Useful Conversions

- 1 gallon = 231 cubic inches
- 1 gallon = 4 quarts
- 1 gallon = 128 fluid ounces
- 1 m³ = 1000 L
- 1 acre = 43,560 ft²
- 1 mile = 8 furlongs
- 1 mile = 5280 ft
- 1 fathom = 6 ft
- 1 rod = 16.5 ft
- 1 chain = 22 yards
- 1 inch = 25.4 mm
- 1 watt = 1 N m/sec
- 1 hp = 745.7 watts (approx.)
- 1 hp = 550 ft lb / sec
- 1 lb = 4.45 N (approx.)
- 1 m = 1000 mm
- 1 g = 32.2 ft/sec² = 9.81 m/sec²

Geometry/Trig

- Area of a circle = πr²
- Volume of a cylinder = πr²h
- Law of Sines
  \[
  \frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}
  \]
- Law of Cosines
  \[
  c^2 = a^2 + b^2 - 2ab \cos C
  \]

Uniform Circular Motion

- \( a_n \) – centripetal acceleration
- \( \mathbf{v} \) – speed
- \( \rho \) – radius of curvature
- \( \omega \) – rotational speed
- \( T \) – period
- \( f \) – frequency
- \( \phi \) – angle

\[
\begin{align*}
  a_n &= \frac{\mathbf{v}^2}{\rho} \quad \text{(any curve)} \\
  a_n &= \rho \omega^2 \\
  \mathbf{v} &= \omega \rho \\
  T &= \frac{2\pi}{\omega} \\
  f &= \frac{1}{T} \\
  \Delta s &= \rho \Delta \phi \\
  \omega &= 2\pi f
\end{align*}
\]

Projectile Motion

\[
y - y_0 = (x - x_0) \tan \theta - \frac{g}{2v_0^2} (1 + \tan^2 \theta) (x - x_0)^2
\]

- \( \theta \) – launch angle
- \( v_0 \) – launch velocity
- \( x_0, y_0 \) – launch position, positive up

Relative Motion

\[
\begin{align*}
  \mathbf{v}_{G/A} &= \mathbf{v}_G - \mathbf{v}_A \\
  \mathbf{v}_{A/G} &= \mathbf{v}_A - \mathbf{v}_G \\
  \mathbf{v}_{G/A} &= -\mathbf{v}_{A/G}
\end{align*}
\]

Force and Acceleration

- \( F_{\text{net}} = m\ddot{a} \)

Friction

- \( F_{\text{friction}} = \mu_s N \quad F_{\text{kinetic}} = \mu_k N \)

Work

- \( W = \mathbf{F} \cdot \Delta \mathbf{r} = F A \cos \theta \)

Power

- \( P = \frac{dW}{dt} \)

Spring force

- \( F = k \Delta x \)

Conservation of Energy

\[
mg h_0 + \frac{1}{2} m v_0^2 + \frac{1}{2} k \Delta x_0^2 + W_{\text{m}} = mg h_f + \frac{1}{2} m v_f^2 + \frac{1}{2} k \Delta x_f^2 + E_{\text{loss}}
\]

Rocket Propulsion

\[
\begin{align*}
  v &= u_a \ln \left( \frac{m_0}{m_f} \right) - gt \\
  \text{thrust} &= u_a \frac{dm}{dt}
\end{align*}
\]

Impulse / Momentum / Restitution

\[
\sum m \mathbf{v}' = \sum m \mathbf{v} + \int \sum \mathbf{F} \, dt
\]

- \( m_1 \mathbf{v}_1 + m_2 \mathbf{v}_2 = m_1 \mathbf{v}_1' + m_2 \mathbf{v}_2' \)
- \( e = \frac{\mathbf{v}_1' - \mathbf{v}_2'}{\mathbf{v}_1 - \mathbf{v}_2} \quad \text{(line of impact)} \)
1. (14 pts) Paul and Patrick push on a 200 lb box with a force as shown in the graph and picture. If the box has a speed of 5.0 ft/s at x=0, what is its speed at x=15 ft?

![Graph showing force vs. distance](image)

2. (14 pts) Dr. Parang is still driving around on his scooter trying to find the EF 151 class to give his departmental overview presentation. The scooter has a 15 hp motor and is only 10% efficient. What is his maximum speed if the drag force he experiences is a constant 157 lbs?

![Scooter image](image)
3. (14 pts) Hokie engineer wannabe Rob Wilson has 2 garage door springs left over from a home-improvement project gone awry. He builds a pumpkin shooter as shown to launch a 6 lb pumpkin straight up. How high above the ground does the pumpkin fly?

4. (14 pts) Isaac decides to build a life-size model of the ball-in-tube roller coaster. In his coaster a 100 kg ball starts from rest at the top of Neyland stadium. A pneumatic device provides 15 kJ of energy to get the ball rolling. After several loops and S-curves the ball ends up 42 m lower at the 50 yd line. The total length of the ride is 1400 m. Assume a constant energy loss of 16 J/m. What is the ball’s final speed?
5. (14 pts) Houston decides a braking device is needed to stop the 100 kg ball from Isaac's coaster. He assumes the maximum speed of the ball when it exits the coaster will be 94 km/hr and that the ball needs to be brought to a stop in 5.0 seconds. What average force is required of the device?

6. (14 pts) Abby takes her class to the Down Under to study collisions. They place a 4 lb box at the end of the lane and roll a 9 lb ball into it. The ball sticks in the box and the combination slides to a stop. The energy loss due to friction is 90 ft-lb. What was the original speed of the ball?
7. (16 pts) Following Abby’s example, Dean takes his class to the Down Under to play billiards. Two identical balls collide as shown, where \( v_1 = 8 \text{ m/s} \) and \( v_2 = 5 \text{ m/s} \). The coefficient of restitution is 0.9. What is the velocity of ball 2 after the collision? Give your answer in i,j notation.