A. An object of mass \( m \) drops from rest for a time \( t \). Ignore air resistance. After time \( t \) the magnitude of the momentum is:
\[
|\vec{p}| = m |\vec{v}| \quad \quad \vec{v} = \vec{v}_0 + at = -gt
\]
(a) \( mg \sqrt{t} \)
(b) \( mg t \)
(c) \( mg \sqrt{t} \)
(d) \( \frac{mg}{t} \)
(e) \( mg \sqrt{t}/2 \) \\
\( \Rightarrow |\vec{p}| = mgt. \)

B. In a totally inelastic collision between 2 equal masses, one of which is initially at rest, show that half the initial kinetic energy is lost.
\[
\text{Momentum conserved; KE not conserved.}
\]
\[
\begin{align*}
\text{KE}_0 &= \frac{1}{2} m \vec{v}_0^2 \\
\text{KE}_f &= \frac{1}{2} (m+m)V_f^2 \\
\text{KE}_f &= \frac{1}{2} (2m)(\frac{1}{2}V_f)^2 \\
\text{KE}_f &= \frac{1}{4} m V_f^2 = \frac{1}{2} \text{KE}_0 \\
\end{align*}
\]

C. The diameter of your tires is 0.6 m. You take a 60 km trip at a speed of 45 km/hr.
(a) During the trip, what was your tire's angular speed?
\[
\begin{align*}
\vec{v} &= R \omega \quad \quad R = 0.3 \text{ m}, \quad \vec{v} = \frac{45 \text{ km/hr}}{1 \text{ km/hr}} \times \frac{1000 \text{ m}}{\text{ km}} \times \frac{1 \text{ hr}}{3600 \text{ s}} = 12.5 \text{ m/s} \\
\omega &= \frac{12.5 \text{ m/s}}{0.3 \text{ m}} = 41.667 \text{ rad/s}
\end{align*}
\]
(b) How long was your trip?
\[
\begin{align*}
t &= \frac{d}{\vec{v}} = \frac{60 \text{ km}}{45 \text{ km/hr}} = 1.333 \text{ hrs} = 80 \text{ min} = 4800 \text{ s}
\end{align*}
\]
(c) How many times did the tire revolve?
\[
\begin{align*}
\theta &= \frac{d}{R} = \frac{60000 \text{ m}}{0.3 \text{ m}} = 200000 \text{ rad.} \\
\frac{200000 \text{ rad}}{2\pi \text{ rad/rev}} &= 31831 \text{ revolutions}
\end{align*}
\]

D. A wheel is rolling to the right without slipping. Rank in order, from fastest to slowest, the speeds of the points labeled 1 through 5. Explain.

\[1 \quad 2 \quad 3 \quad 4 \quad 5\]

Since the wheel is rolling, it is moving to the right with speed \( \vec{v} \), but also rotating with angular speed \( \omega = \frac{\vec{r}}{r} \). The speed at any point is \( \vec{v} + \vec{v}_r \).

1 moves the fastest; tangential and translational velocities are in the same direction.
2 is the next fastest. The vectors \( \vec{v} \) and \( \vec{v}_r \) add for 2, 3, and 4, but because \( \omega \) is constant for each point on the wheel, since \( \vec{v}_2 > \vec{v}_3 = \vec{v}_4 \) \( V_{VR2} > V_{VR3} > V_{VR4} = 0 \).
5 is temporarily at rest; the vectors \( \vec{v} \) and \( \vec{v}_r \) oppose and cancel each other.
A solid sphere rolls on a horizontal surface at 10 m/s, and then rolls up an incline at 30° to the horizontal surface. Neglect friction in your calculations.

(a) Sketch a picture of this.

(b) If friction losses are negligible, find the height \( h \) at which the sphere will stop. Its radius is \( r \), mass \( m \), and the numerical coefficient in its moment of inertia is \( 2/5 \).

\[
I = \frac{2}{5} m r^2
\]

\[
\left( \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2 \right)_0 = (mgh)_{\text{final}}
\]

\[
\Rightarrow \quad h = \frac{7}{10} \frac{v^2}{g} = 2.1 \text{ m}
\]

(c) Would a hollow sphere of the same dimensions and mass reach the same height, lower, or higher? Explain why.

**Higher** (5) (If this is not right, then zero points)

because \( \text{I hollow} > \text{I solid} \). The kinetic energy is larger for hollow sphere, hence it will go higher than solid sphere

(d) Give a physical explanation of why the sphere is rolling and not sliding.

1. \( v = 0 \) at bottom point
2. There's a friction force acting on sphere
3. Torque generated by friction force will let sphere rolling

(if you mention one or more points on the right, that is worth 5 points)
A uniform 12 m ladder of mass 45 kg rests against a frictionless wall. It makes an angle of 53° with respect to the ground. A firefighter whose mass is 72 kg climbs the ladder. The coefficient of static friction between the ladder and the ground is $\mu_s = 0.5$.

(a) Draw a free-body diagram of the forces in this problem.

(b) Calculate what forces are exerted on the ladder by the wall and the ground.

(c) How far up the ladder can the firefighter go before the ladder slips?

(d) Justify your choice of point of rotation in this problem.