Physics 211

Sections 1 & 70

Dr. Geoffrey Lovelace

Fall 2012

Lecture 21 (11/13/12)

Lecture 21 outline

- Announcements
- Gravitation wrap up
  - Kepler's laws
- Some concepts of thermodynamics
  - Temperature
  - Heat
  - Entropy

Announcements

- Homework #9: due **today** at 11:59PM
- Lecture slides posted to piazza.com
- Exam #3: Thursday
  - Post questions at piazza.com
  - Bring: No. 2 pencils, eraser, sharpener, scientific calculator, your CWID
- Reading: Will begin chapter 8 after the break
- Office hours: **bonus 10AM-11AM today only** and 4PM-5PM today
  - McCarthy Hall room 601B

Exam advice

- What to study
  - Examples in text (work, then check)
  - Clicker questions from class
  - Learning path review: summarize materials
  - Homework problems
  - Odd-# problems (conceptual and quant.)
- Exam format
  - Same as last time: conceptual and quantitative problems, mostly multiple choice

Today →

Oct 23	**Exam 2**
Oct 25	Linear momentum, conservation of linear momentum
Oct 30	Conservation of linear momentum, collisions
Nov 1	Center of mass, rockets, *HW #8 due*
Nov 6	Circular motion, gravitation
Nov 8	Gravitation, Kepler's laws
Nov 13	Special feature: temperature, heat, entropy *HW #9 due*
Nov 15	**Exam 3**
Nov 20	*Fall Recess — No class*
Nov 22	*Fall Recess — No class*
Nov 27	Rigid body rotation, torque, rotational dynamics
Nov 29	Rotational dynamics, rotational energy, *HW #10 due*
Dec 4	Angular momentum, conservation of angular momentur
Dec 6	Harmonic motion, *HW #11 due*
Dec 11	Harmonic motion & waves
Dec 13	Gravitational waves, harmonic motion, black holes, *HW*
Dec 20	**Final exam 9:30AM–11:20AM**

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Newton's law of gravity

- Gravity = attractive force of magnitude

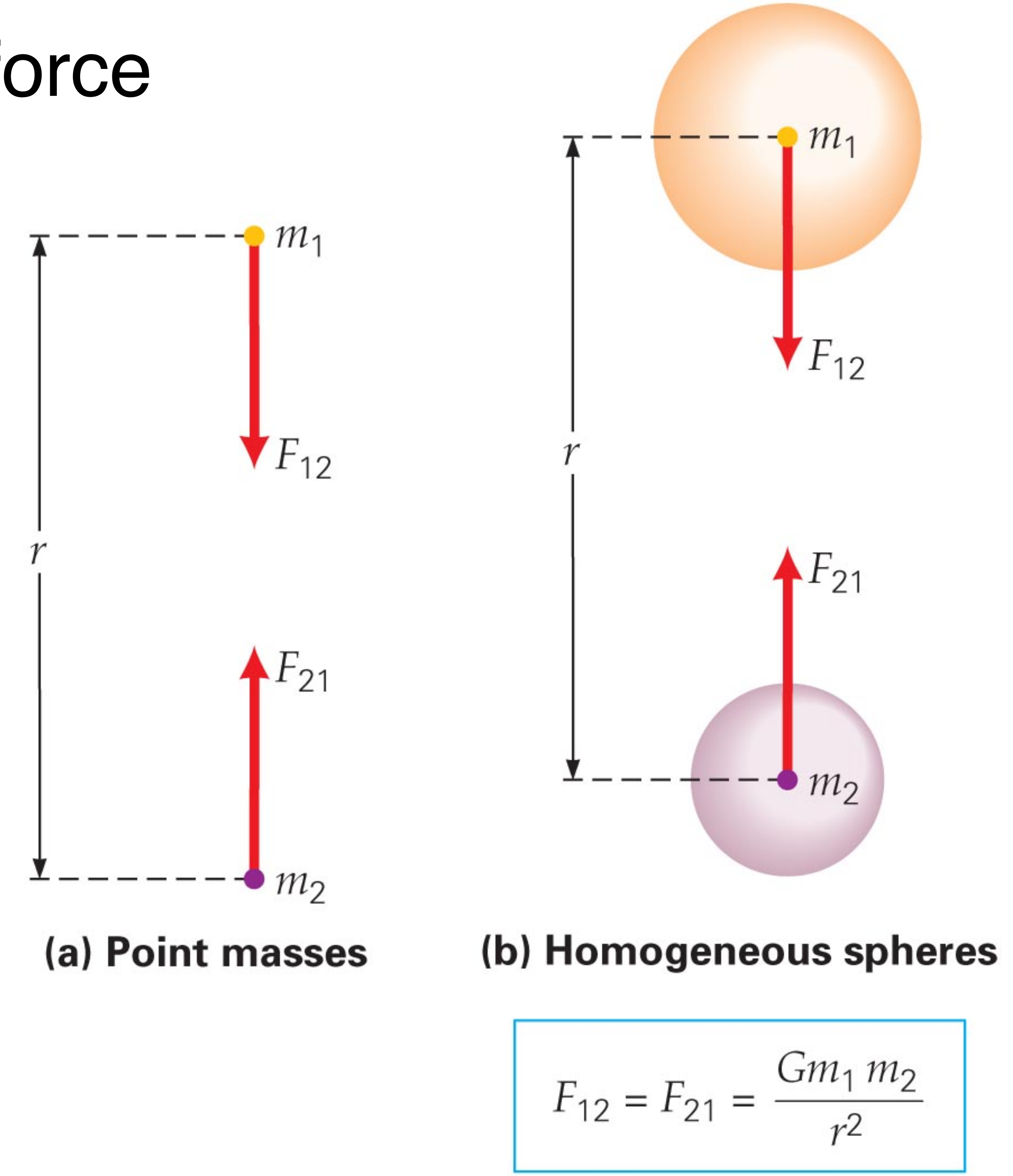
$$F = \frac{Gm_1m_2}{r^2}$$

$$G = 6.67 \times 10^{-11}\mathrm{N}\frac{\mathrm{m}^2}{\mathrm{kg}^2}$$

- Acceleration of gravity

$$F = mg = \frac{GmM_E}{R_E^2}$$

$$g = \frac{GM_E}{R_E^2}$$



Clicker question #94

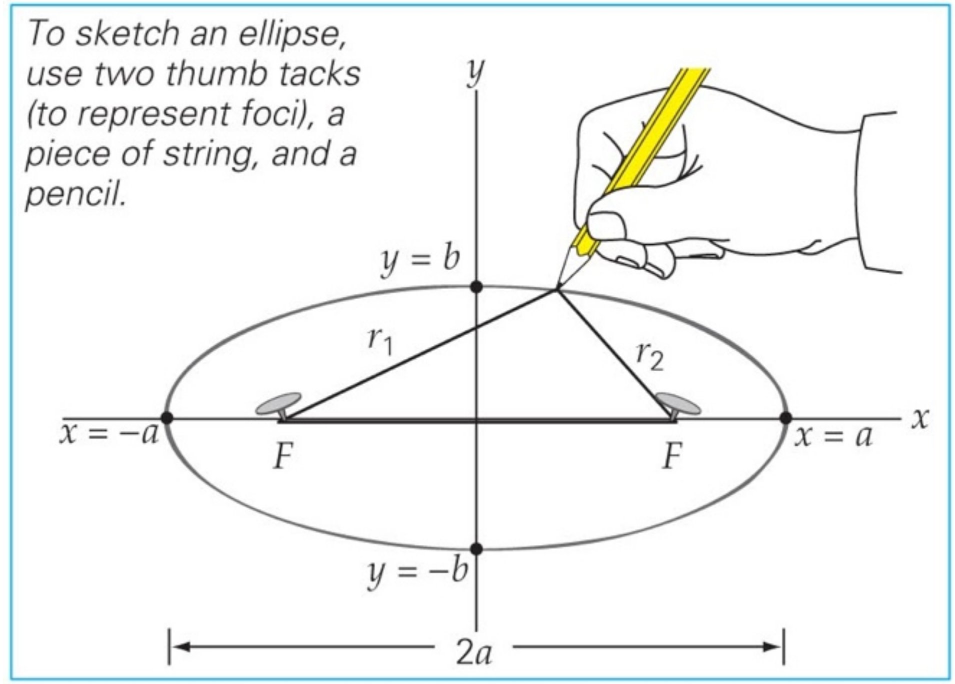
Question 7.8 Fly Me Away

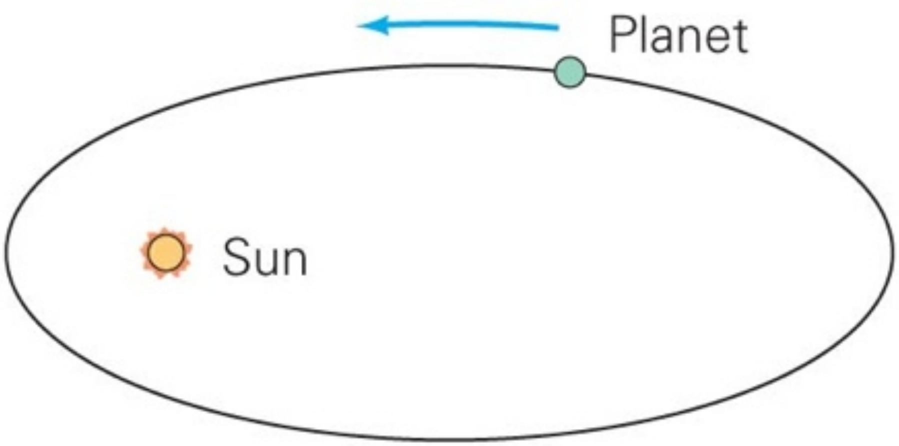
You weigh yourself on a scale inside an airplane that is flying with constant speed at an altitude of 20,000 feet. How does your measured weight in the airplane compare with your weight as measured on the surface of the Earth?

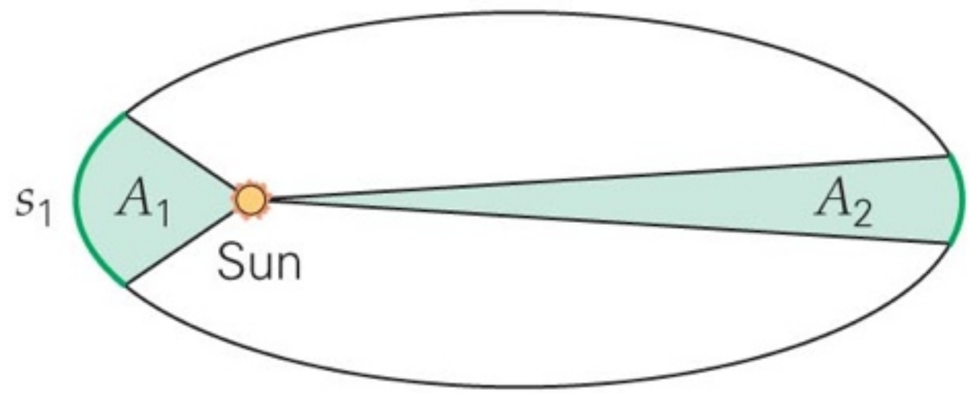
A. greater than
B. less than
C. same

Kepler's laws

- 1st law: planets travel on ellipses with sun at one focus
- 2nd law: planets sweep out equal area in equal time







Kepler's laws

- Third law: orbital periods related
  - Centripetal force = gravitational force

$$\frac{m_p v^2}{r} = \frac{G m_p M_S}{r^2}$$

$$v^2 = \frac{G M_S}{r} \qquad v = \frac{2\pi r}{T}$$

$$\frac{4\pi^2 r^2}{T^2} = \frac{G M_S}{r}$$

$$T^2 = \frac{4\pi^2}{G M_S} r^3$$

r = planet-sun distance

m_p = mass of planet

M_S = mass of Sun

v = velocity of planet

G = Gravitational constant

T = period of planet ("year")

$$T^2 = K r^3$$

$$K = 2.97 \times 10^{-19} \mathrm{s}^2/\mathrm{m}^3$$

  - Example: Exoplanets
    http://www.youtube.com/watch?v=qRJ30fkyiU4

Example: Neptunian year

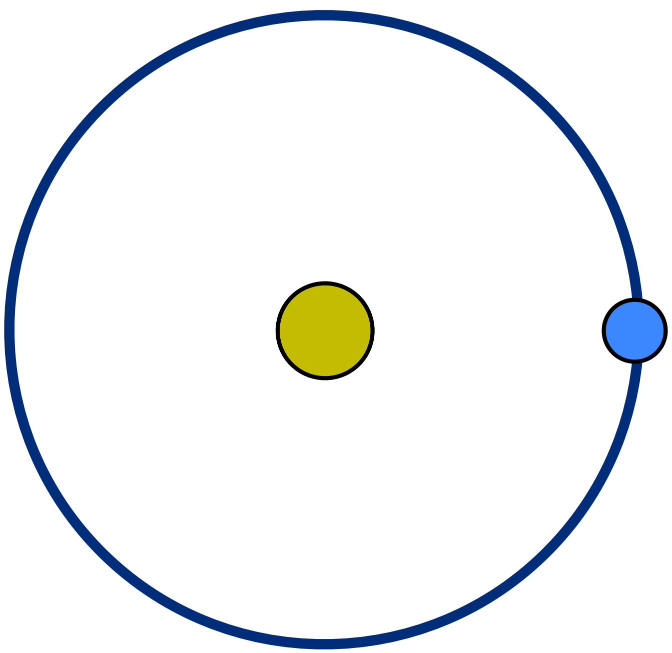
- Given: Neptune orbits the sun at a radius of 4.5 billion km.
- Goal: How long is a Neptunian year?

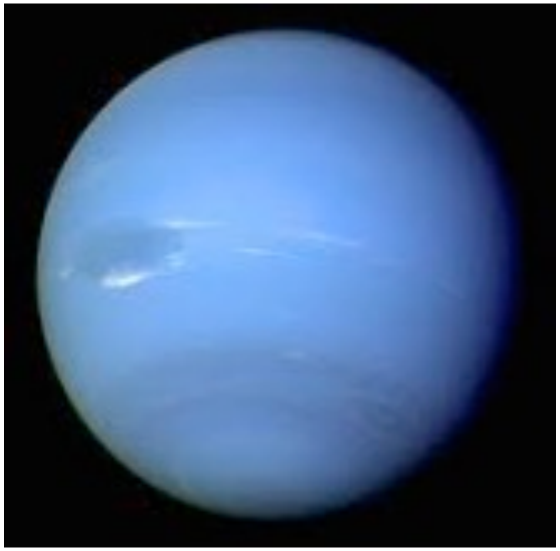
$$T^2 = Kr^3 \qquad T = \sqrt{Kr^3}$$

$$K = 2.97 \times 10^{-19} \mathrm{s}^2/\mathrm{m}^3$$

$$T = \sqrt{\left(3.0 \times 10^{-19} \mathrm{s}^2/\mathrm{m}^3\right)\left(4.5 \times 10^{12} \mathrm{m}\right)^3}$$

$$T = 170 \text{ Earth years}$$





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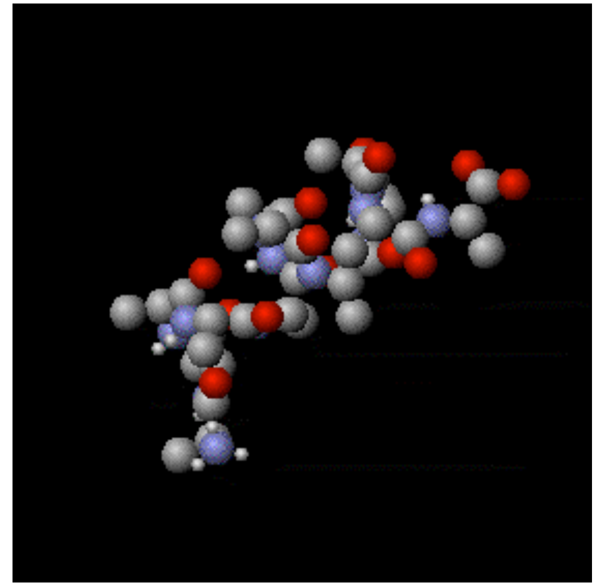
  - Temperature
  - Heat
  - Entropy

Thermodynamics

- Thermodynamics = behavior of many particles
  - Cannot track them individually
  - Average over many particles: bulk properties
- Today: some key concepts
  - Temperature
  - Heat
  - Entropy
- For the exam
  - Only what we cover in class today
  - Drawn from Wilson, Buffa, & Lou sections 10.1-10.2, 11.1, 12.1,12.4

Temperature

- What is temperature?
  - Quantitative measure of hot, cold
  - What a thermometer measures
  - Related to average translational kinetic energy of atoms, molecules
    - http://en.wikipedia.org/wiki/File:Thermally_Agitated_Molecule.gif
- Units: Celsius & Kelvin
  - Kelvin (K): $T_K = T_C - 273.15\ ^\circ\mathrm{C}$
  - Absolute zero (0 K): impossible to reach
  - Smallest temperature measured: O(10^{-12} K)



Thermal motion of segment of a protein alpha helix

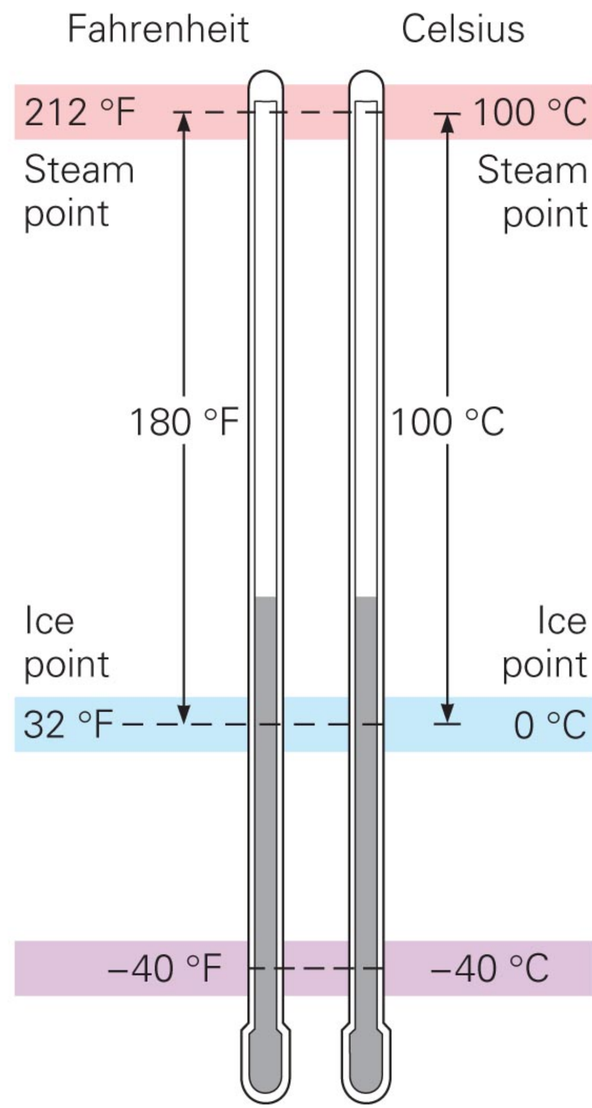
Temperature units

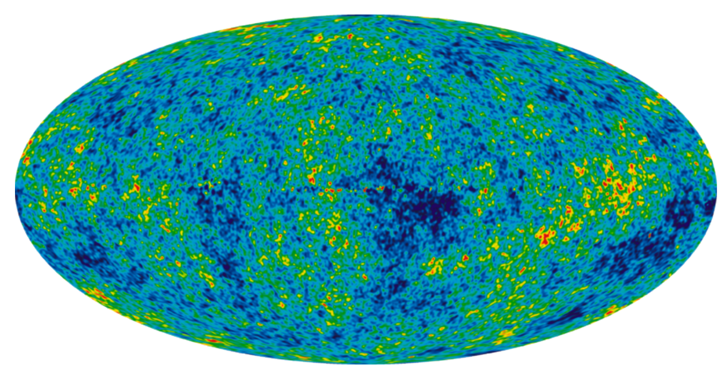
- Farenheight & Celsius

$$T_F = \frac{9}{5} T_C + 32$$

$$T_C = \frac{5}{9} (T_F - 32)$$

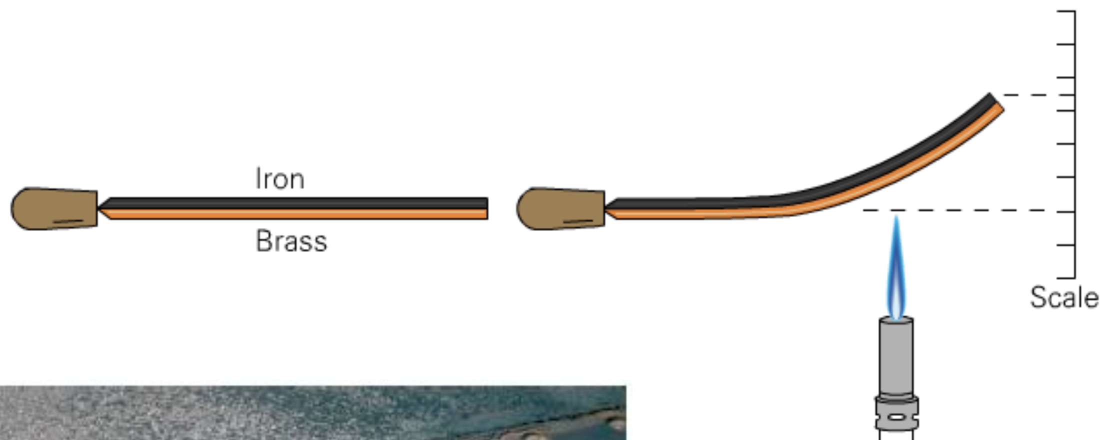
- Examples
  - Sun center: 16 million °C
  - Lightning: 30000°C
  - Sun surface: 5500°C
  - You: 36.8°C
  - Water freezes: 0°C
  - —270.4°C = cosmic microwave background
  - —273.15°C = absolute zero

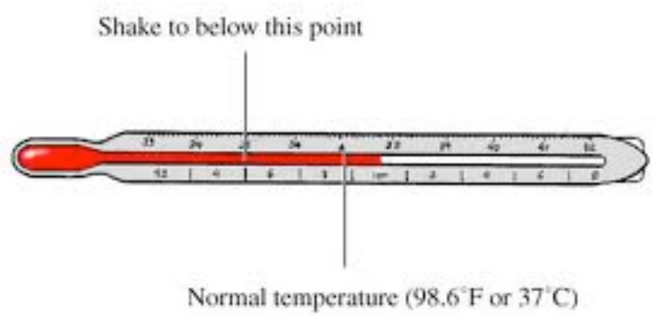




Temperature examples

- Thermal expansion
  - Thermostat: coil of metal expands as it warms
    - tips a bottle of mercury to make/break electrical contact





Clicker question #94

Question 10.4 Glasses

Two drinking glasses are stuck, one inside the other. How would you get them unstuck?

- A run hot water over them both
- B put hot water in the inner one
- C run hot water over the outer one
- D run cold water over them both
- break the glasses

Clicker question #95

Question 10.3 Thermometers

You may notice that if a mercury-in-glass thermometer is inserted into a hot liquid, the mercury column first drops, and then later starts to rise (as you expect). How do you explain this drop?

A) the mercury contracts before the glass contracts

B) the glass contracts before the mercury contracts

C) the mercury contracts before the glass expands

D) the glass expands before the mercury expands

the mercury expands before the glass contracts

Temperature examples

- Body temperature
  - <78°F: heart failure
  - Normal: 96°F to 101°F
  - >106°F: enzyme failure
- Therapeutic hypothermia
  - Artificially cool body to protect tissue
  - Therapeutic hypothermia
    - Survive cardiac arrest longer if body cooled to 90°F-92°F

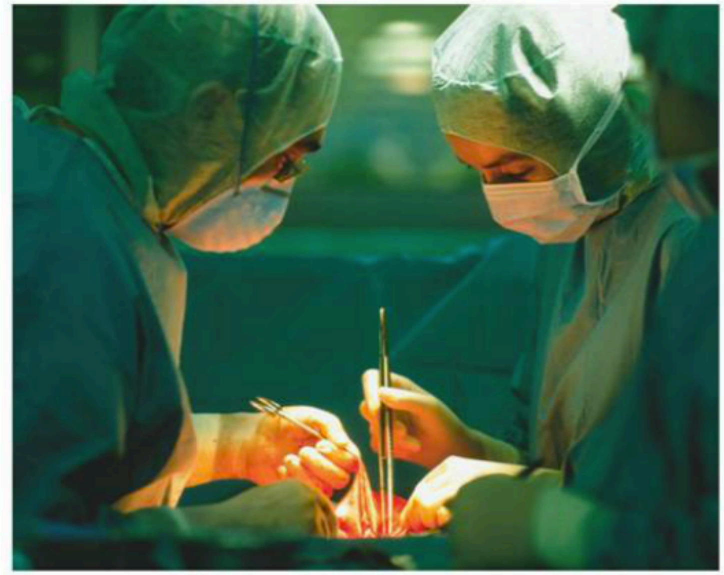


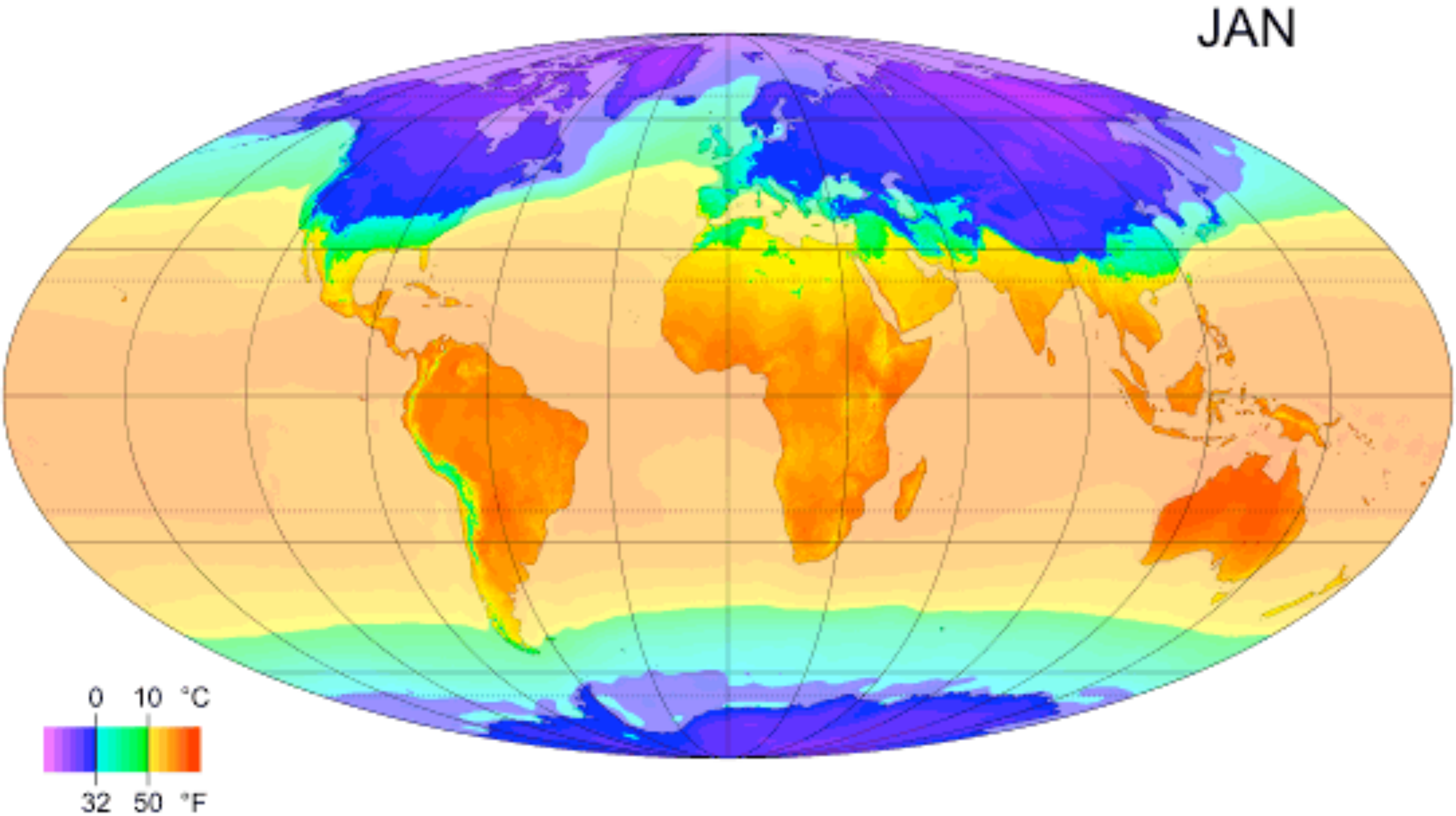
FIGURE 1 Lower than normal During some surgeries, the patient's body temperature is lowered to slow down the body's chemical reactions and to reduce the need for blood to supply oxygen to the tissues.

Michael Schennum for The Wall Street Journal

After falling on his face in mid-sentence, Arizona forensic scientist Russell Vossbrink survived cardiac arrest with the help of therapeutic hypothermia.

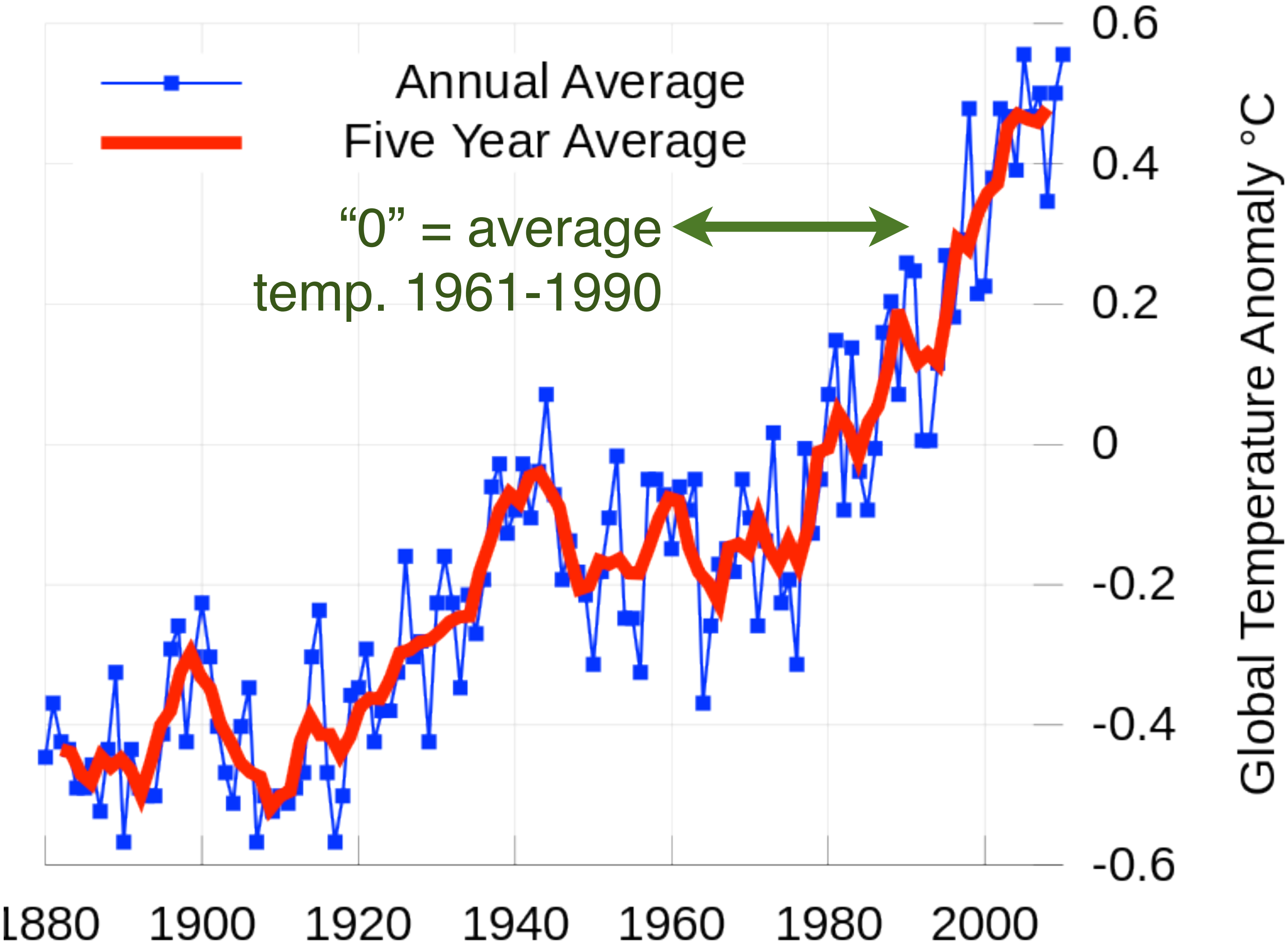
Temperature examples

- Average temperature of earth



Temperature examples

- Average temperature of earth



Heat

- Internal energy
- **Heat = energy transfer** due to temperature difference
- Thermal contact = heat flowing between objects
  - Energy ends up as internal energy
    - Some might become mechanical work
- Thermal equilibrium
  - Objects have same temperature
  - No spontaneous energy flow between them

Heat example

- Aluminum + water
  - Heat: energy transfer from hot object (aluminum) to cool object (water)
  - http://www.youtube.com/watch?v=2qJzDYsQfck

Clicker question #96

Which of the following is the SI unit for heat?

- A Farenheit
- B Celsius
- C Joule
- D Calorie
- Celsius / second

Entropy

$$\Delta S = \frac{Q}{T}$$

S=entropy
T=temperature
Q=heat

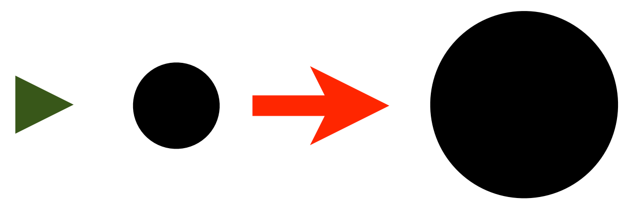
- Heat
  - Does not flow spontaneously from cold to hot
  - Can't be completely transformed into mechanical work
- Entropy = measure of disorder
  - Units: Joule / Kelvin
  - Never decreases in isolated system
    - Universe's entropy is increasing
  - "Arrow of time"
    - Ball bounce vs watermelon shoot

      http://www.youtube.com/watch?v=3jI57WMOzbU
      http://www.youtube.com/watch?v=ihPEvtPuc30

Entropy examples

- Increase in entropy: apartment gets messy

- Life
  - Earth not isolated (sun!)
  - A definition of life: decrease in entropy
- Black holes
  - Size ~ mass: grow as stuff falls in
  - Entropy increases with size
  - Entropy never decreases: so black holes can't shrink



Clicker question #96

Geoffrey's mother tells him to clean his room.

Geoffrey says he can't, because that would reduce the entropy in his room, and entropy can't ever decrease.

What should Geoffrey's mother say?

A "You're right. The entropy of your room can't decrease, so you can't really clean it up."

B "The universe's entropy can decrease.
So clean up your room."

C "The universe's entropy will increase, but your room's entropy will decrease. So clean up your room."

D Tell Geoffrey's brother to clean it up instead.

Class participation

- 0. Full name
- 1. What are you most confident about going into exam #3?
- 2. Least confident?