NEWTON'S SECOND LAW

- **Dynamics** is the study of *why* objects moves, whereas kinematics is the study of *how* objects move

- **Force**: push or a pull
  - measured in newtons (N)
  - vector quantity (has both a direction and magnitude)

* • A **net force** ($\vec{F}_{net}$) is defined as the *sum* or *total* of all forces acting on an object at one time. ↙ not equal to zero

* • An *unbalanced* net force acting on an object will cause the object to accelerate or decelerate
  - Therefore, an unbalanced force will cause an object to experience a *change in velocity*

$\vec{a} = \frac{\vec{F}_{net}}{m}$ on data sheet OR $\vec{F}_{net} = m\vec{a}$

where $\vec{F}_{net}$ is force *net* acting on an object in newtons (N)

m is mass of the object in kilograms (kg)

$\vec{a}$ is acceleration of the object (m/s^2)

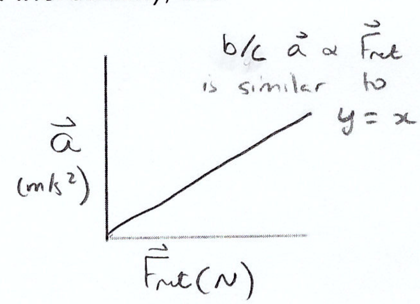
* • The above equation is known as **Newton's Second Law of Motion**
  - the change in velocity (ie. acceleration) of an object is *proportional* to the net force and *inversely proportional* to the object's mass.

* ○ *Proportional:* as the manipulating variable changes (ie. increases), the responding variable changes in the same way (ie. increases as well)

○ $\vec{a} \alpha \vec{F}$ if force increases, acceleration will increase if mass is constant

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

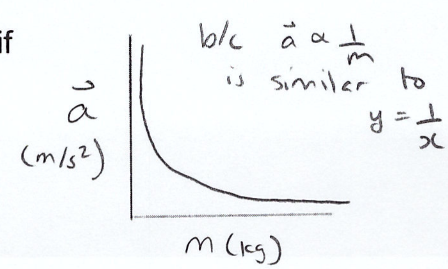
↗ proportional sign



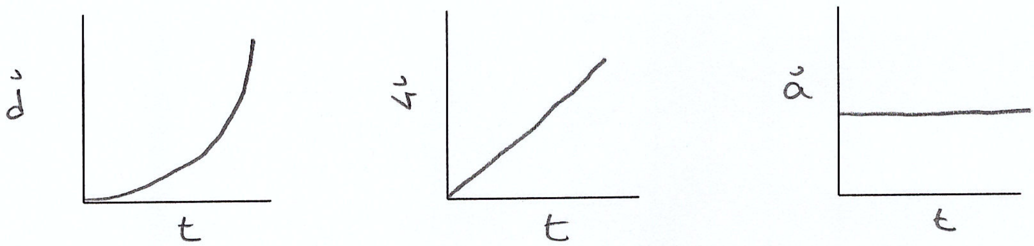
* ○ *Inversely proportional:* as the manipulating variable is changed (ie. increased), the responding variable changes in the opposite way (ie. decreases)

○ $\vec{a} \alpha \frac{1}{m}$ if mass increases, acceleration will decrease if the net force is constant

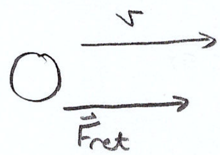
$\vec{a} = \frac{\vec{F}_{net}}{m}$ ∴ $\vec{a} \propto \frac{1}{m}$



- Graphical representation of an unbalanced force (any graph showing acceleration)

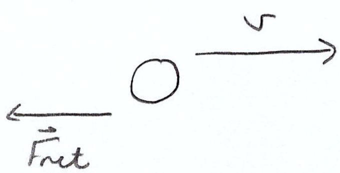


When a force is exerted in the same direction as the object is moving, the object speeds up (ie. accelerates)



= speed up! (acceleration)

- When a force is exerted in the opposite direction to which an object is moving, the object slows down (ie. decelerates)



= slow down! (deceleration)

EXAMPLES

1. An object has a net force of 640N acting on it. If the mass of the object is decreased by a factor of 9 and the acceleration of the object is increased by a factor of 2, what is the new net force acing on the object (magnitude only)?

Original

$\vec{F}_{net} = 640N$

m

$\vec{a}$

$\vec{F}_{net} = m\vec{a} = 640N$

Modified

$\vec{F}_{net}' = ?$

$m' = 2m$

$\vec{a}' = \frac{\vec{a}}{9}$

$F_{net}' = m'a' = (2m)(\vec{a}/9)$

$F_{net}' = m\vec{a}\left(\frac{2}{9}\right)$

$F_{net} = 640N$

$F_{net}' = 640N(2/9) = 142.\bar{2}\ N$

$\boxed{F_{net}' = 142N}$

2. A 22 kg object decelerates uniformly and goes from 2.5 m/s west to a stop in 8.7s. What is the net force acting on the car during this acceleration?

$m = 22\,kg$

$v_i = 2.5\,m/s$

$v_f = 0.0\,m/s$

$t = 8.7\,s$

$\vec{F}_{net} = ?$

$\vec{F}_{net} = m\vec{a}$ (2)

$\vec{a} = \frac{v_f - v_i}{t}$ (1)

(1) $\vec{a} = \frac{v_f - v_i}{t} = \frac{0.0\,m/s - (-2.5\,m/s)}{8.7\,s}$

$\vec{a} = 0.2873...\,m/s^2$

(2) $\vec{F}_{net} = m\vec{a} = (22\,kg)(0.2873....\,m/s^2)$

$\vec{F}_{net} = 6.3218...\,N$

$\boxed{\vec{F}_{net} = 6.3\,N,\ east}$

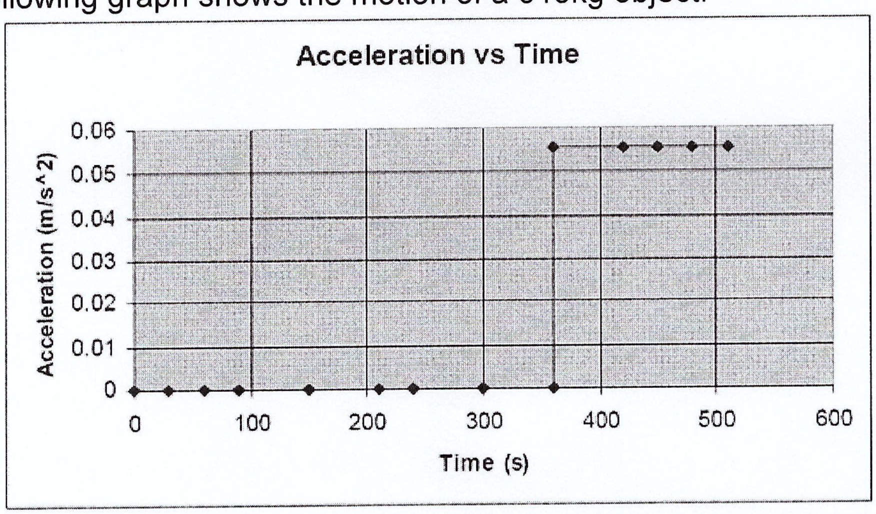
*****Now try pg. 71 # 2-5, 7(acceptable) 9, 11 & Practice Problems (intermediate)*****

Force Practice Problems

1. What happens to the acceleration of an object if the mass is decreased by a factor of 4 and the net force is decreased by a factor of 2? **[X2]**

2. An object has an acceleration of $3.24 m/s^2$. What will be the new acceleration if the mass is tripled and the net force is halved? **[$0.540 m/s^2$]**

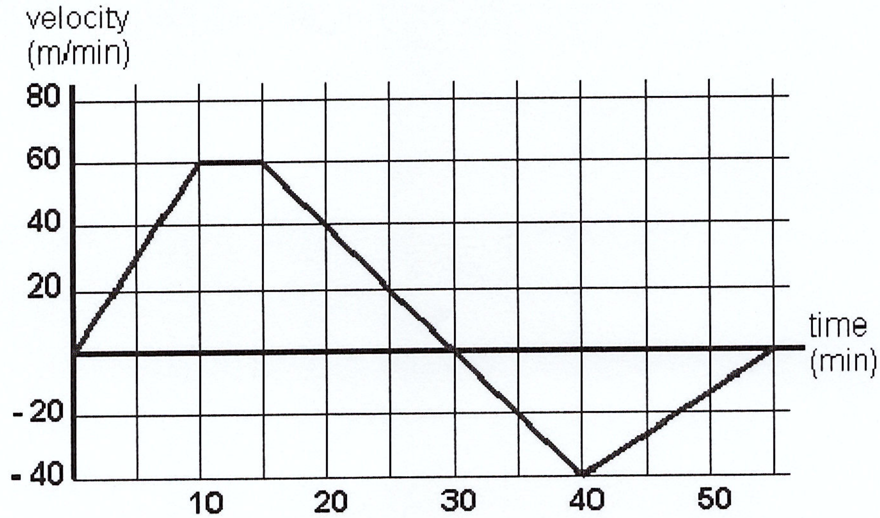
3. The following graph shows the motion of a 915kg object.



   a. What is the magnitude of the net force acting on the object at 200s? **[0 N]**

   b. What is the magnitude to the net force acing on the object at 400s? **[50.3N]**

4. The following graph shows the motion of a 52.0kg object that was initially travelling north.



a. What is the net force acting on the object at 5.0s? **[3.1x10^2 N, north]**

b. What is the net force acting on the object at 12.0s? **[0 N]**

c. What is the net force acting on the object at 25.0s? **[2.1x10^2 N, south]**

- There is another equation that is derived from Newton's second law, which relates the ***mass*** of an object to its ***weight***

$$\vec{g} = \frac{\vec{F}_g}{m}$$ on data sheet or $\vec{F}_g = m g$

where $\vec{F}_g$ is the force due to gravity and is measured in newtons (N). This is what we call ***weight***.

m is the mass of the object (kg)

g is the acceleration due to gravity or *gravitational field strength* (m/s^2 or N/kg). It is always directed toward the center of the mass/planet.

- Difference between weight and mass
  - *Mass* is the amount of matter in an object
  - *Weight* is the force due to gravity acting on an object
  - Mass does not depend on location for a specific object
  - Weight varies from location to location for a specific object
  - Mass is a scalar quantity
  - Weight is a vector quantity

EXAMPLES

1. An object has a mass of 22.0 kg and a weight ($\vec{F}_g$) of 36.0 N near the surface of the moon. What is the acceleration due to gravity near the surface of the moon?

$m = 22.0 kg$

$\vec{F}_g = 36.0 N$

$g = ?$

$$\vec{g} = \frac{\vec{F}_g}{m}$$

$$\vec{g} = \frac{36.0 N}{22.0 kg} = 1.6\overline{3} m/s^2$$

$$\boxed{\vec{g} = 1.64 m/s^2}$$

$\vec{F}_g$

2. An object has a weight of 84N on the surface of the earth. What is the acceleration due to gravity on Mars if the same object has a weight of 62N on Mars?

$\vec{F}_g$

Earth

$\vec{F}_g = 84N$

$\vec{g} = 9.81 m/s^2$

Mars

$\vec{F}_g = 62N$

$\vec{g} = ?$

$\vec{g} = \frac{\vec{F}_g}{m}$ (2)

mars

(1) $\vec{g} = \frac{\vec{F}_g}{m}$

earth

(1) $\vec{g} = \frac{\vec{F}_g}{m}$ "earth" $\Rightarrow m = \frac{\vec{F}_g}{g} = \frac{84N}{9.81 m/s^2} = 8.5626... m/s^2$

(2) $\vec{g} = \frac{\vec{F}_g}{m}$ "mars" $= \frac{62N}{8.5626... m/s^2} = 7.2407... m/s^2$

$\vec{g}$ "mars" $= 7.2 m/s^2$ or N/kg

Now try pg. 74 # 15, 16 (acceptable)