Forces and Motion

IB 11

Observations:

1. A force is **not** necessary for

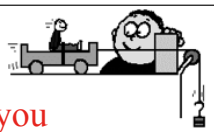
   an object to remain at rest or in constant velocity motion (constant speed in a straight line)

   Two natural states of motion:
   - Constant velocity motion (constant speed in a straight line)
   - Stationary

2. A force **is** necessary for

   an object to change its velocity (speed OR direction of travel)

Why do you feel thrown backwards when a car starts up quickly from rest? Are you really thrown backward? What is actually going on?



You remain at rest – car moves forward underneath you

Why do you feel thrown forward when a speeding car stops abruptly? Are you really thrown forward? What is actually going on?

You remain in motion – car stops

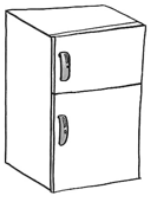
Definitions:

1. Inertia is the tendency of an object to remain at rest or in constant velocity motion

2. Inertia is a measure of the amount of resistance an object has to changing motion (accelerating)

3. Mass is a measure of the amount of inertia an object has.

A

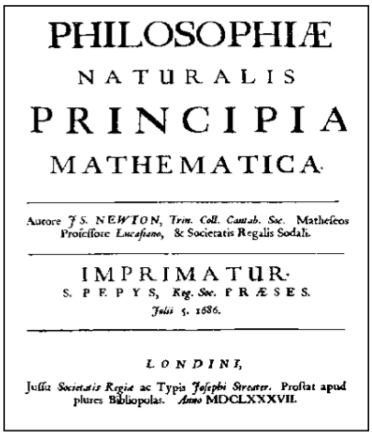


B

1) Which object has more of a tendency to remain at rest?
2) Which object has more of a resistance to changing its state?
3) Which object has more inertia?
4) Which object has more mass?

Isaac Newton

IB 11



PHILOSOPHIÆ
NATURALIS
PRINCIPIA
MATHEMATICA

Autore *J. S. NEWTON*, *Trin. Coll. Cantab. Soc.* Matheseos Professore *Lucasiano*, & Societatis Regalis Sodali.

IMPRIMATUR.
S. PEPYS, *Reg. Soc.* PRÆSES.
Julii 5. 1686.

LONDINI,
Justu *Societatis Regiæ* ac Typis *Josephi Streater*. Prostat apud plures Bibliopolas. *Anno* MDCLXXXVII.

Above is the title page of Isaac Newton's greatest work and one of the most influential books in all of science.

1. What is the title in English?

Mathematical principles of natural philosophy

2. By what title is it commonly known?

The Principia

3. When was it published? 1687

4. What did it contain?

a) 3 laws of motion

b) law of gravity

Sir Isaac Newton
(1643-1727)
English scientist

Newton's Three Laws of Motion (Original Version)

"Every object persists in its state of rest or uniform motion in a straight line unless it is compelled to change that state by forces impressed on it."

"The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed."

"To every action there is always opposed an equal reaction: or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts."

Newton's First Law of Motion (Law of Inertia)

An object at rest remains at rest and an object in motion remains in motion at a constant speed in a straight line (constant velocity) unless acted on by unbalanced forces.

Newton's Second Law of Motion

When unbalanced forces act on an object, the object will accelerate in the direction of the resultant force. The acceleration is directly proportional to the resultant force and inversely proportional to the mass of the object.

Newton's Third Law of Motion

When two objects (A and B) interact, the force that A exerts on B is equal and opposite to the force that B exerts on A.

2

IB 11

Fundamental Forces

gravitational	attraction between matter long range	
electromagnetic	most everyday forces long range	
strong nuclear	holds matter together short range	
weak nuclear	involved with radioactive decay short range	

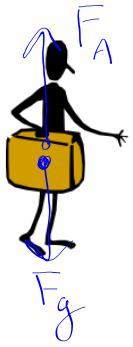
Strong, EM, Weak, Gravitational

On the chart above, rank the fundamental forces from strongest to weakest.

What is a "**free-body diagram?**"

diagram showing all forces on a single object

1. 

2. 

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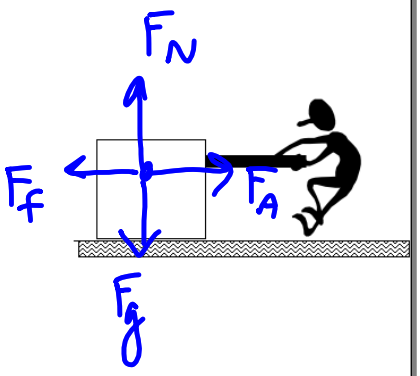
4. 

F_g: force of gravity (weight)

F_A: applied force

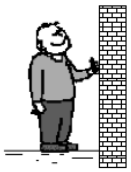
F_N: normal force

F_f: force of friction

1. What is the cause of the normal force?

EM repulsion

2. Why can't you walk through a wall?

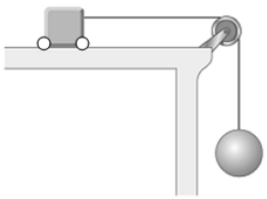


3. What is the cause of the frictional force?

EM attraction

Balanced and Unbalanced Forces

A weight is hung over a pulley by a string that is attached to a cart. The weight is dropped.



1. What will happen to the cart? Why?

   it will accl to the right with fixed accl

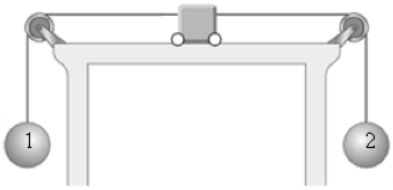
2. What will change if a heavier weight is used?

   higher accl

3. What will change if a heavier cart is used?

   lower accl

A second weight is now hung over a pulley by a string pulling on the cart in the opposite direction.



4. What will happen to the cart if weight #1 is heavier than weight #2?

   accl to the left

5. What will happen to the cart if weight #2 is heavier than weight #1?

   accl to the right

6. What will happen to the cart if both weights are the same?

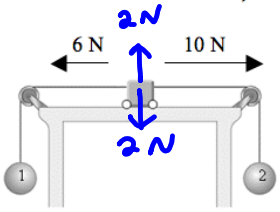
   accl = 0

Net force (F_{net}): resultant of all forces acting on an object – not a separate force – resultant force

ΣF

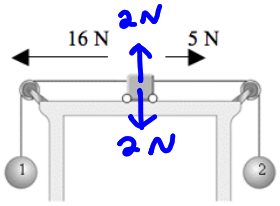
In each case below, determine the net force acting on the cart (magnitude and direction).

7.



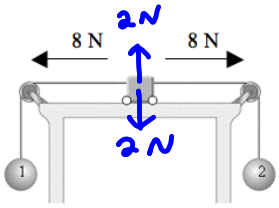
4N right

8.

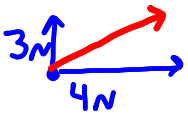


11N left

9.



0N



Conclusions:

1) An object will accelerate in direction of net force.

2) Acceleration of an object is directly proportional to the net force on the object.

3) Acceleration of an object is inversely proportional to the mass of the object.

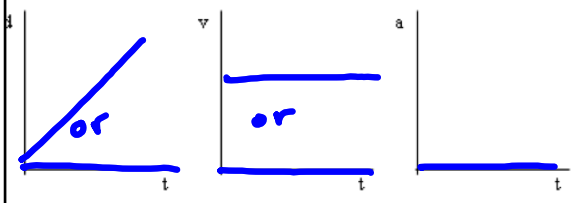
Balanced Forces

If all the forces acting on an object are balanced,

accl = 0

Equilibrium

Newton's 1st law

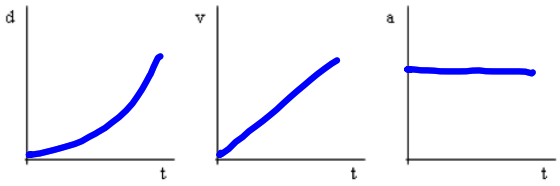


Unbalanced Forces

If all the forces acting on an object are **not** balanced,

accl ≠ 0

Newton's 2nd law



Newton's Second Law of Motion:

$$\Sigma \vec{F} = m\vec{a}$$

Variable:	$\mathbf{F_{net}}$	**m**	**a**
Quantity:	Net Force	mass	acceleration
Units:	$[N]$	$[kg]$	$[m/s^2]$
Type:	vector	scalar	vector

Write the unit for force in terms of fundamental units: $[N] = \left[\frac{kg\ m}{s^2}\right]$

1) A net force of 100. N acts west on a 5.0 kg mass. Determine the magnitude and direction of the acceleration of the mass.

$\Sigma \vec{F} = m\vec{a}$ $\quad \vec{a} = \frac{\Sigma \vec{F}}{m} = \frac{100.N}{5.0kg} = 20 m/s^2$ west

2) A 1.6 -kg box is accelerated at 2.0 m/s^2. Determine the magnitude of the net force.

$\Sigma \vec{F} = m\vec{a}$
$= 1.6kg\,(2.0\ m/s^2) = 3.2N$

3) An 80. kg student is pulled on roller blades by a friend who exerts a force of 20.0 N. Friction between the wheels and the ground exert a force of 5.0 N. What is the student's acceleration?

4) A 1000. kg car accelerates from rest to 20. m/s in 5.0 seconds. What net force acts on the car?

5) A 15.0 kg crate is dragged across the floor with an acceleration of 0.80 m/s^2 by an applied force of 22 N. How much friction is acting on the crate?