**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
  \[
  c^2 = a^2 + b^2 - 2ab \cos C
  \]

**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 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\(^2\)

**Rocket Propulsion**

\[
v = u_e \ln \left( \frac{m_f}{m_i} \right) - gt
\]

thrust = \( u_e \frac{dm}{dt} \)

**Conservation of Energy**

\[
mg h_0 + \frac{1}{2} mv_0^2 + \frac{1}{2} k \Delta x_0^2 + W_s = mg h_f + \frac{1}{2} mv_f^2 + \frac{1}{2} k \Delta x_f^2 + E_{\text{loss}}
\]

**Constant Acceleration**

\[
\begin{align*}
  v_2 &= v_1 + a \Delta t \\
  s_2 &= s_1 + \left( \frac{v_1 + v_2}{2} \right) \Delta t \\
  s_2 &= s_1 + v_1 \Delta t + \frac{1}{2} a \Delta t^2 \\
  s_2 &= s_1 + \frac{v_2^2 - v_1^2}{2a}
\end{align*}
\]

**Circular Motion**

- \( s \) – arc length
- \( v \) – speed
- \( a_n \) – centripetal acceleration
- \( a_t \) – tangential acceleration
- \( \rho \) – radius of curvature
- \( \phi \) – angle
- \( \omega \) – angular speed
- \( \alpha \) – angular acceleration
- \( T \) – period
- \( f \) – frequency

\[
\begin{align*}
  \Delta s &= \rho \Delta \phi \\
  v &= \rho \omega \\
  a_n &= \rho \alpha \\
  a_t &= \frac{v^2}{\rho} = \rho \omega^2 \\
  T &= \frac{2\pi}{\omega} \\
  f &= \frac{1}{T} \\
  \omega &= 2\pi f
\end{align*}
\]

**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**

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

**Force and Acceleration**

\[
F_{\text{net}} = m \ddot{a}
\]

**Friction**

\[
F_{\text{max}} = \mu_s N \quad F_{\text{kinetic}} = \mu_k N
\]

**Work**

\[
W = F \cdot \Delta \vec{r} = F \Delta r \cos \theta
\]

**Power**

\[
P = \frac{dW}{dt}
\]

**Spring force**

\[
F = k \Delta x
\]

**Impulse / Momentum / Restitution**

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

\[
m_1 \vec{v}_1 + m_2 \vec{v}_2 = m_1 \vec{v}'_1 + m_2 \vec{v}'_2
\]

\[
e = - \frac{(\vec{v}_2' - \vec{v}_1')}{\vec{v}_2' - \vec{v}_1} \quad \text{(line of impact)}
\]

**Instructions**

- Do not open the exam until instructed to do so.
- Do not leave if there is less than 5 minutes to go in the exam.
- When time is called, immediately stop writing, remain seated, and pass your exam to the center aisle.
- Do not stand up or leave the room until all exams have been collected.
**Constant Angular Acceleration**
\[
\begin{align*}
\omega_2 &= \omega_1 + \alpha \Delta t \\
\theta_2 &= \theta_1 + \left( \frac{\omega_1 + \omega_2}{2} \right) \Delta t \\
\omega_2 &= \omega_1 + \frac{\omega_1^2 - \omega_2^2}{2 \alpha}
\end{align*}
\]

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

**Work and Power**
\[
W = \vec{r} \cdot \vec{F} \\
P = \vec{r} \cdot \vec{\omega} \\
KE = \frac{1}{2} I \omega^2
\]

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

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

**Angular Impulse / Momentum**
\[
\sum I \vec{\omega}' = \sum I \vec{\omega} + \int_o^t \sum \vec{\tau} dt \\
\vec{L} = \vec{r} \times \vec{p} \\
\vec{L} = \text{angular momentum} \\
\vec{p} = \text{linear momentum}
\]

---

(a) Slender rod, axis through center
(b) Slender rod, axis through one end
(c) Rectangular plate, axis through center
(d) Thin rectangular plate, axis along edge
(e) Hollow cylinder
(f) Solid cylinder
(g) Thin-walled hollow cylinder
(h) Solid sphere
(i) Thin-walled hollow sphere

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**Exam Guidelines**
- Assume 3 significant figures for all given numbers unless otherwise stated
- Show all of your work – no work, no credit
- Write your final answer in the box provided
- Include units for all answers
- Include directions for all vectors
1. A rabbit goes hopping in the woods. First the rabbit hops due East. Then the rabbit hops 68 yards at
an angle of 40° south of east. The rabbit then determines that it needs to hop at an angle of 25° north of
west to get back to the starting point. How far did the rabbit initially hop in the East direction?

2. Determine the distance needed to increase the speed of a car from 40 ft/sec to 70 ft/sec if accelerating
at a constant rate of 0.05g.
3. Mr. Pippin is running the 100 meter dash. Mr. Pippin accelerates at a constant rate reaching a speed of 10 m/sec in 3 seconds and then runs the remainder of the 100 m at a constant speed of 10 m/sec. How long did it take Mr. Pippin to complete the 100 meter dash?

4. Professor Schleter hits a golf ball on level ground with a speed of 90 ft/sec. The ball hits the ground 4 seconds after it was hit. At what angle from the ground did Professor Schleter hit the golf ball?
5. An Alleged Air airplane has an airspeed (velocity with respect to the air) of 300 mph. The wind is blowing at 60 mph 20° North of East. Determine the direction the plane needs to fly so that it fly at due North with respect to the ground.

6. A 1000 kg pickup truck is pulling a 600 kg trailer on level ground. The driving force of the pickup truck is 3000 N. Determine the force in the coupling between the truck and the trailer. Ignore friction. (FBD=KD required)
7. Determine the minimum force $P$ to keep the block from sliding. \textbf{(FBD required)}

8. A 28 kg child, initially at rest, slides down a playground slide from a height of 3 m above the bottom of the slide. If her speed at the bottom of the slide is 6 m/s, and the length of the slide is 5 m, what is the magnitude of the friction force between the child and the slide?
9. Water is lifted out of a 100 ft deep well by a 2 hp motor. Assuming 90% efficiency, how many slugs of water can be lifted in 1 minute?

10. A 0.8 kg ball is thrown horizontally with a velocity of 15 m/s against a wall. If the ball rebounds horizontally with a velocity of 13 m/sec and the contact time is 0.02 seconds, what is the force exerted on the ball by the wall?
11. An explosion of a 10kg bomb releases two separate pieces. The bomb was initially at rest and a 4 kg piece traveled westward at 100 m/s immediately after the explosion. How much kinetic energy was released in the explosion?

12. Use the given coordinate system and assume uniform density and thickness. What is the \textit{x-coordinate} of the center of mass of the shaded area? Each grid line is one inch apart.
13. A child is on the outer edge merry-go-round. The merry-go-round starts with an angular speed of 0.4 rad/sec and has a constant angular acceleration of 0.15 rad/sec\(^2\). If it takes the child 3.5 seconds to reach a total acceleration of 1.8 m/sec\(^2\), what is the radius of the merry-go-round?

14. A disk with a mass of 30 kg and a radius of 40 cm is mounted on a frictionless horizontal axle. A string is wound around the disk and then connected to a 70 kg block. The mass moment of inertia of the disk is 2.4 kg-m\(^2\). Find the acceleration of the block. *(FBD=KD required)*
15. A small car collides with a large truck. Which one experiences the larger impact force?
   A. the car
   B. the truck
   C. both the same
   D. depends upon the velocity of each

16. Dr Bennett is spinning on a rotating platform with his hands close to his body. He then stretches his arms out as far as he can. The angular velocity of the platform will:
   A. Increase
   B. Decrease
   C. Remain the same
   D. Need more information to determine the answer

Please remain seated if there are less than 5 minutes to go in the exam so as not to disturb those still trying to finish. If you finish early you should go back and check your work.