General Physics I **Exam 3 - Chs. 7,8,9 - Momentum, Rotation, Equilibrium** **Oct. 31, 2012**

Name Rec. Instr. Rec. Time

For full credit, make your work clear to the grader. Show formulas used, essential steps, and results with correct units and significant figures. Partial credit is available if your work is clear. Points shown in parenthesis. For TF and MC, choose the *best* answer.

1. (2) **T F** A basketball in free fall has its momentum conserved.

2. (2) **T F** In a collision between two objects, if the contact time can be made smaller, then the force acting between the objects will also be smaller.

3. (2) **T F** When a moving object is stopped over a longer distance, the stopping force required is less.

4. (2) **T F** The total kinetic energy is conserved in an elastic collison of two objects.

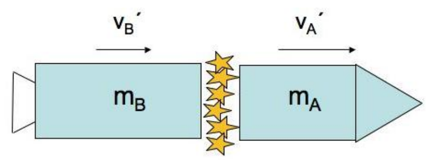
5. (3) A car traveling due north brakes to a stop. In what direction was the momentum change of the car?

a. north b. south c. east d. west.

6. (3) A car traveling at a constant speed on a curve changes the direction of its velocity from east to north. In what direction was the average net force on the car?

a. northeast b. southeast c. southwest d. northwest.

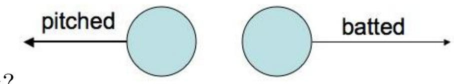
7. (14) A two-stage rocket (mass $M = 7.20 \times 10^3$ kg) initially travels at 4.00 km/s relative to Earth. Then explosive charges separate the capsule ($m_A = 1.20 \times 10^3$ kg) from the booster ($m_B = 6.00 \times 10^3$ kg). After separating, both stages still travel along the original direction of motion, but the booster's speed is now $v'_B = 3.00$ km/s.



a) (8) Find the speed v'_A of the capsule just after the stages separate.

b) (6) How much energy was released by the explosive charges?

8. (14) A 190-gram softball pitched at 22 m/s (horizontally) is batted on a horizontal line drive back to the pitcher at 34 m/s.



a) (8) How large is the magnitude of the impulse imparted to the ball by the bat?

b) (6) The bat contacts the ball during a time of 5.6 ms. What magnitude average force did the ball experience?

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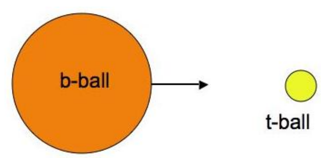
9. (14) A 0.62-kg basketball travelling at 25 m/s makes a head-on elastic collision with a 0.062 kg tennis ball initially at rest. (Ignore gravity, friction, and any other external forces).



a) (2) After the collision, the tennis ball moves *faster* than the basketball by

a. 2.5 m/s. b. 25 m/s. c. 50 m/s. d. 250 m/s.

b) (8) Calculate the speed of the basketball immediately after the collision.

c) (4) Calculate the speed of the tennis ball immediately after the collision.

10. (2) **T F** A force produces the most torque around an axis when acting prependicular to a radius.

11. (2) **T F** An object with small rotational inertia is easier to spin than one with large rotational inertia.

12. (2) **T F** The angular speed of a point on a wheel depends on its distance from the axis of rotation.

13. (2) **T F** The acceleration vector of a point on a spinning wheel always points towards the center of the wheel.

14. (2) **T F** For one rotation of a wheel not skidding, a car travels a distance equal to one wheel circumference.

15. (2) **T F** If the net force on a mass is zero, the object is in static equilibrium.

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16. (24) A solid steel sphere of radius 6.00 cm and mass 7.07 kg is mounted on an axle through its center.

a) (6) How large is the rotational inertia of this sphere, in kg·m^2?

b) (6) Starting from rest, what torque (in N·m) applied to the sphere will cause it to reach an angular speed of 250 rad/s in 10.0 seconds? [Hint: Apply Newton's 2nd law, for rotation.]

c) (6) What force F applied tangentially on the edge of the sphere will produce this acceleration?

d) (6) Once the sphere is spinning at 250 rad/s, how much kinetic energy of rotation does it have?

17. (12) When turned on, a fan requires 5.0 seconds to get up to its final operating rotational speed of 1200 rpm.

a) (6) How large is the final operating angular speed, in rad/s?

b) (6) What was the angular acceleration of the fan, in rad/s^2?

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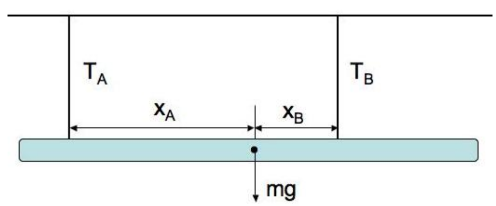
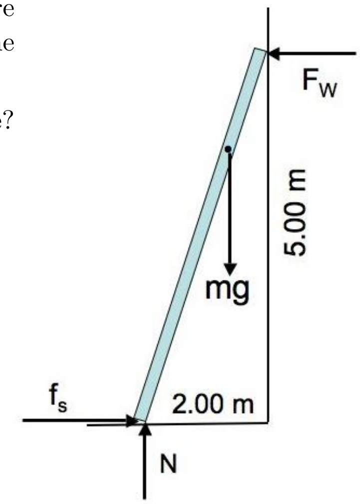
18. (14) A uniform rod 1.00 m long weighs 250.0 newtons and is hanging from two cords, one connected $x_A = 40.0$ cm from the center, and the other connected $x_B = 20.0$ cm from the center. The center of mass of the rod is at its geometric center.



a) (8) Find the tension T_A in the cord connected near the left end.

b) (6) Find the tension T_B in the cord connected near the right end.

19. (14) A ladder of weight mg is set against the wall as shown and does not slip. There is friction between the ladder and the floor, but no friction between the ladder and the wall. The center of mass of the ladder is 3/5 of the way up the ladder.



a) (8) What horizontal force F_W due to the wall is needed to hold the ladder stable? Give the answer in terms of mg.

b) (6) What friction force f_s is needed to hold the ladder stable? Give the answer in terms of mg.

Score = ____________/132.

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$g = 9.80$ m/s^2 (gravitational acceleration)
$M_E = 5.98 \times 10^{24}$ kg (mass of Earth)
$m_e = 9.11 \times 10^{-31}$ kg (electron mass)
$c = 299792458$ m/s (speed of light)
$G = 6.67 \times 10^{-11}$ N·m^2/kg^2 (Gravitational constant)
$R_E = 6380$ km (mean radius of Earth)
$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

Units and Conversions

1 inch = 1 in = 2.54 cm (exactly)
1 mile = 5280 ft
1 m/s = 3.6 km/hour
1 acre = 43560 ft^2 = (1 mile)^2/640
1 foot = 1 ft = 12 in = 30.48 cm (exactly)
1 mile = 1609.344 m = 1.609344 km
1 ft/s = 0.6818 mile/hour
1 hectare = 10^4 m^2

Trig summary

$\sin\theta = \frac{\text{(opp)}}{\text{(hyp)}}$, $\cos\theta = \frac{\text{(adj)}}{\text{(hyp)}}$, $\tan\theta = \frac{\text{(opp)}}{\text{(adj)}}$, $\text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2$.
$\sin\theta = \sin(180^\circ - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180^\circ + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

Acceleration Equations

$\bar{v} = \frac{\Delta x}{\Delta t}$, $\Delta x = x - x_0$, slope of $x(t)$ curve = $v(t)$.
$\bar{a} = \frac{\Delta v}{\Delta t}$, $\Delta v = v - v_0$, slope of $v(t)$ curve = $a(t)$.

For constant acceleration in one-dimension:
$\bar{v} = \frac{1}{2}(v_0 + v)$, $v = v_0 + at$, $x = x_0 + v_0 t + \frac{1}{2}at^2$, $v^2 = v_0^2 + 2a(x - x_0)$.

Vectors

Written $\vec{V}$ or $\mathbf{V}$, described by magnitude=V, direction=θ or by components (V_x, V_y).
$V_x = V\cos\theta$, $V_y = V\sin\theta$,
$V = \sqrt{V_x^2 + V_y^2}$, $\tan\theta = \frac{V_y}{V_x}$. θ is the angle from $\vec{V}$ to x-axis.
Addition: $\mathbf{A} + \mathbf{B}$, head to tail. Subtraction: $\mathbf{A} - \mathbf{B}$ is $\mathbf{A} + (-\mathbf{B})$, $-\mathbf{B}$ is $\mathbf{B}$ reversed.

Chapter 4 Equations

Newton's Second Law:
$\vec{F}_{\text{net}} = m\vec{a}$, means $\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$. $\vec{F}_{\text{net}} = \sum \vec{F}_i$, sum over all forces on a mass.

Friction (magnitude):
$f_s \le \mu_s N$ or $F_{\text{fr}} \le \mu_s F_N$ (static friction). $f_k = \mu_k N$ or $F_{\text{fr}} = \mu_k F_N$. (kinetic or sliding friction)

Gravitational force near Earth:
$F_G = mg$, downward.

Chapter 5 Equations

Centripetal Acceleration:
$a_R = \frac{v^2}{r}$, towards the center of the circle.

Circular motion:
speed $v = \frac{2\pi r}{T} = 2\pi r f$, frequency $f = \frac{1}{T}$, where T is the period of one revolution.

Gravitation:
$F = G\frac{m_1 m_2}{r^2}$; $g = \frac{GM}{r^2}$, where $G = 6.67 \times 10^{-11}$ Nm^2/kg^2;

Orbits:
$\frac{v^2}{r} = g = \frac{GM}{r^2}$; $v = \sqrt{\frac{GM}{r}}$. centripetal acceleration = free fall acceleration.

Chapter 6 Equations

Work & Kinetic & Potential Energies:

$W = Fd\cos\theta$, $\quad$ $\mathrm{KE} = \frac{1}{2}mv^2$, $\quad$ $\mathrm{PE}_{\text{gravity}} = mgy$, $\quad$ $\mathrm{PE}_{\text{spring}} = \frac{1}{2}kx^2$. $\quad$ θ = angle btwn $\vec{F}$ and $\vec{d}$.

Conservation or Transformation of Energy:

Work-KE theorem:

$\Delta\mathrm{KE} = W_{\text{net}}$ = work of all forces.

General energy-conservation law:

$\Delta\mathrm{KE} + \Delta\mathrm{PE} = W_{\mathrm{NC}}$ = work of non-conservative forces.

Power:

$P_{\text{ave}} = \frac{W}{t}$, $\quad$ or use $P_{\text{ave}} = \frac{\text{energy}}{\text{time}}$.

Chapter 7 Equations

Momentum & Impulse:

momentum $\vec{p} = m\vec{v}$, $\quad$ impulse $\Delta\vec{p} = \vec{F}_{\text{ave}}\,\Delta t$.

Conservation of Momentum:

(2-body collision): $\quad m_A\vec{v}_A + m_B\vec{v}_B = m_A\vec{v}_A^{\,'} + m_B\vec{v}_B^{\,'}$.

1D elastic collision–conservation of energy:

$\frac{1}{2}m_Av_A^2 + \frac{1}{2}m_Bv_B^2 = \frac{1}{2}m_Av_A^{'2} + \frac{1}{2}m_Bv_B^{'2}$, $\quad$ or $\quad$ $v_A - v_B = -(v_A' - v_B')$.

Center of Mass:

$x_{\text{cm}} = \frac{m_1x_1 + m_2x_2 + \ldots}{m_1 + m_2 + \ldots}$, $\quad$ $v_{\text{cm}} = \frac{m_1v_1 + m_2v_2 + \ldots}{m_1 + m_2 + \ldots}$.

Chapter 8 Equations

Rotational coordinates:

1 rev $= 2\pi$ radians $= 360°$, $\quad$ $\omega = 2\pi f$, $\quad$ $f = \frac{1}{T}$, $\quad$ $\bar{\omega} = \frac{\Delta\theta}{\Delta t}$, $\quad$ $\bar{\alpha} = \frac{\Delta\omega}{\Delta t}$, $\quad$ $\Delta\theta = \bar{\omega}\Delta t$.

Linear coordinates vs. rotation coordinates and radius:

$l = \theta r$, $\quad$ $v = \omega r$, $\quad$ $a_{\tan} = \alpha r$, $\quad$ $a_R = \omega^2 r$, $\quad$ (must use radians in these).

Constant angular acceleration:

$\omega = \omega_0 + \alpha t$, $\quad$ $\theta = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$, $\quad$ $\bar{\omega} = \frac{1}{2}(\omega_0 + \omega)$, $\quad$ $\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$.

Torque & Dynamics:

$\tau = rF\sin\theta$, $\quad$ $I = \Sigma mr^2$, $\quad$ $\tau_{\text{net}} = I\alpha$, $\quad$ $L = I\omega$, $\quad$ $\Delta L = \tau_{\text{net}}\Delta t$, $\quad$ $\mathrm{KE}_{\text{rotation}} = \frac{1}{2}I\omega^2$.

Rotational Inertias about centers:

$I = MR^2$,	$I = \frac{1}{2}MR^2$,	$I = \frac{2}{5}MR^2$,	$I = \frac{1}{12}ML^2$.
hoop	solid cylinder	sphere	thin rod

Chapter 9 Equations

Static Equilibrium:

$\Sigma F_x = \Sigma F_y = \Sigma F_z = 0$, $\quad$ $\Sigma\tau = 0$, $\quad$ $\tau = rFsin\theta$.