Unit Two - Chapter Three - Forces

Learning Goal: By the end of today, I will be able to calculate the acceleration of an object when given the resultant net force acting on the object, and its mass.

When an object has a **Net Force of ZERO**, the object can either be

(i) **AT REST**

or (MUST KNOW)

(ii) **Moving at a CONSTANT Velocity**

What happens if the Net Force on an object is NOT zero?

Section 3.2 - Newton's Second Law of Motion

If I load a cart with progressively more weights and apply a constant force each time, what happens to the acceleration of the cart?

Second Law of Motion

If the net external force on an object is not zero, the object will accelerate in the direction of this net force. The magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass of the object.

Yikes, what does that all mean....?

If the mass of the object remains constant, it takes a larger force to create a larger acceleration.

If the force applied to the object is constant, a smaller mass will accelerate faster than a larger mass.

$$F_{Net} = m \cdot a$$

Sample Problem 1: Determining Acceleration

A net force of 36 N [forward] is applied to a volleyball of mass 0.24 kg. Determine the acceleration of the volleyball.

Given: $\vec{F}_{net} = 36$ N [forward]; $m = 0.24$ kg

Required: $\vec{a}$

Analysis: $\vec{F}_{net} = m\vec{a}$. Choose forward as positive.

Solution: $\vec{F}_{net} = m\vec{a}$

$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

$$a = \frac{+36\text{ N}}{0.24\text{ kg}}$$

$$a = +150\text{ m/s}^2$$

$$\vec{a} = 150\text{ m/s}^2\text{ [forward]}$$

Statement: The acceleration of the volleyball is 150 m/s^2 [forward].

Sample Problem 2: Calculating Net Force

A 64 kg runner starts walking at 3.0 m/s [E] and begins to speed up for 6.0 s, reaching a final velocity of 12.0 m/s [E]. Calculate the net force acting on the runner.

Given: $m = 64$ kg; $\vec{v}_1 = 3.0$ m/s [E]; $\vec{v}_2 = 12.0$ m/s [E]; $\Delta t = 6.0$ s

Required: $\vec{F}_{net}$

Analysis: $\vec{F}_{net} = m\vec{a}$, but first we have to calculate the acceleration using the kinematics equation $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$.

Choose east as positive.

Solution: $\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t}$

$$a = \frac{+12.0\text{ m/s} - (+3.0\text{ m/s})}{6.0\text{ s}}$$

$$a = +1.5\text{ m/s}^2$$

$$\vec{a} = 1.5\text{ m/s}^2\text{ [E]}$$

Now we can calculate the net force.

$$\vec{F}_{net} = m\vec{a}$$

$$F_{net} = (64\text{ kg})(+1.5\text{ m/s}^2)$$

$$F_{net} = +96\text{ N}$$

$$\vec{F}_{net} = 96\text{ N [E]}$$

Statement: The net force on the runner is 96 N [E].

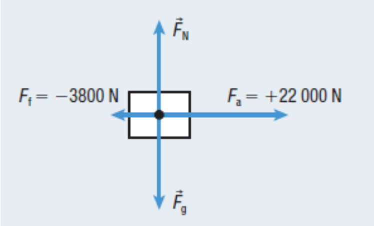
Example - FBD

A 9100 kg jet moving slowly on the ground fires its engines, resulting in a force of 22 000 N [E] on the jet. The force of friction on the jet is 3800 N [W].

(a) Draw the FBD for the jet.

(b) Calculate the net force acting on the jet.

(c) Calculate the acceleration of the jet.



F_{net} horizontal

F_{net} vertical

Newton's Second Law and Gravity

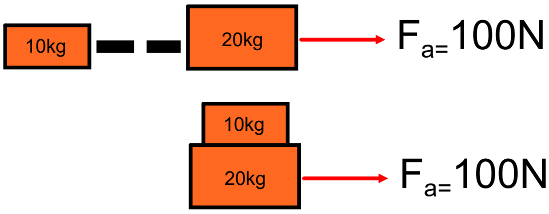
Previously we concluded that $F_g = m * g$, where "m" was the mass of the object in kg and "g" was the acceleration due to gravity (9.8 m/s^2).

If we compare the formula's we can see they are the same, except that the gravitational acceleration is constant so we can use a different symbol, g.

$$F_{Net} = m \cdot a \qquad F_g = m \cdot g$$

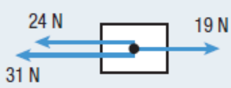
Analyzing Problems - Parts vs Systems

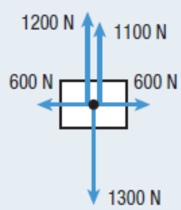
If I have two blocks that are attached with a perfect chain (no mass, no stretch), I can investigate the parts **OR** the entire system. To the applied force, it doesn't know if the blocks are chained together or stacked, it just knows there is 30kg of mass that require 100N to pull.



Practice (Pause and try, answers are in textbook)

1. A net force of 126 N [S] is applied to a 70 kg sprinter. Determine the acceleration of the sprinter. T/I [redacted]
2. A car accelerates at 1.20 m/s^2 [forward]. The net force on the car is 1560 N [forward]. What is the mass of the car? T/I [redacted]
3. A cyclist starts to pedal vigorously, increasing her velocity from 6.0 m/s [E] to 14.0 m/s [E] in 6.0 s. The total mass of the cyclist and the bicycle is 58 kg. Find the net force acting on the cyclist and bicycle. T/I [redacted]
4. During a road test, a driver brakes a 1420 kg car moving at 64.8 km/h [W]. The car slows down and comes to a stop after moving 729 m [W]. T/I
   (a) Calculate the net force acting on the car. [redacted]
   (b) What is the force of friction acting on the car while it is slowing down? Explain your reasoning. [redacted]
5. For each FBD shown below, determine the net force applied to the object and its acceleration. T/I
   (a) $m = 8.0$ kg [redacted] (b) $m = 125$ kg [redacted]





6. In a two-person bobsled competition, athlete 1 pushes forward on the sled with 310 N and athlete 2 pushes forward with 354 N. A force of friction of 40 N [backwards] is acting on the bobsled. The mass of the bobsled is 390 kg. Calculate the acceleration of the bobsled. T/I [redacted]

3.3 Questions

1. Calculate the net force in each situation. T/I
   (a) A 72 kg rugby player accelerates at 1.6 m/s^2 [forward].
   (b) A 2.3 kg model rocket accelerates at 12 m/s^2 [up].
2. Calculate the acceleration in each situation. T/I
   (a) A cannon exerts a force of 2.4×10^4 N [E] on a 5.0 kg shell.
   (b) A hockey stick hits a 160 g puck forward with a force of 24 N.
3. Determine the mass of the object in each situation. T/I
   (a) A driver brakes and the car accelerates at 1.2 m/s^2 [backwards]. The net force on the car is 1400 N [backwards].
   (b) A woman throws a shot put with a net force of 33 N [forward] with an acceleration of 6.0 m/s^2 [forward].
4. A 54 kg skier starts from rest at the top of a snow-covered hill, reaching a velocity of 12 m/s in 5.0 s. Calculate the net force acting on the skier. T/I
5. A dynamics cart is pulled from rest by a net force of 1.2 N [forward]. The cart moves 6.6 m, reaching a velocity of 3.2 m/s [forward]. Determine the mass of the cart. T/I
6. During a parachute jump, a 58 kg person opens the parachute and the total drag force acting on the person is 720 N [up]. T/I
   (a) Calculate the net force acting on the person.
   (b) Determine the acceleration of the person.
7. A net force of magnitude 36 N gives an object of mass m_1 an acceleration of 6.0 m/s^2. The same net force gives m_1 and another object of mass m_2 fastened together an acceleration of 2.0 m/s^2. What acceleration will m_2 experience if the same net force acts on it alone? T/I
8. A 1300 kg car accelerates at 1.6 m/s^2 [E]. A frictional force of 3800 N [W] is acting on the car. T/I C
   (a) Draw the FBD of the car.
   (b) Determine the applied force acting on the car.
9. A long, heavy, metal chain is held at rest on a table with part of the chain hanging over the edge (**Figure 9**). The chain is released and it starts to accelerate. K/U

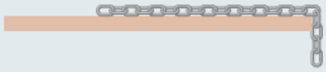


Figure 9

   (a) In which direction will the chain accelerate? What causes the acceleration? Explain your reasoning.
   (b) What will happen to the acceleration of the chain as more chain moves over the edge of the table? Explain your reasoning.
10. Three students push horizontally on a large 80 kg crate sitting on the floor. Two of them push to the left on the crate, each with a force of 170 N. The third pushes to the right on the crate with a force of 150 N. Assume that no friction acts on the crate. T/I
    (a) What is the acceleration of the crate?
    (b) What will happen to the net force and acceleration if a fourth student jumps on top of the crate? Explain your reasoning.
11. A string can hold up 12 kg without breaking. You tie the string to a 30 kg object sitting on ice and use it to pull the object horizontally for 22 m. Calculate the minimum possible time to complete the task. T/I
12. Examine the data in **Table 1**. T/I C
    (a) Copy and complete the table.
    (b) Graph $\vec{F}_a$ versus $\vec{a}$ and draw the line of best fit. What does the *y*-intercept represent? Explain.
    (c) Graph $\vec{F}_{net}$ versus $\vec{a}$ and draw the line of best fit. Calculate the slope of the line. What does the slope represent? Explain.

Section 3.3

#1 - 5, 8