### Useful Conversions

- **1 gallon** = 231 cubic inches
- **1 gallon** = 4 quarts
- **1 gallon** = 128 fluid ounces
- **1 m**\(^3\) = 1000 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 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**
  \[ \frac{\sin A}{\sin B} = \frac{\sin C}{\sin C} \]
- **Law of Cosines**
  \[ c^2 = a^2 + b^2 - 2ab \cos C \]

### Circular Motion

- **s** – arc length
- **v** – speed
- **a\(_n\)** – normal acceleration
- **p** – radius of curvature
- **\(\theta\)** – angle
- **\(\omega\)** – angular speed
- **\(\alpha\)** – angular acceleration
- **\(T\)** – period
- **\(f\)** – frequency

### Projectile Motion

- **\(v_x\)** – launch angle
- **\(v_y\)** – launch velocity
- **\(s_x\)**, **\(s_y\)** – launch position, positive up

### Relative Motion

- **\(v_x\)** – component of velocity
- **\(v_y\)** – component of velocity

### Force and Acceleration

- **\(F = ma\)**
- **\(a = \frac{F}{m}\)**
- **\(v = \frac{1}{2} \frac{2F}{m} \sqrt{\frac{F}{m}}\)**

### Friction

- **\(F_{\text{friction}} = \mu F_N\)**
- **\(F_{\text{friction}} = \mu_0 F_N\)**

### Work

- **\(W = F \cdot \Delta s = F \cdot \theta \cdot \cos \theta\)**

### Power

- **\(P = F \cdot v\)**
- **\(P = \frac{dW}{dt}\)**

### Spring force

- **\(F = kx\)**

### Conservation of Energy

- **\(mg h + \frac{1}{2} m v_x^2 + \frac{1}{2} I \alpha^2 + W_{\text{ext}} = mg h + \frac{1}{2} m v_y^2 + \frac{1}{2} I \alpha^2 + E_{\text{int}}\)**

### Impulse / Momentum / Restitution

- **\(\sum m v_f = \sum m v_i + \int \sum F \cdot dt\)**
- **\(m_1 v_1 + m_2 v_2 = m_1 v'_1 + m_2 v'_2\)**
- **\(c = -\frac{(v'_1 - v_1)}{v_2 - v_1}\)** (line of impact)

### Constant Angular Acceleration

- **\(\theta = \theta_0 + \alpha t + \frac{1}{2} \alpha t^2\)**
- **\(\theta = \theta_0 + \omega t + \frac{1}{2} \omega^2 t^2\)**

### Torque and Acceleration

- **\(\tau = F r \sin \theta\)**
- **\(\tau = \vec{r} \times \vec{F}\)**

### Torque

- **\(W = \vec{r} \cdot \vec{F}\)**
- **\(P = \frac{1}{2} I \omega^2\)**

### Angular Impulse / Momentum

- **\(L = \tau \cdot \Delta t\)**
- **\(L = \vec{r} \times \vec{p}\)**
- **\(L = \text{angular momentum}\)**
- **\(\vec{p} = \text{linear momentum}\)**

### Rocket Propulsion

- **\(v = s_0 - gt\)**
- **\(v = s_0 - s_{\text{burn}}\)**
- **\(v = v_{\text{ex}} - v_{\text{in}}\)**
- **\(v_{\text{ex}}\)** – exhaust speed of gases relative to the rocket.

### Center of Mass

- **\(\bar{r} = \frac{m_1 \vec{r}_1 + m_2 \vec{r}_2 + \cdots + m_n \vec{r}_n}{m_1 + m_2 + \cdots + m_n}\)**

### Parallel Axis Theorem

- **\(I = I_m + Md^2\)**

### Conservation of Linear Momentum

- **\(I \bar{v} = I \bar{v}'\)**
- **\(I \bar{v} = I \bar{v}' + \int \sum F \cdot dt\)**

### Impulse / Momentum / Restitution

- **\(\sum m v_f = \sum m v_i + \int \sum F \cdot dt\)**
- **\(m_1 v_1 + m_2 v_2 = m_1 v'_1 + m_2 v'_2\)**
- **\(c = -\frac{(v'_1 - v_1)}{v_2 - v_1}\)** (line of impact)
1. (2 pts) Write your name, section, and netid above. Tear off the cover page so you have easy access to the equations.

2. (7 pts) Determine the magnitude and angle counterclockwise from the x-axis of vector $D$, where $D = A + B - C$.

3. (7 pts) Prof. Schleter takes a road trip. He travels for 30 miles at 40 mph, then 20 miles in 0.6 hours, and finally 35 mph for 0.4 hours. Determine Prof. Schleter’s average speed for the entire trip.

4. (7 pts) Dr. Bennett also goes on a road trip. He starts from rest and accelerates at 4 ft/s$^2$ for 30 seconds. He then slows down at a constant rate, covering an additional 4000 ft before coming back to rest. How many seconds did the entire trip last?

5. (7 pts) Bruce Pearl hits a golf ball off a 100 ft high cliff at an angle of 60° above the horizontal. The ball hits the ground 3.0 seconds later. What is the horizontal distance the golf ball traveled?
6. (7 pts) A horse on a merry-go-round starts from rest and increases speed at the rate of 3.0 ft/s². The horse is 40 ft from the center of the merry-go-round. Determine the magnitude of the total acceleration of the horse after 4.0 seconds.

7. (7 pts) Derek Dooley is pushing a 200 N crate of Music City Bowl programs up a 10° incline. He pushes with a force of 120 N at an angle of 37° from the horizontal. Determine the magnitude of the acceleration of the crate. Ignore friction. (FBD required)

8. (7 pts) Determine the minimum force $T$ to start the block moving. (FBD required)

9. (7 pts) A 4000 kg roller coaster starts from rest and is then launched by electric motors. The roller coaster crests a 12 m high hill with a speed of 15 m/s. There is a constant friction force of 1200 N which acts over the 250 m distance the roller coaster traveled before getting to the top of the hill. The electric motors used for the launch are 70% efficient. How much energy was consumed by the electric motors?
10. (7 pts) A 50 kg cart is rolling down a 20° incline at a speed of 12 m/s when one end of an initially unstretched spring (k = 200 N/m) is hooked to it. The other end of the spring is fixed. How far down the incline does the cart go before coming to a stop?

11. (7 pts) Cart A (140 kg) is traveling at +14 m/s when it collides with cart B (210 kg) that is initially at rest. The coefficient of restitution is 0.80. What is the speed of cart A after the collision?

12. (7 pts) Use the given coordinate system and assume uniform density and thickness. What is the y-coordinate of the center of mass of the shaded area? Each grid line is one inch apart. The center of mass of a right triangle is 1/3h above its base, where h is the height of the triangle.

13. (7 pts) A 9.4 inch diameter basketball (a thin wall hollow sphere) weighs 1.25 lb and is flying through the air at 22 ft/s while spinning at 180 rpm. What is its total kinetic energy?
14. (7 pts) A horizontal disk with a mass of 30 kg rotates about its center. Friction causes a constant torque of 10 N⋅m. A 6.0 kg fan is mounted on the disk and provides a constant force as shown. Treat the fan as a point mass. What is the magnitude of the angular acceleration of the system?

![Diagram showing a horizontal disk with a mass of 30 kg, a constant torque of 10 N⋅m, and a 6.0 kg fan mounted on the disk. The force is shown at an angle of 110°.] 

15. (7 pts) A varying force of \( F = (18t) \) N (where \( t \) is time in seconds) is applied to a 6.0 kg object that has an initial speed of 13 m/s. The direction of the force and the initial motion of the object are perpendicular. What is the speed of the object after 4.0 seconds?