# Study Guide 2 for Algebra-Based Physics-1: Mechanics (PHYS135A-01)

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## 1 Equations

- Newton's First Law: $\vec{F}_{Net} = 0$ if $\vec{v}$ is constant. Newton's Second Law: $\vec{F}_{Net} = m\vec{a}$. Newton's Third Law: $\vec{F}_{AB} = -\vec{F}_{BA}$.
- Normal force: $\vec{N} = +mg\hat{y}$, if weight is $w = -mg\hat{y}$ (flat surface).
- Force of Friction: $\vec{F} = -\mu\vec{N}$ (minus sign: opposes motion).
- Static versus kinetic friction: $\mu_s \geq \mu_k$.
- Definition of velocity: $\vec{v} = \frac{\Delta\vec{x}}{\Delta t}$
- Definition of acceleration: $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$
- Constant acceleration:
  1. $v(t) = at + v_i$
  2. $x(t) = \frac{1}{2}at^2 + v_i t + x_i$
  3. $v^2 = v_i^2 + 2a\Delta x$

## 2 Newton's Laws

1. An swimmer sinks at constant velocity to the bottom of the ocean near the shore. The swimmer has a weight force downwards. In which direction is there another force on the swimmer?
   - A: **Upwards.** - Newton's first law.
   - B: Downwards.
   - C: Towards the shore.
   - D: Away from shore.
2. A soccer player in training begins to sprint down the field. She has a mass $m$, is wearing a harness than has mass $M$, and has acceleration $a$. If she exerts constant force through her cleats on the turf, and drops the harness, which of the following is true?
   - A: Her new acceleration will be less than $a$.
   - B: **Her new acceleration will be greater than $a$.** - Newton's second law.
   - C: Her new acceleration will be equal to $a$.
   - D: Her new acceleration will be 0.
3. Consider Fig. 1. Which of the following is true regarding the system in the diagram?
   - A: It has no net force.
   - B: It is accelerating to the left.
   - C: **It is accelerating to the right.** - Newton's second law. The vector pointing to the left is not a force.
   - D: It is accelerating downwards.
4. Consider Fig. 1. Suppose the system reaches a point where there is no longer friction. Which of the following is true?
   - A: **The system will move at a constant velocity.** - Newton's second law. The vertical vectors will cancel and $F_{net}$ will be zero.
   - B: The system will accelerate to the right.

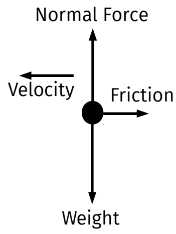


Figure 1: A free body diagram for a system.

- C: The system will stop moving.
- D: The system will accelerate to the left.

5. A 70 kg sprinter begins a run at rest and reaches 10 m/s in 3.0 seconds. What force does he exert on the track?

   The acceleration is needed to compute the force. **Using the *definition of acceleration*, we have** $a = (10 - 0)/(3.0 - 0.0) = 10/3$ **m/s**$^2$**. Knowing the acceleration, we can use Newton's second law** $F = (70)(10/3) = 233$ **N.**

6. Consider Fig. 2, in which two children pull their friend on a sled resting on snow with forces $\vec{F_1}$ and $\vec{F_2}$. (a) What is the magnitude of the net force (no friction)? (b) If sled and the child on it have total mass 40 kg, what is the acceleration?

   **(a) To obtain the magnitude of the net force, we first must add the force vectors to obtain the net force. Let** $\theta_1$ **and** $\theta_2$ **be the corresponding angles.**

$$F_{1x} = F_1 \cos\theta_1 \tag{1}$$
$$F_{2x} = F_2 \cos\theta_2 \tag{2}$$
$$F_{1y} = F_1 \sin\theta_1 \tag{3}$$
$$F_{2y} = F_2 \sin\theta_2 \tag{4}$$

   **Add the vectors to get the net force:** $\vec{F}_{net} = (F_1 \cos\theta_1 + F_2 \cos\theta_2, F_1 \sin\theta_1 + F_2 \sin\theta_2)$**. Plugging in numbers, we obtain** $F_{net} = (7.07 + 6.93, 7.07 - 4.0) = (14, 3.07)$ **N. Use the Pythagorean theorem to obtain the magnitude** $\sqrt{14^2 + 3.07^2} = 14.3$ **N. (b) Knowing the net force, we can obtain the acceleration** $a = F_{net}/m = 14.3/40 = 0.36$ **m/s**$^2$**.**

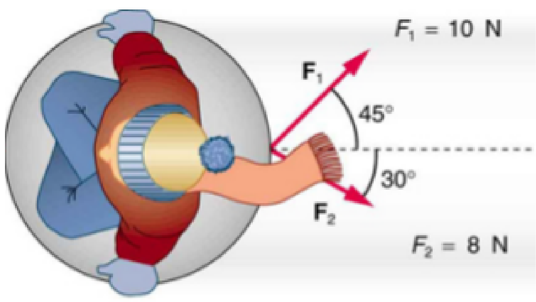


Figure 2: Two children pull a third on a sled.

7. A 20,000 kg jet pushes through the air with a forward force of $10^6$ N, and faces air resistance equivalent to $5 \times 10^4$ N. What is the acceleration of the jet?

   **We need the net force to obtain the acceleration:** $F_{net} = 10^6 - 5 \times 10^4$ **N. The acceleration is** $F_{net}/m = (10^6 - 5 \times 10^4)/(2 \times 10^4 = \frac{100}{2} - \frac{5}{2} = 47.5$ **m/s**$^2$**. This is the equivalent of** $47.5/9.8 = 4.8$ **g's.**

# 3 Friction and Drag

1. A woman drags a piece of luggage across a floor. If the mass of the luggage is 30 kg, and she exerts a force of 300 N, what is the coefficient of kinetic friction between the luggage and floor?

   Let's just assume $g = 10$, and we have the normal force $N$ is $mg \approx 30 \times 10 = 300$ N. The frictional force is $\mu N$, so $F_{lady} = \mu mg$, or $\mu = 1.0$. (This assumes the luggage is being dragged at constant velocity).

Table 5.1 Coefficients of Static and Kinetic Friction

| System | Static friction $\mu_s$ | Kinetic friction $\mu_k$ |
|---|---|---|
| Rubber on dry concrete | 1.0 | 0.7 |
| Rubber on wet concrete | 0.7 | 0.5 |
| Wood on wood | 0.5 | 0.3 |
| Waxed wood on wet snow | 0.14 | 0.1 |
| Metal on wood | 0.5 | 0.3 |
| Steel on steel (dry) | 0.6 | 0.3 |
| Steel on steel (oiled) | 0.05 | 0.03 |
| Teflon on steel | 0.04 | 0.04 |
| Bone lubricated by synovial fluid | 0.016 | 0.015 |
| Shoes on wood | 0.9 | 0.7 |
| Shoes on ice | 0.1 | 0.05 |
| Ice on ice | 0.1 | 0.03 |
| Steel on ice | 0.4 | 0.02 |

Figure 3: (Left) Frictional coefficients for exercise 2, **Friction and Drag**.

2. Consult Fig. 3. (a) What is the magnitude of the force of friction exerted on an oiled steel piston experiencing a normal force of 10 N from another steel surface? (b) What would the result have been if the steel had no oil?

   **The frictional force is just $\mu N$, and according to the table, $\mu_k = 0.03$, so $0.03 \times 10$ N, which is 0.3 N. If there is no oil, $\mu_k = 0.3$, so the friction would be 3 N.**

3. Consult Fig. 4. Recall the lab in which we measured the coefficient of static friction, $\mu_s$. If $\mu_s = 0.5$, and $m_2 = 200$ grams, what is the smallest mass $m_1$ can be before the system begins to accelerate?

   **If the system is static, then the net force is zero (Newton's first law). The weight creates tension which balances the frictional force (just as we saw in the lab activity). $F_f = T$. Thus, $\mu_s m_1 g = m_2 g$, so $m_1 = m_2/\mu_s = 200/0.5 = 400$ grams. If $m_1$ were *smaller*, the system would accelerate because it would overcome static friction.**

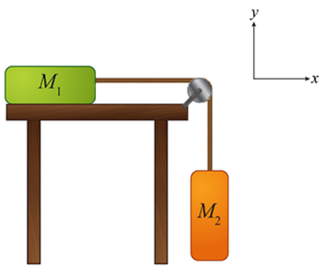


Figure 4: Diagram for exercise 3, **Friction and Drag**.

4. A system travels at a *terminal velocity* $v_T = \sqrt{2mg/C\rho A}$. (a) What is $v_T$ for a falling system who with $m = 200$ kg, $A = 2$ m$^2$, $C \approx 0.4$, in air with $\rho_{air} = 1.225$ kg/m$^3$? (See section 5.3 of the textbook).

   Plug and chug: $v_T = \sqrt{2 * 200 * 10/(4/10)/1.225/2} \approx 64$ m/s.