New HW assignment

- Turn in homework by section number
- Chapter 4
- Conceptual Exercises
  - 2, 30, 36, 40
- Problems
  - 4, 6, 16

From Before...

- Defined mass $m$ and inertia:
  - Mass is amount of inertia of a body
  - Measured in kg
- Defined momentum $p$:
  - $p=mv$, momentum is said to be conserved
- Defined force $F$:
  - Something that changes a body’s velocity: acceleration
  - Can transfer momentum from one body to another
- Related force, mass, and acceleration:
  - $F=ma$, or $a=F/m$
  - Subject to the same force, more massive objects accelerate more slowly.
- Weight:
  - Force of gravity on a body = $mg$
  - Measured in newtons (N). $1\text{ N} = 1\text{ kg-m/s}^2$

Colliding balls again

Before collision:

During collision

Force on ball 1 decelerates it to zero velocity

Force on ball 2 accelerates it

After collision:

Example: Net Force

- $M=10\text{ kg}$, $F_1=200\text{ N}$

Find $a$

$a = \frac{F_{\text{net}}}{M} = \frac{200\text{ N}}{10\text{ kg}} = 20\text{ m/s}^2$

Example: Force and Dif Masses

- A force $F$ acting on a mass $m_1$ results in an acceleration $a_1$.
  - The same force acting on a different mass $m_2$ results in an acceleration $a_2 = 2a_1$. What is the mass $m_2$?

(a) $m_2 = 2m_1$
(b) $m_2 = m_1$
(c) $m_2 = m_1/2$

$F=ma$

- $F= m_1a_1 = m_1(2a_1)$
- $F= m_1(a_1) = 2m_2(a_2)$
- Therefore, $m_2 = m_1/2$

Or in words...twice the acceleration means half the mass

Example: Net Force

- $M=10\text{ kg}$, $F_1=200\text{ N}$, $F_2 = 100\text{ N}$

Find $a$

$a = \frac{F_{\text{net}}}{M} = \frac{(200\text{ N} - 100\text{ N})}{10\text{ kg}} = 10\text{ m/s}^2$

A little more about weight

- Force of gravity acts downward on the block, but the block does not fall.
- Another force is present, which balances the gravitational force.
- It is exerted by the table, on the block.
How can the table exert a force?

- The interaction between the table and the block is a microscopic one.

Force of table on block

- The table can compress, bend, and flex by distorting the atomic positions.
- The atomic bond is like a spring - it exerts a force on the block.
- All forces arise at the atomic (or smaller) scale.

Law of force pairs

- Every force is an interaction between two objects
- Each of the bodies exerts a force on the other.
- The forces are equal and opposite
  - An action-reaction pair.

Question

How do the forces on the wall and car compare?

A. Force on car larger than on wall
B. Force on car smaller then on wall
C. Both forces are the same.

Question, part 1

Suppose you are an astronaut in outer space giving a brief push to a block whose mass is bigger than your own.

1) Compare, while you are pushing, the magnitude of the force you exert on the block, \( F_{\text{Block}} \), to the magnitude of the force exerted by the block on you, \( F_{\text{Astronaut}} \).

A. \( F_{\text{Astronaut}} = F_{\text{Block}} \)
B. \( F_{\text{Astronaut}} > F_{\text{Block}} \)
C. \( F_{\text{Astronaut}} < F_{\text{Block}} \)

Third law! Equal and opposite reaction force

Question, part 2

Compare, while you are pushing, the magnitudes of the acceleration you experience, \( a_{\text{Astronaut}} \), to the magnitude of the acceleration of the block, \( a_{\text{Block}} \).

A. \( a_{\text{Astronaut}} = a_{\text{Block}} \)
B. \( a_{\text{Astronaut}} > a_{\text{Block}} \)
C. \( a_{\text{Astronaut}} < a_{\text{Block}} \)

\[ a = \frac{F}{m} \]

With the same \( F \), the smaller mass has the greater \( a \).
Identifying forces

- If horse exerts force on cart, and cart exerts equal and opposite force on horse, how can the cart move?

Keep the forces straight!

- For motion of cart, need to identify the net force on the cart.
- Net horizontal force is force from horse, combined with frictional force of wheels.

Question

- A person weighing 600 N wants to hover using a jet pack. What should the thrust be?
  
  A. 0  
  B. 600 N  
  C. 9.8 m/s/s

Question, part 2

- The thrust of the jet pack is increased to 800 N. What is the acceleration of the person?
  
  A. g  
  B. (4/3)g  
  C. g/3

Net force = 800N - 600N = 200N
What is the mass? \( mg = 600N \) (weight), so \( m = \frac{600N}{g} \)
\( a = F_{net}/m = \frac{200N}{(600N/g)} = g/3 \)

Newton’s 1st law of motion

1. Every object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.

   This is the law of inertia

Newton’s 2nd law of motion

2. The acceleration of a body along a direction is
   - proportional to the total force along that direction, and
   - inversely proportional to the mass of the body.

   \( F = ma \) or, \( a = F/m \)
Newton’s 3rd law of motion

• The forces exerted between two interacting objects are equal in magnitude and opposite in direction.

Action equals reaction. A general statement about forces between objects.

How can a car move?

Vertical forces

Horizontal forces

Gravitational force on car

Force exerted by road on car

Rolling resistance by road on tires

Drive Force by road on tires

Wheels push push backward against the road, Road pushes forward on the tire

Equal accelerations

• If more massive bodies accelerate more slowly with the same force...

... why do all bodies fall the same, independent of mass?

• Gravitational force on a body depends on its mass:

\[ F_{\text{gravity}} = mg \]

• Therefore acceleration is independent of mass:

\[ a = \frac{F_{\text{gravity}}}{m} = \frac{mg}{m} = g \]

A fortunate coincidence

• A force exactly proportional to mass, so that everything cancels nicely.

• But a bit unusual.

• Einstein threw out the gravitational force entirely, attributing the observed acceleration to a distortion of space-time.

Curved space-time

• Bodies obey inertial law

• But the ‘straight-line’ motion appears curved

• Body follows shortest space-time path (geodesic)

• This is a heuristic view of general relativity – an accurate description is quite complicated.

• Will discuss this in Chap. 11