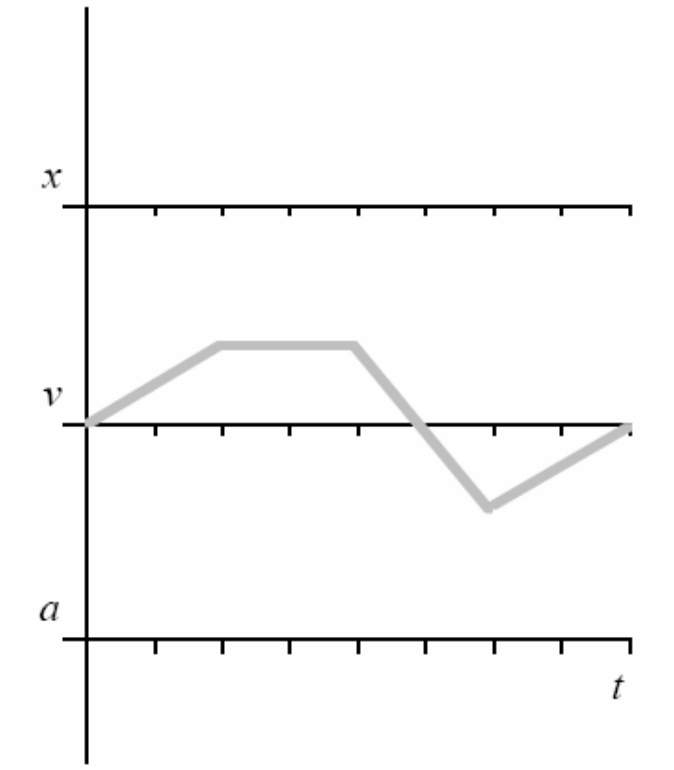
Kinematics II & Dynamics

Kinematics II

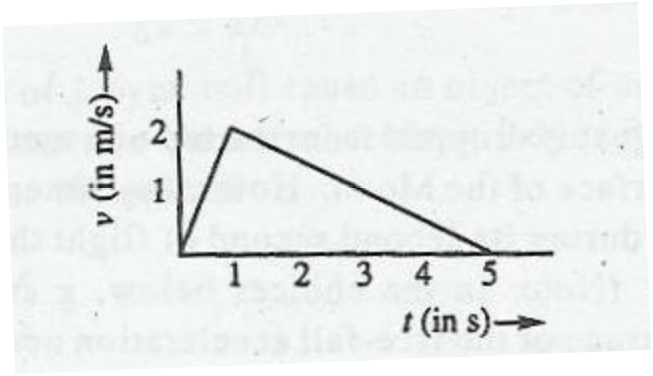
Graph	Slope	Area Under Curve
Position vs. Time	Velocity	
Velocity vs. Time	Acceleration	Displacement
Acceleration vs. Time		Change in Velocity



Things to remember:

- Positive *v* implies forward motion. Negative *v* implies backward motion.
- If $v = 0$, the object has stopped.
- Positive *a* means velocity is increasing. Negative *a* means velocity is decreasing.
- If $a = 0$, the object is moving at constant velocity.

Exercise #1:



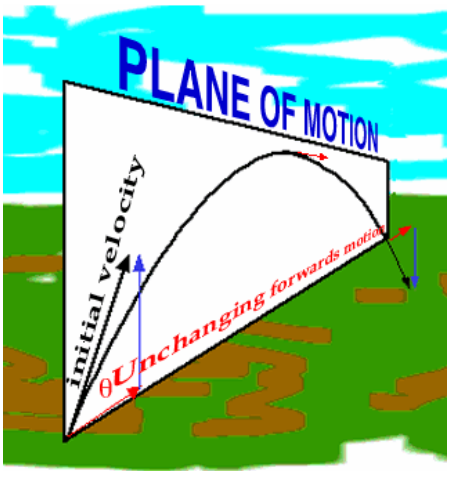
- How far does the object travel from t = 0 to t = 5?
  A. 4 m
  B. 5 m
  C. 6 m
  D. 8 m

- Which of the following statements is (are) true?

  I. At t = 5, the object had returned to its original position.
  II. The object's average speed between t = 0 and t = 1 was greater than its average speed between t = 1 and t = 5.
  III. The object changed its direction of travel at t = 1.

  A. I and II only
  B. I and III only
  C. II and III only
  D. None of the above

Final Look at Projectile Motion:



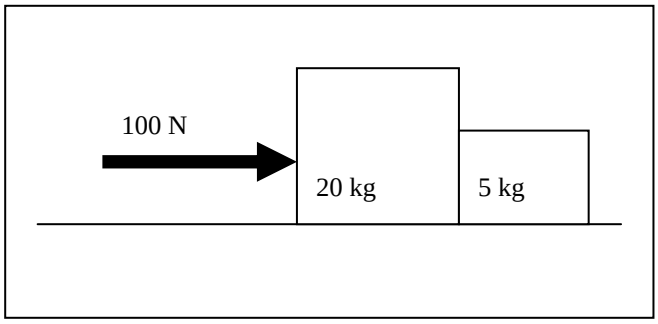
	Horizontal Motion	Vertical Motion
Displacement	$x = v_{o,x}t$	$y = v_{o,y}t - \frac{1}{2}gt^2$
Velocity	$v_x = v_{o,x}$ (constant)	$v_y = v_{o,y} - gt$
Acceleration	$a_x = 0$ (zero acceleration case)	$a_y = -g$ (constant acceleration)

Note that the convention is that **up = positive**. The convention can also be down = negative but then $a_y = +g$

Intro to Dynamics

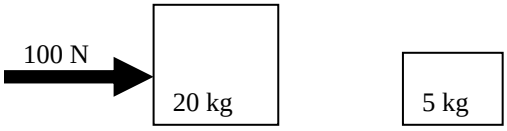
- Basics
  - Dynamics is the study of forces. We NOW care about MASS.
  - A force is a push or pull exerted by one object on another. It is a vector.
  - Newton is the SI unit for force.
  - There are really two types of (commonly used) forces:
    - Gravitational Force
    - Electromagnetic Force
      - normal force (force due to surface)
      - friction (force due to motion along surface or within fluid)
      - tension (force along wire/rope)
- Newton's laws
  - (First law) If there is no **net** force acting on an object, then:
    - An object at rest will stay at rest
    - An object in motion will move at **constant velocity** (constant speed in straight line)
  - (Second law) $F_{net} = ma$
    - F_{net} includes all forces **acting on** object.
    - Acceleration **always** in direction of force, but velocity is **not** always in the same direction as force.
    - Zero net force **always** implies zero acceleration, which implies **constant** velocity.
  - (Third law) Contact forces are **equal** and **opposite**.

Example:



[Let's draw free body diagram]

- Is there a force acting on the 5 kg block?
- What is the net force on the 20 kg block?
- What is the acceleration on each block?



- What is the force on each block?

Which of Newton's laws does this example best illustrate?

Exercise #2:
A hockey puck slides on a surface of frictionless ice. If the mass of the puck is 250 g, and it moves in a straight line with a constant velocity of 4 m/s, find the net force acting on the puck?
A. 0 N
B. 1 N
C. 62.5 N
D. 1000 N

Exercise #3:
An object is being acted upon by two (and only two) external forces F_1 and F_2. If the object has a nonzero acceleration, which of the following must be true?
A. The object cannot move at constant speed.
B. The forces F_1 and F_2 have the same line of action.
C. The magnitude of F_1 can't equal the magnitude of F_2.
D. The sum F_1 and F_2 is nonzero.

- Weight and mass (again)
  - Mass is a scalar and measures an object's resistance to acceleration (inertia):
    $m = F / a$
  - Weight is a force (hence, a vector) and represents the pull on an object by Earth's gravity:
    $W = mg$
  - Weight and mass are directly proportional, but remember that they have different units. Weight (a force) is measured in Newtons. Mass is measured in kg.
  - g = 10 m/s^2
  - The MCAT will always try to trick you on the difference between mass and weight. They sometimes will tell you an object weighs 50 N or they may tell you that an object has a mass of 50 kg. These are **NOT** the same!!
    - An object that weighs 50 N has a mass of 5 kg.
    - An object with a mass of 50 kg weighs 500 N.
- Newton's law of gravitation

$$F_{gravity} = \frac{Gm_1m_2}{R^2}$$

R = **straight** line distance between mass 1 and mass 2
G = gravitational constant, but what are the units?

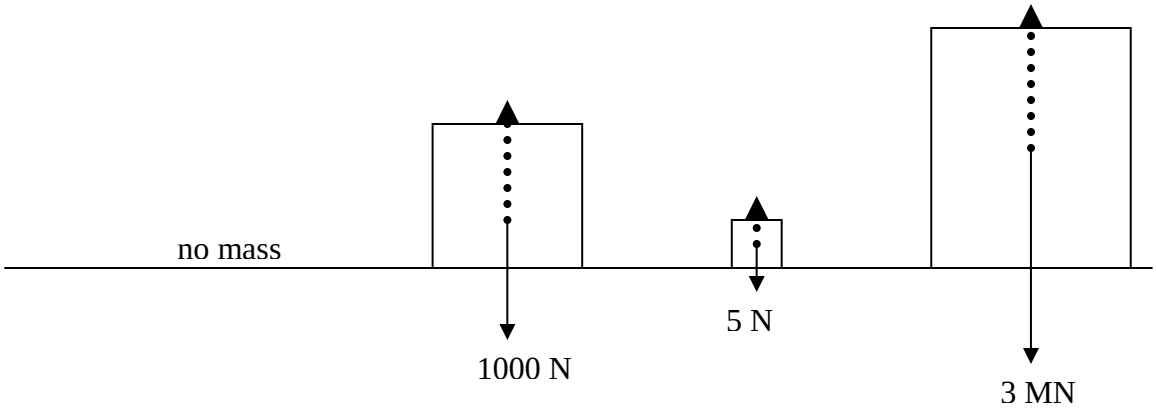
- What's important about gravitational force?
  - Inversely proportional to the **square** of distance
    (If two objects are twice as far from each other, their gravitational force is ¼ less)
  - Always attractive, in that masses always move towards each other
  - Forces come in pairs (equal and opposite) even if there is **no contact**!

Exercise #4:
Find the force that must be provided to lift a 49 N object with an acceleration of 9.8 m/s^2?
(Use g = 9.8 m/s^2)
A. 9.8 N
B. 49 N
C. 98 N
D. 147 N

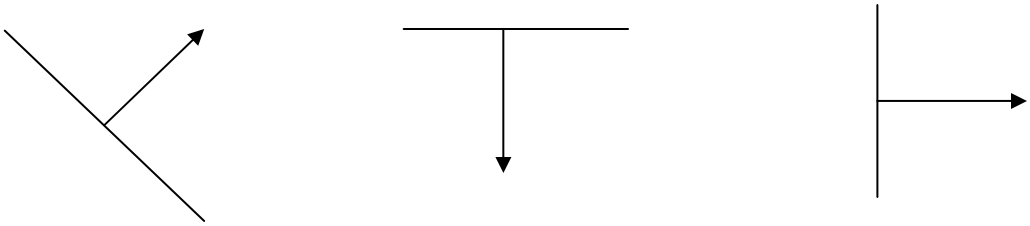
Exercise #5:
An object has a mass of 36 kg and weighs 360 N at the surface of the Earth. If this object is transported to an altitude equal to twice the Earth's radius, then at this new elevated position the object will have:
A. Mass = 4 kg; W = 40 N
B. Mass = 36 kg; W = 40 N
C. Mass = 9 kg; W = 90 N
D. Mass = 36 kg; W = 90 N

- Friction and passive forces
  - Passive forces only react to forces, and act in a direction opposite to an applied force. They never exceed the magnitude of the applied force.
  - Examples of passive force include:
    - Friction
    - Normal force

What's the normal force? (Assume the maximum strength of table is 1 MN)



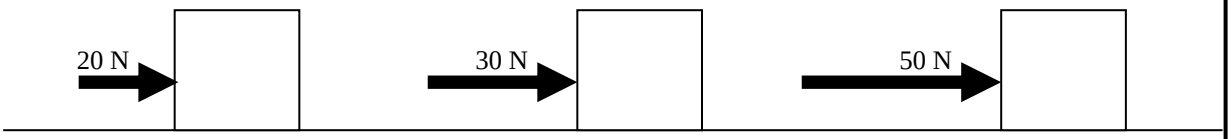
What's the direction of normal force? **ALWAYS PERPENDICULAR**



- Friction depends on normal force and **always retards motion**:
  $f = mN$
- Friction also depends on a constant called the coefficient of friction, which depends of the characteristics of the surface (cement as opposed to ice). There are two types:
  - coefficient of static friction (used when object begins at rest or is **rolling**) = m_s
  - coefficient of kinetic friction (used when object in motion is skidding) = m_k
- The coefficient of static friction is always bigger than the coefficient of kinetic friction, because it's always harder to start something in motion than to keep something in motion.

Example: All objects begin at rest and have a mass of 10 kg. The coefficient of static friction (m_s) is 0.3 and the coefficient of kinetic friction (m_k) is 0.2.

Find the frictional force in each case:



What is the maximum the frictional force can ever be?

Exercise #6:
A person applies a horizontal force *F* on a block of mass m resting against a vertical wall. If the block slides down the wall at constant speed, what must be true about the coefficient of kinetic friction m between the block and the wall?

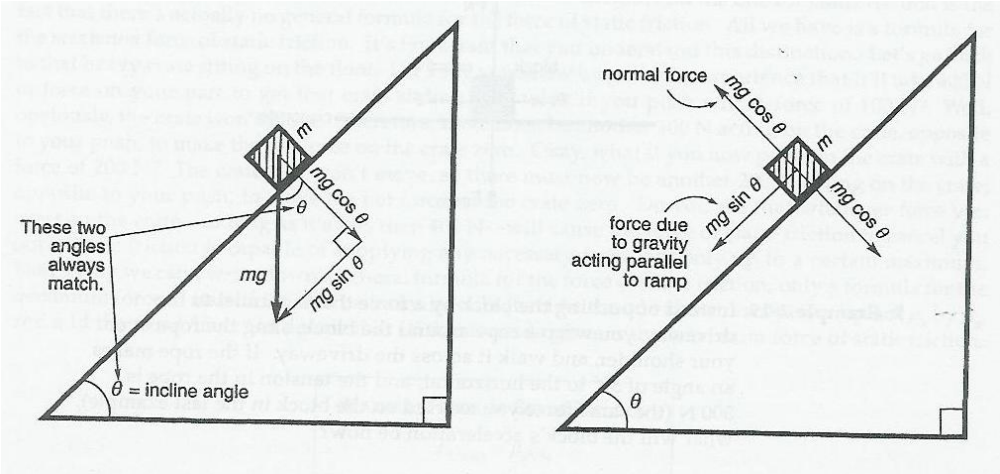
A. $m = \frac{mg}{F}$

B. $m = \frac{F}{mg}$

C. $m = 1$

D. $m = g$

§ Inclined planes
- Note that the incline angle is equal to the angle between weight ($W = mg$) and the normal line (to the inclined surface).
- The normal force is always equal to $N = mg\cos q$.
- In the absence of friction, the acceleration of a block down an incline is $a = g\sin q$. When the incline angle is zero (which means surface is perfectly horizontal), note that the acceleration is g, just a gravitational acceleration straight down.
- Friction always opposed motion. So what would the free body diagram look like if the inclined surface had friction?



§ Pulleys
- A pulley changes the direction of tension (force exerted by stretched string or cord).
- Pulleys are often used to decrease the force needed to lift an object.

§ Free-body diagrams are really important in solving dynamics problems. Always do them!

Example: Find the acceleration experienced by both blocks. (Ans. 1 and 24 m/s^2)