Announcements

1. **Exam:** The first exam covers material from chapters 2 and 3 only. That is, this lecture marks the first stuff for exam 2.
   → Exam 1 doesn't start until a week from Friday
2. **Sample Exam(s)**: on website. With and without solutions.
3. **Calculator:** Graphing calculators are not allowed on the exams. You will need an inexpensive calculator that has scientific functions such as trig, exponents, etc.
   a. Tip: You should be doing your HW on this calculator so you are very used to it.
4. **Interacting with TAs**: "Could you explain it to me a different way?"

Exam Formulas

To be given on exam

g=9.80 m/s^2

If $ax^2 + bx + c = 0, \quad x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

For constant a:

$$x = x_o + v_o t + \frac{1}{2}at^2$$

$$v^2 = v_o^{\,2} + 2a\left(x - x_o\right)$$

To be memorized (not an exhaustive list!)

Definition: $v_{ave} = \langle v \rangle = \dfrac{\Delta x}{\Delta t}$

Definition: $a_{ave} = \langle a \rangle = \dfrac{\Delta v}{\Delta t}$

For constant a:

$v = v_o + at$ (reflects fact that $v(t)$ is a straight line when a is constant)

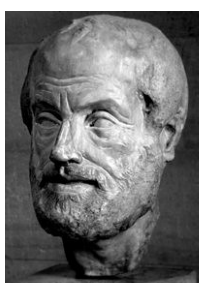
$v_{ave} = \langle v \rangle = \dfrac{v_i + v_f}{2}$ (since v is linear when a is constant, the average must be halfway between the beginning and ending velocities)

Forces and motion

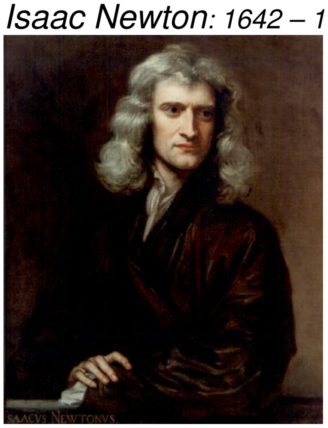
Aristotle: 384 – 322 BC, Greece

gravity - earth and water want to come to rest on the ground

levity - air and fire want to rise above us



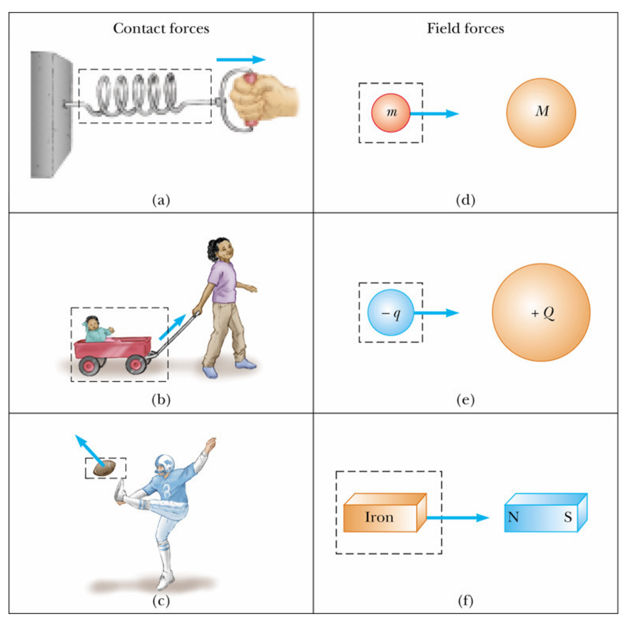
Isaac Newton: 1642 – 1727, England



- Laws of mechanics
- Universal Gravitation
- Calculus
- Light and optics

Force:

A push or pull between **pairs** of objects



*Newton's First Law: **Inertia***

How do astronauts know which chocolate milk carton is empty?

N1: "Objects will continue to move at *constant velocity* unless acted upon by an outside force."
→ the velocity could be zero
→ remember, velocity includes direction

Demo: Inertia Balls

***Mass** m: "A measure of the resistance of an object to changes in its motion due to a force"*
SI unit: kilogram

Newton's second law

N2: $\Sigma\vec{F} = m\vec{a}$

Forces are vectors!

$\rightarrow a \propto F$
$\rightarrow a \propto 1/m$

Units of force:
1Newton = 1 kg m/s^2

1 N = 0.2248 lb
(pounds: mass or weight?)

Typical question: find the acceleration (…and then other quantities)

Q4. You push your 40 kg shopping cart with a constant force of 50 N, and find there is a backwards frictional force of 20 N on it. What will be the acceleration?
a. 0.50 m/s^2
b. 0.75 m/s^2
c. 1.25 m/s^2
d. 1.33 m/s^2
e. 2.00 m/s^2

Gravity

Force of gravity: "weight"

Acceleration of "g", then…

$\boldsymbol{F_g = mg}$

→ the force is still pulling down even if the object is not allowed to accelerate

Weight

→ proportional to the mass

→ depends on location (whereas mass does not!)

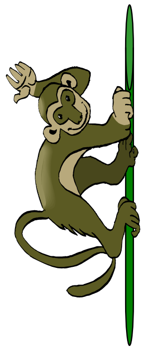
Free-body diagrams
aka "force diagrams"

1. Draw the object of interest alone (you can combine several objects as a "single object" if they have the same *a*).
2. Draw all outside forces on the object as arrows
3. Label each outside force
4. Choose a positive direction
5. Draw the object's net $\vec{a}$ on the diagram, but not directly on the object (it's not a force)
6. Apply N2 to both the x- and y-components:
   $\Sigma F_x = ma_x$ and $\Sigma F_y = ma_y$

   (*m* is the mass of the object *in the diagram*)

Connected objects
- You need as many equations as you have unknowns to find. Substitute to solve system of equations.
- Shortcut: You can also draw a FBD for the objects as a **group**, and use the second law. *Sometimes* you don't need to solve equations simultaneously.

Q5. A monkey starts to slide down a rope. As it speeds up, it tightens its grip, until it slides at a constant velocity down the rope. Which of these choices correctly represents the relative magnitude of the forces as it is sliding with constant velocity?



a. The gravitational force is equal to the frictional force.
b. The gravitational force is greater than the frictional force.
c. The gravitational force is less than the frictional force.

Worked Problem

A 2-gram (0.002 kg) ping-pong ball is pushed 3 meters along an evacuated tube by a constant force of 40 N from air behind it. What is the exit velocity?

Demo: Ping-pong ball cannon (2^{nd} Law)

Newton's Third Law

Forces always come in *pairs*, one on *each object* in the pair.

$$\vec{F}_{12} = -\vec{F}_{21}$$

The magnitudes of the forces in a pair are always ________, and the direction is _____________.

Video: Reaction gliders (3^{rd} Law)

Are the ***acceleration*** magnitudes of the two objects in a pair the same?

Demo: Bearing Carts (3^{rd} Law)

A car is at rest on a road. Identify the forces on the car, and their partner forces on other objects.

Q6. The car accelerates forward when the gas pedal is pushed.
The **force** that actually **accelerates** the **car** is:

1. a force of the car pushing backward on the road
2. a force of the car pushing forward on the road
3. a force of the road pushing forward on the car
4. a force of the road pushing backward on the car

Hint: the acceleration is in the same direction as the total force.

Worked Problem

Mary (40 kg) and Fred (60 kg) have an argument on frictionless ice. Mary pushes Fred with a force of 120 N (27 lbs) for 0.5 second

What is Fred's acceleration while she pushes him?

Mary's acceleration while she pushes him?

What is Fred's acceleration after he is out of Mary's reach?

What are their final velocities?

A 3000 kg truck pushes on a 1000 kg stalled car, and together they **accelerate at 2 m/s^2**

Ignore vertical forces.

Q7. What is the net force on the car? (in N)
A. 1000 B. 2000 C. 3000 D. 6000 E. 8000

Q8. What is the net force on the truck? (in N)
A. 1000 B. 2000 C. 3000 D. 6000 E. 8000

Q9. What is the force of the car on the truck? (in N)
A. 1000 B. 2000 C. 3000 D. 6000 E. 8000

Q10. What is the forward force of the ground on the truck?
A. 1000 B. 2000 C. 3000 D. 6000 E. 8000

Elevator Problem

Mary has a mass of 40 kg (weight = 392 N), and stands on a SI-unit scale in the elevator.

a. The elevator is at rest. What is the scale reading?

b. The elevator accelerates **downward** at 2 m/s^2. What is the scale reading?

c. After a while the elevator moves down at a constant speed of 8 m/s. What is the scale reading?