0 t + at^2/2$

$v^2 = v_0^2 + 2a(x-x_0)$

$g = 9.81\ m/s^2 = 32.2\ ft/s^2$

$\mathbf{v}_{A,B} = \mathbf{v}_{A,C} + \mathbf{v}_{C,B}$

Uniform Circular Motion
$a = v^2/r = \omega^2 r$

$v = \omega r$

$\omega = 2\pi/T = 2\pi f$

Dynamics
$\mathbf{F}_{net} = m\mathbf{a} = d\mathbf{p}/dt$

$\mathbf{F}_{A,B} = -\mathbf{F}_{B,A}$

$F = mg$ (near earth's surface)

$F_{12} = -Gm_1m_2/r^2$ (in general)

(where $G = 6.67\times10^{-11}\ Nm^2/kg^2$)

$\mathbf{F}_{spring} = -k\,\mathbf{\Delta x}$

Friction
$f = \mu_k N$ (kinetic)

$f \leq \mu_S N$ (static)

Work & Kinetic energy
$W = \int \mathbf{F}\cdot\mathbf{dl}$

$W = \mathbf{F}\cdot\mathbf{\Delta r} = F\,\Delta r\,\cos\theta$

(constant force)

$W_{grav} = -mg\Delta y$

$W_{spring} = -k(x_2^2 - x_1^2)/2$

$K = mv^2/2 = p^2/2m$

$W_{NET} = \Delta K$

Potential Energy
$U_{grav} = mgy$ (near earth surface)

$U_{grav} = -GMm/r$ (in general)

$U_{spring} = kx^2/2$

$\Delta E = \Delta K + \Delta U = W_{nc}$

Power
$P = dW/dt$

$P = \mathbf{F}\cdot\mathbf{v}$ (for constant force)

System of Particles
$\mathbf{R}_{CM} = \Sigma m_i \mathbf{r}_i / \Sigma m_i$

$\mathbf{V}_{CM} = \Sigma m_i \mathbf{v}_i / \Sigma m_i$

$\mathbf{A}_{CM} = \Sigma m_i \mathbf{a}_i / \Sigma m_i$

$\mathbf{P} = \Sigma m_i \mathbf{v}_i$

$\Sigma\mathbf{F}_{EXT} = M\mathbf{A}_{CM} = d\mathbf{P}/dt$

Impulse
$\mathbf{I} = \int \mathbf{F}\,dt$

$\Delta\mathbf{P} = \mathbf{F}_{av}\Delta t$

Collisions:
If $\Sigma\mathbf{F}_{EXT} = 0$ in some direction, then $\mathbf{P}_{before} = \mathbf{P}_{after}$ in this direction:

$\Sigma m_i\mathbf{v}_i$ (before) $= \Sigma m_i\mathbf{v}_i$ (after)

In addition, if the collision is elastic:

* $E_{before} = E_{after}$

* *Rate of approach = Rate of recession*

* *The speed of an object in the Center-of-Mass reference frame is unchanged by an elastic collision.*

Rotational kinematics
$s = R\theta$, $v = R\omega$, $a = R\alpha$

$$\left.\begin{aligned}\theta &= \theta_0 + \omega_0 t + {}^1\!/_2\alpha t^2\\ \omega &= \omega_0 + \alpha t\\ \omega^2 &= \omega_0^2 + 2\alpha\Delta\theta\end{aligned}\right\}$$

Rotational Dynamics
$I = \Sigma m_i r_i^2$

$I_{parallel} = I_{CM} + MD^2$

$I_{disk} = I_{cylinder} = {}^1\!/_2 MR^2$

$I_{hoop} = MR^2$

$I_{solid\text{-}sphere} = {}^2\!/_5 MR^2$

$I_{spherical\ shell} = {}^2\!/_3 MR^2$

$I_{rod\text{-}cm} = {}^1\!/_{12} ML^2$

$I_{rod\text{-}end} = {}^1\!/_3 ML^2$

$\tau = I\alpha$ (rotation about a fixed axis)

$\boldsymbol{\tau} = \mathbf{r}\times\mathbf{F}$, $|\tau| = rF\sin\phi$

Work & Energy
$K_{rotation} = {}^1\!/_2 I\omega^2$,

$K_{translation} = {}^1\!/_2 MV_{cm}^2$

$K_{total} = K_{rotation} + K_{translation}$

$W = \tau\theta$

Statics
$\Sigma\mathbf{F} = 0$, $\Sigma\tau = 0$ (about any axis)

Angular Momentum:
$\mathbf{L} = \mathbf{r}\times\mathbf{p}$

$L_z = I\omega_z$

$\mathbf{L}_{tot} = \mathbf{L}_{CM} + \mathbf{L}^*$

$\boldsymbol{\tau}_{ext} = d\mathbf{L}/dt$

$\boldsymbol{\tau}_{cm} = d\mathbf{L}^*/dt$

$\Omega_{precession} = \tau / L$

Simple Harmonic Motion:
$d^2x/dt^2 = -\omega^2 x$

(differential equation for SHM)

$x(t) = A\cos(\omega t + \phi)$

$v(t) = -\omega A\sin(\omega t + \phi)$

$a(t) = -\omega^2 A\cos(\omega t + \phi)$

$\omega^2 = k/m$ (mass on spring)

$\omega^2 = g/L$ (simple pendulum)

$\omega^2 = mgR_{CM}/I$ (physical pendulum)

$\omega^2 = \kappa/I$ (torsion pendulum)

General harmonic transverse waves:
$y(x,t) = A\cos(kx - \omega t)$

$k = 2\pi/\lambda$, $\omega = 2\pi f = 2\pi/T$

$v = \lambda f = \omega/k$

Waves on a string:
$$v^2 = \frac{F}{\mu} = \frac{(\text{tension})}{(\text{mass per unit length})}$$

$$\bar{P} = \frac{1}{2}\mu v\omega^2 A^2$$

$$\frac{d\bar{E}}{dx} = \frac{1}{2}\mu\omega^2 A^2$$

$$\frac{d^2y}{dx^2} = \frac{1}{v^2}\frac{d^2y}{dt^2} \quad \text{Wave Equation}$$

Fluids:
$$\rho = \frac{m}{V} \qquad p = \frac{F}{A}$$

$$A_1 v_1 = A_2 v_2$$

$$p_1 + \tfrac{1}{2}\rho v_1^2 + \rho g y_1 = p_2 + \tfrac{1}{2}\rho v_2^2 + \rho g y_2$$

$$F_B = \rho_{liquid} g V_{liquid}$$

$$F_2 = F_1\frac{A_2}{A_1}$$