Uniform Circular Motion

\(a_n = \text{centripetal acceleration}\)
\(v = \text{speed}\)
\(r = \text{radius of curvature}\)
\(\omega = \text{rotational speed}\)
\(T = \text{period}\)
\(f = \text{frequency}\)
\(\phi = \text{angle}\)

\[a_n = \frac{v^2}{r} \quad \text{(any curve)}\]
\[a_n = r\omega^2\]
\[v = \omega r\]
\[T = \frac{2\pi}{\omega}\]
\[f = \frac{1}{T}\]
\[\Delta s = r\Delta \phi\]
\[\omega = 2\pi f\]

Stress and Strain

\(\text{Stress} = \sigma = \frac{F}{A}\)
\(\text{Strain} = \varepsilon = \frac{\Delta L}{L}\)
\[\Delta L = \frac{FL}{AE}\]
\[E = \frac{\sigma}{\varepsilon}\]

Factor of Safety (FS)

\[FS = \frac{\text{Strength}}{\text{Load}}\]

Fluids

\(\rho = \text{pressure}\)
\(h = \text{height}\)
\(\rho = \text{mass density}\)
\(v = \text{velocity}\)
\(K = \text{empirical constant}\)
\(A = \text{area}\)
\(d = \text{depth}\)
\(p_0 = \text{pressure on top of fluid}\)

Conservation of Mass
(Continuity)

\[v_1 A_1 = v_2 A_2\]

Bernoulli’s Equation

\[p_1 + \frac{1}{2} \rho v_1^2 + \rho gh_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho gh_2\]

Lift

\[L \geq \rho K A v^2\]

Pressure in a fluid

\[p = \rho gd + p_0\]

Atmospheric Pressure

101.3 kPa
14.7 psi

Conversions

\(1 \text{ ft}^3 = 7.48 \text{ gal}\)
\(1 \text{ m}^3 = 1000 \text{ L}\)

Density of Water

62.4 lb/ft\(^3\)
1000 kg/m\(^3\)

Stokes’ Law

\[F_{\text{drag}} = 6\pi \eta v\]

Poiseuille’s Equation

\[Q = \frac{\pi r^4 (p_1 - p_2)}{8\eta L}\]
\[\eta_{\text{water}} = 1.0 \times 10^{-3} \text{ Pa·s}\]

Universal Law of Gravitation

\[F_G = G \frac{m_1 m_2}{r^2}\]
\[G = 6.67 \times 10^{-11} \text{ N·m}^2/\text{kg}^2\]

Kepler’s Third Law

\[T^2 = \left(\frac{2\pi}{\omega}\right)^2 = \frac{(2\pi)^3}{\omega^3} = \frac{R^3}{Gm}\]

Satellites

\[v = \sqrt{\frac{Gm}{r + h}}\]
\[v_{\text{esc}} = \sqrt{\frac{2Gm}{r}}\]
\[U = -\frac{GmM}{r}\]
\[r_{\text{Earth}} = 6.378 \times 10^6 \text{ m}\]
\[m_{\text{Earth}} = 5.976 \times 10^{24} \text{ kg}\]

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.
1. (14 pts) Determine the reaction (magnitude and direction) at point A. A separate, complete FBD is required for full credit.

2. (14 pts) Determine the minimum force P to keep the box from tipping over. Assume the center of mass of the box is at the middle of the box. A separate, complete FBD is required for full credit.
3. (14 pts) The ultimate strength of nylon is 75 MPa. Determine the minimum diameter of a nylon cable to hold up a 900 N force with a factor of safety of 2.5. Express the answer to the nearest 2 mm.

4. (14 pts) In 2004 astronomers discovered a new planet orbiting very close to a star called HD. It’s orbit is 1/9 the distance of Mercury from the Sun and it takes only 3.09 days to complete one orbit (assumed circular). What is the mass of star HD?
   - The orbit radius of Mercury is $5.79 \times 10^{10}$ m
5. (14 pts) A hollow plastic sphere is held below the surface of a fresh water lake by a cord anchored to the bottom of the lake. The sphere has a volume of 0.65 m$^3$ and the tension in the cord is 900N. What is the mass of the sphere?

6. (14 pts) At point A in a pipeline the speed of the water is 2.5 m/s and the gauge pressure is 1.80 kPa. Find the gauge pressure at point B in the line if it is 0.5m lower than point A and the cross-sectional area at point B is twice that at point A.
7. (14 pts) 2.0 cm$^3$ of water is being pushed out of a syringe through a 3.5 cm long needle in 0.4 s. The interior diameter of the needle is 1.37 mm. What is the pressure difference between the tip of the needle and the end that is connected to the syringe?

8. (2 pts) A ladder is leaning against a wall. If you were going to climb the ladder are you better off if there is no friction between the ladder and the wall or no friction between the ladder and the floor?

a. No friction between the ladder and the floor
b. No friction between the ladder and the wall
c. Does not matter