Useful Conversions

- 1 gallon = 231 cubic inches
- 1 gallon = 4 quarts
- 1 gallon = 128 fluid ounces
- \( 1 \text{ m}^3 = 1000 \text{ L} \)
- 1 acre = 43,560 ft\(^2\)
- 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/sec\(^2\) = 9.81 m/sec\(^2\)

Geometry/Trig

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

Circular Motion

- \( a \) – centripetal acceleration
- \( a_t \) – tangential acceleration
- \( \rho \) – radius of curvature
- \( \phi \) – angle
- \( \omega \) – angular speed
- \( \alpha \) – angular acceleration
- \( T \) – period
- \( f \) – frequency

\[
\Delta s = \rho \Delta \phi
\]
\[
v = \rho \omega
\]
\[
a_t = \rho \alpha
\]
\[
a_n = \frac{v^2}{\rho} = \rho \omega^2
\]
\[
T = \frac{2\pi}{\omega}
\]
\[
f \equiv \frac{1}{T}
\]
\[
\omega = 2\pi f
\]

Constant Acceleration

- \( v_2 = v_1 + a \Delta t \)
- \( s_2 = s_1 + \left( \frac{v_1 + v_2}{2} \right) \Delta t \)
- \( s_2 = s_1 + v_1 \Delta t + \frac{1}{2} a t^2 \)
- \( s_2 = s_1 + \frac{v_1^2 - v_2^2}{2a} \)

Projectile Motion

- \( y - y_0 = (x-x_0) \tan \theta - \frac{g}{2v_0^2} \left[ 1 + \tan^2 \theta \right] (x-x_0)^2 \)
- \( \theta \) – launch angle
- \( v_0 \) – launch velocity
- \( x_0, y_0 \) – launch position, positive up

Relative Motion

- \( \vec{v}_{/G} = \vec{v}_{/A} + \vec{v}_{/G} \)
- \( \vec{v}_{/A} = \vec{v}_{/G} - \vec{v}_{/A} \)
- \( \vec{v}_{/R} = -\vec{v}_{/R} \)

Force and Acceleration

- \( \vec{F}_{\text{net}} = m\vec{a} \)

Friction

- \( F_{\text{max}} = \mu_s N \) \hspace{1cm} \( F_{\text{kinetic}} = \mu_k N \)

Work

- \( W = \vec{F} \cdot \Delta \vec{r} = F \Delta x \cos \theta \)

Power

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

Spring force

- \( F = k \Delta x \)

Rocket Propulsion

- \( v = u_e \ln \left( \frac{m_0}{m_f} \right) - gt \)
- \( \text{thrust} = u_e (dm/dt) \)

Conservation of Energy

- \( mgh_0 + \frac{1}{2} m v_o^2 + \frac{1}{2} k \Delta x_o^2 + W_m = mgh_f + \frac{1}{2} m v_f^2 + \frac{1}{2} k \Delta x_f^2 + E_{\text{ion}} \)

Impulse / Momentum / Restitution

- \( \sum m v_i' = \sum m v_i + \int \sum \vec{F} \, dt \)
- \( m_1 \vec{v}_1 + m_2 \vec{v}_2 = m_1 \vec{v}_1' + m_2 \vec{v}_2' \)
- \( e = \frac{(\vec{v}_2 - \vec{v}_1')}{{\vec{v}_2' - \vec{v}_1'}} \) (line of impact)
Constant Angular Acceleration
\[ \omega_2 = \omega_1 + \alpha \Delta t \]
\[ \theta_2 = \theta_1 + \left( \frac{\omega_1 + \omega_2}{2} \right) \Delta t \]
\[ \theta_2 = \theta_1 + \omega_1 \Delta t + \frac{\alpha \Delta t^2}{2} \]
\[ \theta_2 = \theta_1 + \frac{\omega_2^2 - \omega_1^2}{2 \alpha} \]

Torque
\[ \tau = Fr \sin \theta \]
\[ \tau = \bar{r} \times \bar{F} \]

Torque and Acceleration
\[ \tau_{net} = I \ddot{\alpha} \]

Center of Mass
\[ \bar{R} = \frac{m_1 \bar{r}_1 + m_2 \bar{r}_2 + \cdots + m_n \bar{r}_n}{m_1 + m_2 + \cdots + m_n} \]

Parallel Axis Theorem
\[ I = I_{cm} + Mh^2 \]

Angular Impulse / Momentum
\[ I_1 \bar{\omega}_1 + I_2 \bar{\omega}_2 = I_1 \bar{\omega}_1' + I_2 \bar{\omega}_2' \]
\[ \sum I \bar{\omega}' = \sum I \bar{\omega} + \int \sum \bar{r} \, dt \]
\[ L = \bar{r} \times \bar{p} \]
\[ L = \text{angular momentum} \]
\[ \bar{p} = \text{linear momentum} \]

Work and Power
\[ W = \bar{r} \cdot \bar{\theta} \]
\[ P = \tau \cdot \omega \]
1. A pileated woodpecker flies 320 feet to the north, 160 ft to the east, and 410 ft at 25° south of east. How far and in what direction does the pileated woodpecker need to fly to get back home?

2. Dr. Bennett is riding the 11A to work. The bus uniformly accelerates to a velocity of 30 ft/sec in 15 seconds. The bus then travels at a constant velocity for 70 seconds. Finally, the bus slows down at a rate of 3 ft/s² before coming to a stop. What is the distance the bus traveled?
3. An acre-ft of water is the volume of water that would cover one acre to a depth of 1.00 ft. How many 5 gallon buckets of water would it take to make 0.6 acre-ft?

4. A tennis ball is thrown with a speed of 15 m/s at a hole in a wall that is 4 m above the level at which the ball is thrown. To make it through the hole, the ball’s velocity must be horizontal when it goes through the wall. Determine the angle from the horizontal at which the ball must be thrown to go through the hole.
5. Bruce Pearl pulls on a box of portfolios with a force of 80N at an angle of 20° from the horizontal. What is the acceleration of the box? (FBD=KD required)

6. A 480 lb motorcycle is pulling a 250 lb trailer up a 2° incline. The motorcycle and trailer are accelerating at 3 ft/s². What is the force in the coupling between the motorcycle and trailer (FBD=KD required)?
7. An airplane is flying at an angle of 15° West of North with a speed of 370 mph. Both angle and speed are with respect to the air. A person on the ground notes that the plane appears to be moving due North with a speed of 330 mph. Determine the velocity (magnitude and direction) of the wind.

8. A bicyclist (combined mass of ride and bike of 110 kg) crests the top of a 25 m high hill with a speed of 8 m/s. The cyclist loses 8000 J of energy on the way down the hill, but inputs 3000 J of energy by pedaling on the way down the hill. Determine the speed of the cyclist at the bottom of the hill.

9. A 12 kg box of portfolios is sliding across the floor. The box is moving with a speed of 5 m/s when it contacts an initially uncompressed spring with stiffness of 300 N/m. There is a friction force of 40 N between the box and floor. How far does the spring compress before the box comes to rest.
10. A 3 lb air puck moving at 8 ft/s collides head on with a 5 lb air puck that is initially at rest. After the collision, the 3 lb air puck is at rest. Determine the coefficient of restitution between the two air pucks.

11. Determine the y-coordinate of the center of mass of object shown, which is made of a piece of steel of uniform thickness and density.
12. A 0.6 kg, 5 cm radius drinking glass starts from rest and is rolled 3 m down an incline. The speed of the drinking glass at the bottom of the incline is 2.1 m/s. Determine the mass moment of inertia of the glass.

13. A disk (I = 6.5 kg·m²) rotates freely about its center. Two constant forces are applied as shown. What is the angular acceleration of the disk? Use CCW as the positive direction.
Concept Questions – 1 point each – circle the correct answer.

C1. The picture depicts a person pushing a box with a force of 20 N. The box is not moving. What is the magnitude of the friction force between the box and the floor?
   A. Need the mass of the box and the coefficient of static friction in order to calculate the force.
   B. Need the mass of the box and the coefficient of kinetic friction in order to calculate the force.
   C. 20 N
   D. 2.038 N

C2. In the following picture, as $\alpha$ increases, the normal force acting on block $m_1$:
   A. Increases
   B. Decreases
   C. Does not change
   D. Not enough information

C3. A 20 kg monkey has a firm hold on a light rope that passes over a frictionless pulley and is attached to a 20 kg bunch of bananas. The monkey starts to climb the rope to get to the bananas. As the monkey climbs:
   A. The bananas move up
   B. The bananas move down
   C. The bananas remain at rest

C4. Can the gravitational potential energy be a negative number?
   A. No, energy is a scalar, hence it’s always positive.
   B. Yes, energy is a vector, and vectors can be negative.
   C. Yes, the gravitational potential energy changes according to the datum and thus can be negative.

C5. The two plots on the right depict a force as a function of time. The area under both of the curves is the same. Which force delivers a larger impulse?
   A. Both forces deliver the same impulse
   B. Force A delivers a larger impulse
   C. Force B delivers a larger impulse
C6. In a completely inelastic collision,
   A. The energy is conserved but the momentum is not.
   B. The momentum is conserved but the energy is not.
   C. Both energy and momentum are conserved.
   D. Both energy and momentum are not conserved.

C7. The picture depicts a sky diver and the forces acting on him. When reaching terminal speed:
   A. $F_{\text{Weight}} > F_{\text{Drag}}$
   B. $F_{\text{Weight}} = F_{\text{Drag}}$
   C. $F_{\text{Weight}} < F_{\text{Drag}}$

C8. A small block is attached to a cord passing through a hole on a frictionless horizontal surface. The block is rotating with a constant angular velocity $\omega$. If the string is now pulled down (as shown in the picture), will $\omega$:
   A. Increase
   B. Decrease
   C. Stay the same
   D. Need to know the initial mass moment of inertia to answer the question.

C9. If $\vec{A} \times \vec{B} = \vec{C}$ then $\vec{B} \times \vec{A} =$
   A. $\vec{C}$
   B. $-\vec{C}$
   C. $\vec{C} / 2$
   D. Not enough information