

# Further Application of Newton's Laws

## Friction, Drag, and Elasticity

### Chapter 5

2024

# Contents

- 5.1 Friction
- 5.2 Drag Forces
- 5.3 Elasticity: Stress and Strain

## Problem 10: Snowboarder Deceleration

### Problem

Calculate the deceleration of a snow boarder going up a  $5.0^\circ$  slope assuming the coefficient of friction for waxed wood on wet snow is  $\mu_k = 0.100$ .

Screenshot 2024-10-29 103504.png

# Problem 10: Solution Steps

- 1 Draw the free body diagram
  - Forces: Weight ( $w = mg$ ), Normal force ( $N$ ), Friction force ( $f$ )
- 2 Apply Newton's Laws:
  - net  $F_x = w_x + f = ma$
  - net  $F_y = N - w_y = 0$
- 3 Given values:
  - $\theta = 5^\circ$
  - $\mu_k = 0.100$

## Problem 10: Solution Steps (continued)

4 Using trigonometry:

- $w_x = w \sin \theta = mg \sin \theta$
- $w_y = w \cos \theta = mg \cos \theta$
- $f = \mu_k N = \mu_k mg \cos \theta$

5 Solve for acceleration:

$$a = \frac{w_x + f}{m} = \frac{mg \sin \theta + \mu_k mg \cos \theta}{m} = g(\sin \theta + \mu_k \cos \theta)$$

6 Final calculation:

$$a = (9.80 \text{ m/s}^2)(\sin 5^\circ + (0.100) \cos 5^\circ) = 1.83 \text{ m/s}^2$$

## Problem 25: Rain Drop Velocity

### Problem

Calculate the velocity a spherical rain drop would achieve falling from 5.00 km:

- (a) in the absence of air drag
- (b) with air drag

Given:

- Drop size: 4 mm
- Density:  $1.00 \times 10^3 \text{ kg/m}^3$
- Cross-section area:  $\pi r^2$

## Problem 25: Solution (Part a)

Without air drag:

- 1 Use free fall equation:  $v = \sqrt{2ax}$
- 2 Substitute values:

$$v = \sqrt{2(9.80 \text{ m/s}^2)(5000 \text{ m})} = 313 \text{ m/s}$$

## Problem 25: Solution (Part b)

With air drag:

① Calculate mass of raindrop:

- Volume =  $\frac{4}{3}\pi r^3$
- $m = \rho V = 1000 \text{ kg/m}^3 \times \frac{4}{3}\pi(2 \times 10^{-3} \text{ m})^3$
- $m = 3.351 \times 10^{-5} \text{ kg}$

② Terminal velocity equation:

$$v_t = \sqrt{\frac{2mg}{\rho CA}}$$

where:

- $\rho = 1.21 \text{ kg/m}^3$  (air density)
- $C = 0.45$  (drag coefficient)
- $A = \pi r^2 = \pi(0.002 \text{ m})^2$



## Problem 25: Final Calculation

Substituting values into terminal velocity equation:

$$v_t = \sqrt{\frac{2(3.351 \times 10^{-5} \text{ kg})(9.80 \text{ m/s}^2)}{(1.21 \text{ kg/m}^3)(0.45)\pi(0.002 \text{ m})^2}} = 9.80 \text{ m/s}$$

## Problem 30: Wrestler's Arm Bone Compression

### Problem

During a wrestling match, a 150 kg wrestler briefly stands on one hand. Calculate the shortening of the upper arm bone.

Given:

- Bone length: 38.0 cm
- Bone radius: 2.10 cm
- Young's modulus (bone):  $9 \times 10^9 \text{ N/m}^2$

## Problem 30: Solution

- ① Compression equation:

$$\Delta L = \frac{1}{Y} \frac{F}{A} L_0$$

where:

- $Y$  = Young's modulus =  $9 \times 10^9 \text{ N/m}^2$
- $F$  = Force =  $mg = (150 \text{ kg})(9.80 \text{ m/s}^2)$
- $A$  = Cross-sectional area =  $\pi r^2 = \pi(0.0210 \text{ m})^2$
- $L_0$  = Original length =  $0.380 \text{ m}$

- ② Final calculation:

$$\Delta L = 4.5 \times 10^{-5} \text{ m}$$