Show ALL work. All work must be done on these test sheets. There is no way for you to receive credit for work that is not explicitly written down. I also recommend showing work for the multiple choice questions as partial credit may be possible on a few of them.

Credit for problems will be awarded based upon "our standard problem solving approach" which emphasizes starting from fundamentals and following standard problem solving procedures. Problem solving style is important here. You do not receive credit for any pictures I have supplied – draw your own.

Moments of Inertia of Rolling Objects about their center-of-mass and symmetry axis:
$I_{solid\ ball} = 2/5\ MR^2$ $\quad I_{disk} = 1/2\ MR^2$ $\quad I_{hoop} = MR^2$

Moments of Inertia of Objects spun about an edge:
$I_{rod\ about\ an\ end} = 1/3\ ML^2$ $\quad I_{rectangle\ about\ an\ axis\ along\ edge} = 1/3\ ML^2$

100 mph = 44.7 m/s, 1 inch = 2.54 cm, sin 30° = 0.5, sin 45° = 0.707, sin 60° = 0.866
G=6.67e-11 Nm^2/kg^2, M_{Earth}=5.96e+24 kg, M_{moon}=7.35e+22 kg, M_{Sun}=2.0e+30 kg
Radius of Moon=1740 km, Radius of Sun=6.96e+5 km, Radius of Earth=6370 km
1 eV = 1.602e-19 J, 1 hp = 746 W, c=3.00e+8 m/s

True/False

T 1. A force which is always perpendicular to the velocity of a particle does no work on the particle. Work ~ $\int \vec{F}\cdot d\vec{s}$ since $\vec{F} \perp d\vec{s}$, then $\vec{F}\cdot d\vec{s} = 0$

F 2. A kiloWatt-hour is a unit of power. Watt is power, Watt • time = Energy

T 3. Internal forces do not affect the motion of the center-of-mass of the system.

T 4. All parts of a rotating wheel have the same angular velocity.

T 5. All parts of a rotating wheel have the same angular acceleration.

T 6. The moment of inertia of an object depends upon the location of the rotation axis.

F 7. The moment of inertia of a body depends on the angular velocity of the body.

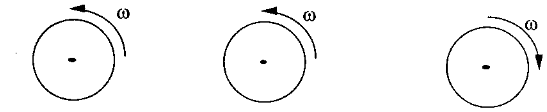
T 8. The momentum of a system can be conserved even if the mechanical energy is not.

F 9. In a perfectly inelastic collision all of the kinetic energy of the particles is lost.
The motion of the center of mass persists

F 10. If the net torque on a body is zero, the angular momentum must be zero.
$\frac{d\vec{L}}{dt} = \Sigma\vec{\tau}$ If $\vec{\tau}=0$, then the angular momentum isn't changing. $\vec{L}$ could have a non-zero value though.

1. The figures below show a disk spinning about an axis through its center. For each of the three situations described, indicate the direction of the angular velocity ω and the angular acceleration α. [Note: in=into-the-paper, out=out-of-the-paper, 0=zero].

Situation 1	Situation 2	Situation 3
disk turning at increasing ω in ccw direction	disk turning at constant ω in ccw direction	disk turning at decreasing ω in cw direction



Situation 1 ω	Situation 1 α	Situation 2 ω	Situation 2 α	Situation 3 ω	Situation 3 α
out ⊙	out ⊙	out ⊙	zero	in ⊗	out ⊙

MC1. The Earth is in an elliptical path about the Sun, getting closer in the winter and further away in the summer. When the Earth moves in closer to the Sun, its angular momentum
A) increases
B) decreases
C) remains constant

There is no Torque, because $\vec{r}$ is anti parallel to $\vec{F}_{grav}$

MC2. Automobile air bags are effective because they:
A) increase the impulse time
B) decrease the impulse
C) decrease the momentum change
D) decrease the time that the impulse acts
E) none of the above

Impulse = $\Delta p = F_{AVE}\,\Delta t$
longer Δt leads to smaller F_{AVE} for a given Δp

MC3. A spinning ice skater draws her arms in closer to her body. As she does the:
A) angular speed decreases
B) angular momentum increases
C) torque on the skater decreases
D) angular momentum is constant.
E) None of the above

All the forces are internal
All the torques are internal
∴ No Net Torque
∴ $\frac{dL}{dt} = 0$

150 rev = 150 (2π) radians
5400 $\frac{rev}{min}$ = 5400 $\frac{2\pi\ rad}{60\ sec}$ = 565 rad/s

MC4. A computer hard drive rotates at 5400 rpm. What angular acceleration will get it up to speed in just 150 revolutions starting from rest?
A) 2.7 rad/s^2
B) 3.3 rad/s^2
C) 150 rad/s^2
D) 170 rad/s^2
E) None of the above

Could use either
$\theta = \frac{1}{2}\alpha t^2$, $\omega = \omega_0 + \alpha t$ OR $\omega_f^2 - \omega_i^2 = 2\alpha\,\Delta\theta$
$(565)^2 - 0^2 = 2\alpha\,(150\cdot 2\pi)$
$\alpha = 169\ rad/s^2$

MC5. A 5 kg block is projected up an inclined plane making an angle of 30° with the horizontal. The initial speed of the block is 5 m/s. If the plane is frictionless, the block will rise along the incline a distance of
A) 1.27 m
B) 2.55 m
C) 3.23 m
D) 4.45 m
E) None of the above

5 m/s h

Tot Init Energy = Tot Final Energy
$\frac{1}{2}\cancel{m}v^2 = \cancel{m}gh$
$\frac{1}{2}5^2 = 9.8\ h$
$h = 1.28\ m$

L h
$h = L\sin\theta$
$1.28 = L\sin 30°$

MC6. A block of mass 5 kg slides down an inclined plane of length 3 m that makes an angle of 30° with the horizontal. The coefficient of friction between the block and the plane is 0.2. The block is released from rest at the top of the incline, and at the bottom has a speed
A) 2.5 m/s
B) 3.3 m/s
C) 5.4 m/s
D) 7.1 m/s
E) None of the above

L v

Tot Init Energy − Lost to friction = Tot Final Energy
$mgh - fL = \frac{1}{2}mv^2$
$\mu N\,L$
$\cancel{m}gh - \mu\cancel{m}g\cos\theta\,L = \frac{1}{2}\cancel{m}v^2$
$(9.8)(1.5) - 0.2\cdot 9.8\cdot\cos 30°\cdot 3 = \frac{1}{2}v^2$
$v = 4.4\ m/s$

3m h
$h = 3\sin 30°$
$= 1.5$

MC7. A ball is dropped from a height h and hits the ground with speed v. To have the ball hit the ground at a speed of 2v it should be dropped from a height
A) h/2
B) h
C) 2h
D) 3h
E) 4h

h v_0 $\frac{1}{2}mv_0^2$

If we want $v \to 2v_0$ Then KE will be 4 times greater. And the initial potential energy would need to be 4 times great

MC8. Blackholes – Schwarzschild Radius. The radius R of an object of mass M whose escape velocity equals the speed of light c is:
A) R = M/c
B) R=GM/c^2
C) R=2GM/c^2
D) R^2 = 2GM/c^2

$KE = \frac{1}{2}mc^2$, $U = -G\frac{mM}{R}$ → KE~0, U~0
Initial Energy = Final Energy
$\frac{1}{2}mc^2 + -G\frac{mM}{R} = 0 + 0$
$c^2 = \frac{2GM}{R}$
$R = \frac{2GM}{c^2}$

MC9. The mass of Mars is 11% that of Earth and its radius is 54% that of Earth. The value of g on the surface of Mars is closest to
A) 3.8 m/s^2
B) 4.6 m/s^2
C) 9.8 m/s^2
D) 33.6 m/s^2

$|\vec{F}_{grav}| = G\frac{mM}{R^2} = m\left(\frac{GM}{R^2}\right) = m$ "g"

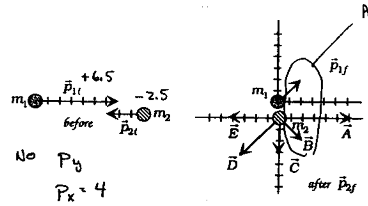
The M is 0.11 the Earth's
The R is 0.54 the Earth's
So the "g" scales like:
$\frac{0.11}{0.54^2}(9.8\ m/s^2) = 3.7$

SP211.1126
3 Nov 2009
JVanhoy

MC10. Shown below are masses m_1 and m_2 with initial momenta p_{1i} and p_{2i} before the collision as well as the final momentum p_{1f} of mass m_1 after the collision. The vector which could best represent the final momentum p_{2f} of m_2 after the collision is

Add these two's y-components (cancel) x-comp will add to 4.

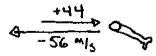
A) A
$\boxed{\text{B) B}}$
~~C) C~~
D) D
E) E



No P_y
$P_x = 4$

MC11. A pitcher throws a 44 m/s fastball. The bat reverses the ball's velocity and it leaves the bat at 56 m/s. What was the average force on the 0.145 kg baseball during the contact time of 15 ms?

A) 0.43 kN
~~B) 0.54 kN~~
$\boxed{\text{C) 0.97 kN}}$
~~D) 1.45 kN~~



$$\text{Impulse} = \Delta p = F_{AVE}\,\Delta t$$
$$p_f - p_i = F_{AVE}\,\Delta t$$
$$mv_f - mv_i =$$
$$0.145(-56) - 0.145(+44) = F_{AVE}(0.015)$$
$$F_{AVE} = 967 \text{ Newtons}$$

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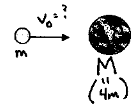
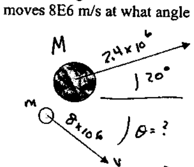
Problem 1. A proton hits a stationary alpha particle causing the alpha particle to recoil at 2.4E6 m/s at 20° with respect to the initial proton velocity. Assuming the mass of the alpha to be 4 times the proton mass, the deflected proton moves 8E6 m/s at what angle with respect to its initial velocity?





$\overrightarrow{\text{Initial Momentum}} = \overrightarrow{\text{Final Momentum}}$

Init P_x = Final P_x

$$mv_0 = MV\cos 20^\circ + mv\cos\theta$$

Init P_y = Final P_y

$$0 = MV\sin 20^\circ \mp mv\sin\theta$$

As it turns out to answer the question, we only need the y-component equation

$$0 = (4m)(2.4\times10^6)\sin 20^\circ - (m)(8\times10^6)\sin\theta$$
$$\theta = 24^\circ$$

we could plug in over here if we wanted to know the initial speed v_0

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Problem 2. A solid sphere of mass m and radius r rolls without slipping along the track shown in Figure P10.79. It starts from rest with the lowest point of the sphere at a height h above the bottom of the loop of radius R, much larger than r. What is the minimum value of h (in terms of R) such that the sphere completes the loop?

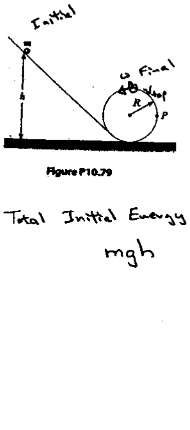


Figure P10.79

$R \gg r$

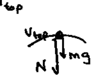
Solid ball
$I = \frac{2}{5}mr^2$

Total Initial Energy = Total Final Energy

$$mgh = mg(2R) + \tfrac{1}{2}mv_{top}^2 + \tfrac{1}{2}I\omega_{top}^2$$

No slipping $v_{top} = r\omega_{top}$

$$= mg\,2R + \tfrac{1}{2}mv_{top}^2 + \tfrac{1}{2}\tfrac{I}{r^2}v_{top}^2$$



$$ma_{rad} = \Sigma F_{rad}$$
$$m\frac{v^2}{R} = \cancel{N} + mg$$

min speed $\Rightarrow$ 0

$$v^2 = gR$$

$$= mg2R + \tfrac{1}{2}mgR + \tfrac{1}{2}\tfrac{2}{5}mgR$$
$$mgh = mg\left[2R + \tfrac{1}{2}R + \tfrac{1}{5}R\right]$$

$$2 + \tfrac{5}{10} + \tfrac{2}{10} = \tfrac{27}{10}$$

$$h = \frac{27}{10}R$$

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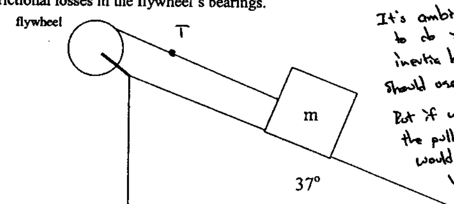
Problem 3. A block with mass m=5 kg slides down a surface inclined 37° to the horizontal. The coefficient of kinetic friction is 0.20. A string attached to the block is wrapped around a flywheel on a fixed axis. The flywheel has a mass M=20 kg, an outer radius R=0.20 m, and a moment of inertia with respect to the axis of 0.300 kg m^2. There are no frictional losses in the flywheel's bearings.

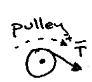


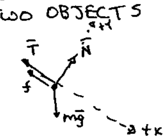
It's ambiguous what to do for moment of inertia here. Should use $I = 0.3\ \text{kg m}^2$. But if were to assume the pulley was a disk, would get a different value.

a) What is the acceleration of the block down the plane?

b) What is the tension in the string?

TWO OBJECTS





$$I\alpha = \Sigma\tau\text{'s}$$
$$I\alpha = RT$$

No slipping $a = R\alpha$

$$\frac{I}{R^2}a = T$$

$$ma_x = \Sigma F_x\text{'s} \qquad ma_y = \Sigma F_y\text{'s}$$
$$ma_x = mg\sin\theta - f - T \qquad m\cancel{a_y} = N - mg\cos\theta$$
$$= mg\sin\theta - \mu N - T \qquad N = mg\cos\theta$$
$$ma_x = mg\sin\theta - \mu mg\cos\theta - T$$

Add equations

$$\left[m + \frac{I}{R^2}\right]a = mg\sin\theta - \mu mg\cos\theta$$

solve for a

Plug back in to get T