PHY131H1F - Class 9

Today, Chapter 5 “Force and Motion”:

- Forces
- Free Body Diagrams
- Newton’s First Law
- Newton’s Second Law

Clicker Question

- You toss a ball straight up in the air.
- Immediately after you let go of it, what forces are acting on the ball?

1. The downward force of gravity from the Earth.
2. An upward throwing force from your hand.
3. A small downward drag-force from air resistance.

A. 1, 2 and 3
B. 1 and 3
C. 1 and 2
D. 1 only
E. 2 and 3

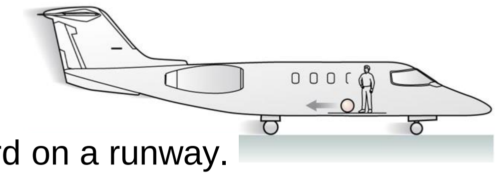
Last day I asked at the end of class:

- A paperback novel has a mass of 0.3 kg and slides at a constant velocity of 5 m/s, to the right. A physics textbook has a mass of 3.0 kg, and slides at a constant velocity of 5 m/s, to the right. How does the net force on the textbook compare to the net force on the novel?
- ANSWER: SAME – zero!
- The net force on any object is proportional to its acceleration.
- In the case of these two books, they are both traveling at a constant velocity, meaning acceleration is zero.
- Any friction must be offset by some pushing force, not mentioned in the question.

Isaac Newton

- Born in 1643, the year Galileo died.
- Was a "physicist, mathematician, astronomer, natural philosopher, alchemist, and theologian and one of the most influential people in human history." (http://en.wikipedia.org/wiki/Isaac_Newton)
- In *Philosophiæ Naturalis Principia Mathematica*, published 1687, he described **universal gravitation** and the **three laws of motion**, laying the groundwork for classical mechanics.

Clicker Question



- You are in a plane which is accelerating forward on a runway.
- Some careless person has left a tennis ball in the aisle. You notice this tennis ball is accelerating toward the back of the plane.
- Newton's Second Law states that $F_{net} = ma$, so there must be a net force on the tennis ball. What is the source of this backward net force?

A. Air resistance

B. The plane must be at an angle, so a component of gravity provides the net force toward the back of the plane.

C. The inertial force

D. The normal force

E. Newton's second law is not valid in your reference frame.

SI Units

- The SI unit of mass is the kilogram. What is the SI unit of weight?

A. m/s^2

B. the newton

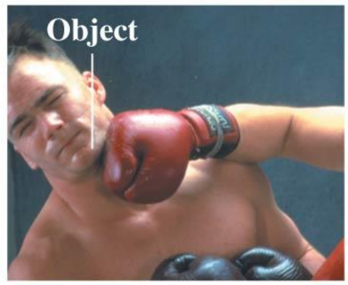
C. metric mass

D. the kilogram

E. the joule

What is a force?

- A force is a push or a pull on an object.
- Pushes and pulls are applied *to* something
- From the object's perspective, it has a force *exerted* on it
- A force is either a contact force (like normal) or a long-range force (like gravity).
- The S.I. unit of force is the Newton (N)
- N is not a fundamental unit; it can be broken down into fundamental units:

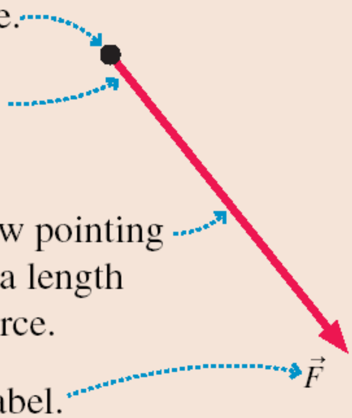


$$1\ \mathrm{N} = 1\ \mathrm{kg\ m\ s^{-2}}$$

Tactics: Drawing force vectors

TACTICS BOX 5.1 **Drawing force vectors**

1. Represent the object as a particle.
2. Place the *tail* of the force vector on the particle.
3. Draw the force vector as an arrow pointing in the proper direction and with a length proportional to the size of the force.
4. Give the vector an appropriate label.



A Short Catalog of Forces

The forces we deal with most often in PHY131/132 are:

- Gravity ($F_g = mg$)
- Normal Force
- Tension
- Kinetic Friction ($f_k = \mu_k n$)
- Static Friction
- Spring Force
- Electric
- Magnetic
- Thrust (like from a rocket)
- Drag (fluid resistance)
- Muscle

Crash test dummies model the muscles of the neck as springs

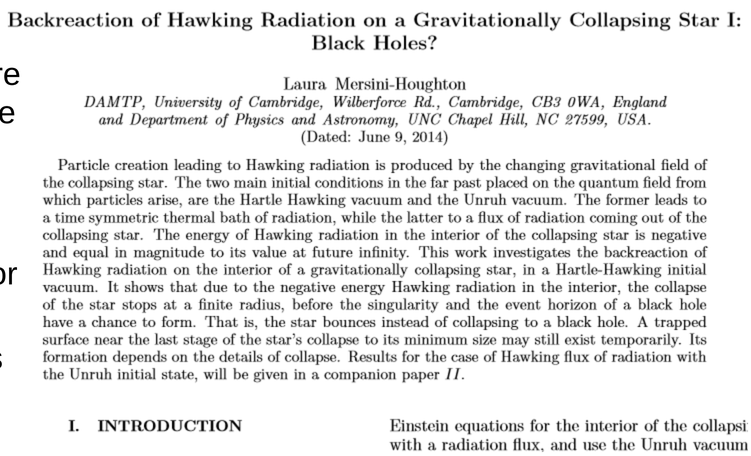
Gravity

- $\vec{F}_G = m\vec{g}$ when the object is near the surface of Earth
- $\vec{g} = 9.80\,\frac{\mathrm{N}}{\mathrm{kg}}, down$
- Sometimes called "weight"

Gravity Research

- There was a paper this year claiming that, mathematically speaking, black holes cannot exist.
- Certainly, from an astronomer's point of view, black holes (or something very much like them) are very prevalent and numerous in the universe!
- The first black hole for which there was strong evidence was Cygnus X-1, discovered by U of T professor Tom Bolton in 1972
- Since then over 100 of black holes have been discovered

http://arxiv.org/pdf/1406.1525v1.pdf



Backreaction of Hawking Radiation on a Gravitationally Collapsing Star I: Black Holes?

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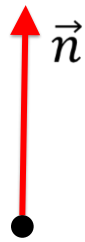
(Dated: June 9, 2014)

Particle creation leading to Hawking radiation is produced by the changing gravitational field of the collapsing star. The two main initial conditions in the far past placed on the quantum field from which particles arise, are the Hartle Hawking vacuum and the Unruh vacuum. The former leads to a time symmetric thermal bath of radiation, while the latter to a flux of radiation coming out of the collapsing star. The energy of Hawking radiation in the interior of the collapsing star is negative and equal in magnitude to its value at future infinity. This work investigates the backreaction of Hawking radiation on the interior of a gravitationally collapsing star, in a Hartle-Hawking initial vacuum. It shows that due to the negative energy Hawking radiation in the interior, the collapse of the star stops at a finite radius, before the singularity and the event horizon of a black hole have a chance to form. That is, the star bounces instead of collapsing to a black hole. A trapped surface near the last stage of the star's collapse to its minimum size may still exist temporarily. Its formation depends on the details of collapse. Results for the case of Hawking flux of radiation with the Unruh initial state, will be given in a companion paper *II*.

I. INTRODUCTION

Einstein equations for the interior of the collapsi
with a radiation flux, and use the Unruh vacuum

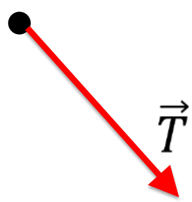
Normal Force



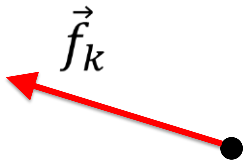
"The diving board exerts a normal force on the dog."

Tension

"The rope exerts a tension force on Harlow."



Kinetic Friction



$$f_k = \mu_k n$$

"The ground exerts a kinetic friction force on Suleyman."

where n is the magnitude of the normal force, and μ_k is a constant, which happens to be low for plastic on snow.

Static Friction

"The ground exerts a static friction force on the shoe."

Clicker Question

- A car is parked on flat, horizontal pavement.
- Which of the following forces are acting on the car?

A. Gravity
B. Normal
C. Static friction
D. Both A and B
E. A, B and C

Clicker Question

The Net Force

- A car is parked on flat, horizontal pavement.
- The “net force” is the vector sum of all the forces on the car.
- What is the direction of the net force on the car?

A. Up
B. Down
C. The net force is zero

An ***Even Shorter*** Catalog of Forces

The four fundamental forces in the universe are:

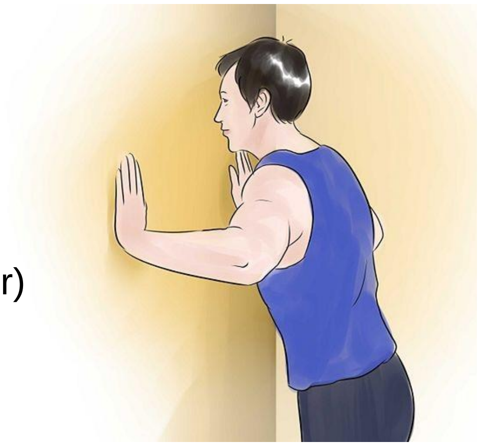
- Gravity ($F_g = mg$)
- Electric & Magnetic
- "Strong Nuclear" – holds the nucleus together
- "Weak Nuclear" – governs beta-decay

Every force you can experience is a manifestation of one or more of the above.

A Person Exerts a Force on A Wall

This contact force is an example of:

A. Gravity Force
B. Electric & Magnetic Force
C. Strong (holds nucleus together)
D. Weak (radioactive decay)
E. None of the above



The Fundamental Forces of Nature

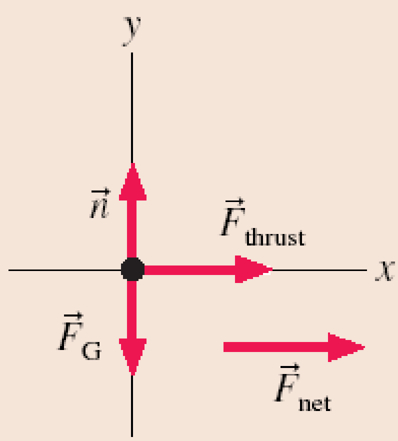
The four fundamental forces of nature:

1. **Gravity**
2. **Electromagnetism**
3. **Weak** Nuclear Force
4. **Strong** Nuclear Force

- **Gravity** is always attractive, and acts between any two objects.
- **Electromagnetism** causes repulsion and attraction between charged particles, such as the protons and electrons in matter. This gives rise to almost *all* of the forces we deal with in PHY131/132: Normal, Tension, etc.
- **Weak** and **Strong** Nuclear forces are important in understanding how atomic nuclei are held together and certain forms of radiation – not important for PHY131/132.

Free-Body Diagrams

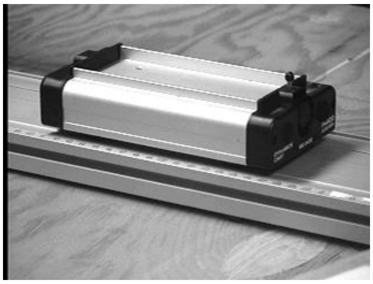
A free-body diagram represents the object as a particle at the origin of a coordinate system. Force vectors are drawn with their tails on the particle. The net force vector is drawn beside the diagram.



1

Newton's First Law

The natural state of an object with no net external force on it is to either remain at rest or continue to move in a straight line with a constant velocity.



What is Mass?

- Mass is a scalar quantity that describes an object's inertia.
- It describes the amount of matter in an object.
- **Mass is an intrinsic property of an object.**
- It tells us something about the object, regardless of where the object is, what it's doing, or whatever forces may be acting on it.

2 Newton's Second Law

The acceleration of an object is directly proportional to the net force acting on it, and inversely proportional to its mass.

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

Clicker Question

A fan attached to a cart causes it to accelerate at 2 m/s^2.
Suppose the same fan is attached to a second cart with smaller mass.
The mass of the second cart plus fan is half the mass of the first cart plus fan. The acceleration of the second cart is

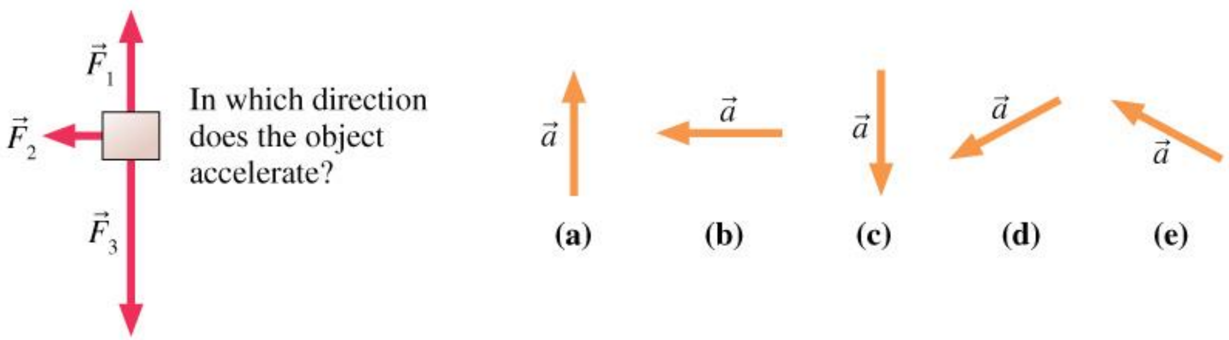
A. 16 m/s^2.
B. 8 m/s^2.
C. 4 m/s^2.
D. 2 m/s^2.
E. 1 m/s^2.

Projectile Motion Example

- An angry bird of mass $m = 0.12\ \mathrm{kg}$ is flying through the air. His wings are tucked in, and air resistance is negligible.
- What is the acceleration of the bird?

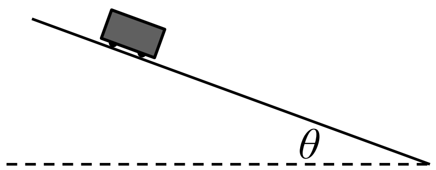
Clicker Question

Three forces act on an object. In which direction does the object accelerate?



Mass on Frictionless Inclined Plane Example

- A cart of mass $m = 0.195$ kg is rolling on a track that is inclined at an angle θ above the horizontal. Friction is negligible.
- What is the acceleration of the cart?



Problem Solving Strategy

- Acceleration is the link between dynamics and kinematics.
- From F_{net}, find a.
- From a and initial conditions, find v_x, v_y, x, y.
- $a = 0$ is the condition for equilibrium.
  - "static equilibrium" is when $a = 0$ and $v = 0$.
  - "dynamic equilibrium" is when $a = 0$ and $v \neq 0$.
- Equilibrium occurs if and only if $F_{net} = 0$.

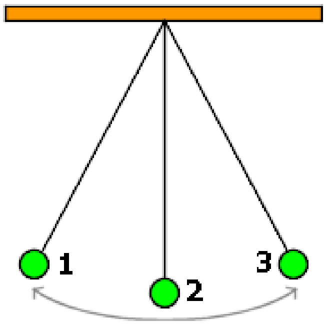
Clicker Question

- A green ball swings back and forth between positions 1, 2 and 3. F_g is the magnitude of the force of gravity on the ball. T is the magnitude of the tension force on the ball. At the instant the ball is in position 2,

A. $F_g > T$

B. $F_g < T$

C. $F_g = T$



Before Class 10 on Wednesday

- Please read Chapter 6 of Knight, sections 6.1 through 6.3.
- Something to think about:
- When astronauts are floating in a space station, are they really weightless?

Have you seen Canadian Astronaut Chris Hadfield singing a revised version of David Bowie's "Space Oddity" on the International Space Station? http://youtu.be/KaOC9danxNo .