Dynamics Part One

Newtons Three Laws:
- Every object in a state of uniform motion will remain in that state of motion, or an object at rest will remain at rest, unless an external force acts on it.
- Force equals mass times acceleration.
- For every action there is an equal and opposite reaction.

Example #1
Find the weight of a 10. kg object
a) on the Earth       b) on the moon

\[
F_g = m g = (10 \text{ kg})(9.8 \text{ N/kg}) = 98 \text{ N}
\]

\[
F_g = (10 \text{ kg})(1.6 \text{ N/kg}) = 16 \text{ N}
\]

Force equation

\[ F_{\text{net}} = ma \]

\[ F_{\text{net}} \text{ or } \sum F = \text{net force (Newtons)} \]
\[ m = \text{mass of object (kg)} \]
\[ a = \text{acceleration of object (m/s}^2) \]

With forces:
- if we have balanced forces, then "objects at rest remain at rest and objects in motion remain in motion" (newton’s first law)
- if we have unbalanced (net) forces: then the object accelerates in the direction of the net force. (newton’s second law)

Example #2
A 2000.N rock accelerates upwards at 3.00 m/s².

a. draw a FBD
b. compare the forces that act on the object
c. write a net force equation
d. find the tension in the cable

\[
T = F_a = ma = 2000 \text{ N} \cdot 3.0 \text{ m/s}^2 = 6000 \text{ N}
\]

\[
m = \frac{2000 \text{ N}}{9.8 \text{ m/s}^2} = 204.1 \text{ kg}
\]

\[
F_{\text{net}} = \text{larger force - smaller force} = T - F_g
\]

\[
dx = \frac{F_{\text{net}}}{a} = \frac{6000 \text{ N}}{3.0 \text{ m/s}^2} = 2000 \text{ m}
\]

\[
T = ma + F_g = 204.1 \text{ kg} \cdot 3.0 \text{ m/s}^2 + 2000 \text{ N} = 2612.3 \text{ N}
\]
Example #3
A 35 kg student stands on a kilogram scale (which reads FN/9.8). If the elevator accelerates down at 2.25 m/s², then find the:
   a. normal force
   b. scale reading

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\[ F_{\text{net}} = m \cdot a \]
\[ F_N = m \cdot g - m \cdot a \]
\[ F_N = 35 \cdot 9.8 - 35 \cdot 2.25 \]
\[ F_N = 343 - 78.75 \]
\[ F_N = 264.25 \text{ N} \]
\[ = 264.25 \text{ N} \]

\[ \text{Weight} = \frac{F}{9.8 \text{ m/s}^2} \]
\[ \text{Weight} = \frac{264.25}{9.8} \]
\[ \text{Weight} = 27 \text{ kg} \]
Force of Friction equation:

\[ F_f = \mu \, F_N \]

\( F_f \) = force of friction in Newtons (N)
\( \mu \) = coefficient of friction (no units)
\( F_N \) = normal force in Newtons (N)

\( \mu_s \) = static \( \mu \) (when an object is static)
\( \mu_k \) = kinetic \( \mu \) (when an object is moving)

**Example #4**

A 5.0 kg object sits on a surface with \( \mu_{s,\text{max}} = 0.30 \) and \( \mu_k = 0.25 \).

a. Determine the force required to move the object.
b. The object is pulled with 10 N. Find the acc'n and force of friction
c. The object is pulled with 20 N. Find the force of friction and acc'n.

\[ y: \, \ddot{x} = 0 \quad \therefore F_N = F_g \]

\[ a) \, \text{To move object } F_A \geq \mu_s \text{ max static friction} \]
\[ F_A = F_{A,\text{max}} \]
\[ F_A = \mu_s F_N \]
\[ = (0.30 \times 5\, \text{kg})(9.8\, \text{m/s}^2) \]
\[ = 14.7\, \text{N} \]

\[ b) \, F_A = 10\, \text{N} \quad \therefore \text{there is no motion, } \dot{x} = 0 \, \text{m/s}^2 \]
\[ \vec{F}_{\text{net}} = F_A - F_f \]
\[ \vec{F}_{\text{net}} = 0 \]
\[ F_A = F_f \quad \therefore (F_f \text{ is } 10\, \text{N}) \]

\[ c) \, F_A = 20\, \text{N} \quad \therefore \text{IT MOVES, YAYA, PARTY!!} \]
\[ F_f = \mu_k F_N \text{ because object is moving} \]
\[ F_f = (0.25 \times 5.0)(9.8) \]
\[ = 12.25\, \text{N} \]
\[ \vec{F}_{\text{net}} = F_A - F_f \]
\[ ma = 20\, \text{N} - 12.25\, \text{N} \]
\[ a = \frac{20 - 12.25}{5} \]
\[ \therefore a = 1.55\, \text{m/s}^2 \]
Example #5
A mass on a frictionless table is attached to a hanging mass over a frictionless pulley. The mass on the table is 8.0 kg and the mass hanging from the pulley is 6.0 kg. Find:

a) The acceleration of the masses.

b) The tension on the rope.

Example #6
In the previous question, assume the force of friction is 25 N acting on the 8.0 kg mass. Find:

a) The acceleration of the masses

b) The tension of the rope
b) The tension in the rope.

\[ T = mg + F_f \]

**Questions**

1. A rope is attached to a 2.0 kg rock and pulled. Write a net force equation if the mass is:
   a. accelerating up \((T - mg = ma)\)
   b. accelerating down \((mg - T = ma)\)
   c. find the cord tension if the mass is accelerating at:
      i. \(0.0 \, \text{m/s}^2\) \((20. \, \text{N})\)
      ii. \(1.0 \, \text{m/s}^2\) UP \((22 \, \text{N})\)
      iii. \(2.0 \, \text{m/s}^2\) DOWN \((16 \, \text{N})\)
      iv. \(9.8 \, \text{m/s}^2\) DOWN \((0 \, \text{N})\)

2. Find the acceleration of the mass if the cord tension is
   a) \(30. \, \text{N}\) b) \(19.6 \, \text{N}\) c) \(9.6 \, \text{N}\) \((5.2 \, \text{m/s}^2\) up; \(0.0 \, \text{m/s}^2\); \(5.0 \, \text{m/s}^2\) down)

3. A mass is being pulled up by a cable. If the mass is moving up and slowing down, compare the forces that act on the mass and write a net force equation \((mg>T; mg-T=ma)\)

4. Add the force vectors to find the net force and direction: 6250 N North and 3500. N, 30.0° S of West \((5420 \, \text{N}; 56.0° \, \text{N of W})\)

5. A person stands in an elevator. Write a net force equation in each case
   a. elevator at rest
   b. elevator accelerates up
   c. elevator moves up at constant speed
   d. elevator moves down at constant speed
   e. elevator accelerates down
      \((FN=mg; FN-mg=ma; FN=mg; FN=mg; mg-FN=ma)\)

6. A 55.0 kg student is in an elevator accelerating up at 2.50 m/s².
   a. write a net force equation \((FN-mg=ma)\)
   b. what would a force scale placed under their feet read? \((676 \, \text{N})\)

7. A 55.0 kg student is in an elevator accelerating up at 2.50 m/s².
   a. write a net force equation \((FN-mg=ma)\)
   b. what would a force scale placed under their feet read? \((676 \, \text{N})\)
Friction

8. Using the image to the right, find the acceleration if the applied force is:
   a. 5 N (0.5 m/s² LEFT)
   b. 10 N (0 m/s²)
   c. 20 N (1 m/s² right)

9. A force of 400 N is required to start a box moving across the floor (so friction must be about 400 N). If the box has mass 40.0 kg, find the friction coefficient (1.02)

10. A 20.0 kg box sits on a floor with m=0.30. What force is required to move the box across the floor
    a. a) at steady speed (58.8 N )
    b. accelerating at 1 m/s² (78.8 N)

11. A mass of 125 kg is being pulled to the right across a rough floor with an applied force of 200. N. Find the coefficient of friction if the acceleration of the mass is
    a. 0.0 m/s² (0.163)
    b. 1.50 m/s² right/speeding up (0.0102)
    c. 2.20 m/s² left/slowing down (0.388)

12. A 10.0 kg box sits on a floor with μ=0.25 and μk=0.20. Find the acceleration if the box is pulled with
    a) 15 N  b) 22 N  c) 30. N (0 m/s²; 0 m/s²; 1.0 m/s²)

13. A 20.0 kg box sits on a floor with μ=0.30. What force is required to move the box across the floor
    a. at steady speed (58.8 N )
    b. accelerating at 1 m/s² (78.8 N)

Body Problems

14. A mass of 125 kg is being pulled to the right across a rough floor with an applied force of 200. N. Find the coefficient of friction if the acceleration of the mass is
    a. 0.0 m/s² (0.163)
    b. 1.50 m/s² right/speeding up (0.0102)
    c. 2.20 m/s² left/slowing down (0.388)

15. Find acceleration and cord tension (0.27 m/s²; 25 N)

16. Find the acceleration of the system (4.1 m/s²)
17. Two masses, one of 1.0 kg, the other of 3.0 kg, are suspended from the ends of a light string passing over a frictionless pulley. What is the magnitude of the acceleration of these masses?

![Diagram](image1)

18. If the tension in the line joining two masses as shown to the right is 12 N, what is the mass, \( m_1 \)?