



**As you come in:**

- If you are new, come say hi to me!
- Choose a table to sit at
- Put your name on a name tent
- Introduce yourself to your neighbors
- Start chatting!

**Physics of Weather and Climate**

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**Tentative Schedule**

Week 1: Why do I always ride my bike into the wind?

Week 2: Why do clouds stay up in the air?

Week 3: If you can't predict the weather, how can you predict the climate?

Week 4: Why are there rainforests on the equator?

Week 5: How could aliens know there is life on Earth?

Week 6: How does the earth keep warm, and why is it getting warmer?

Week 7: What can we do about climate change?

**Today's Questions**

- Why did I always ride my bike into the wind?
- If hot air rises, why is it cold in the mountains?
- Why is it colder on clear nights than cloudy?

**Physics Principles**

**Buoyancy**

**Energy**

**Thermal Radiation**

**But First:**

**Miso Soup**

**Observations**

As the soup cools, what do you notice?

Does stirring / blowing on the soup change the effect?



**But First:**

**Cartesian Diver**

**Observations**

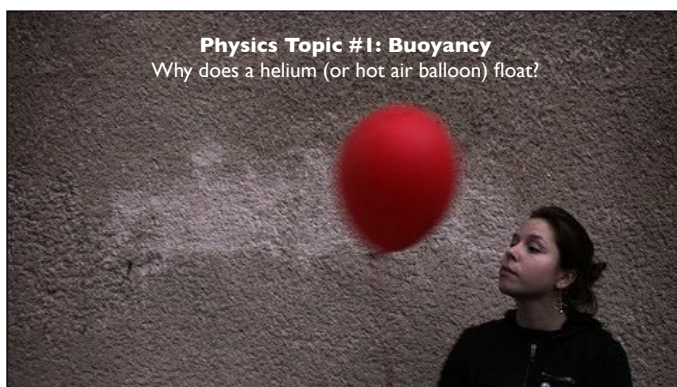
Give the bottle a squeeze.

Now, explore and explain: What is going on here???



**Physics Topic #1: Buoyancy**

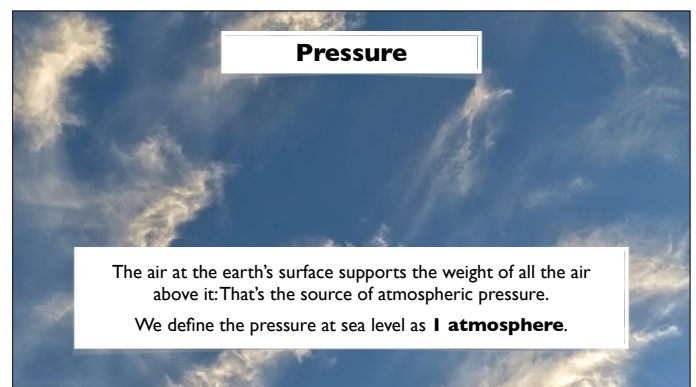
Why does a helium (or hot air balloon) float?

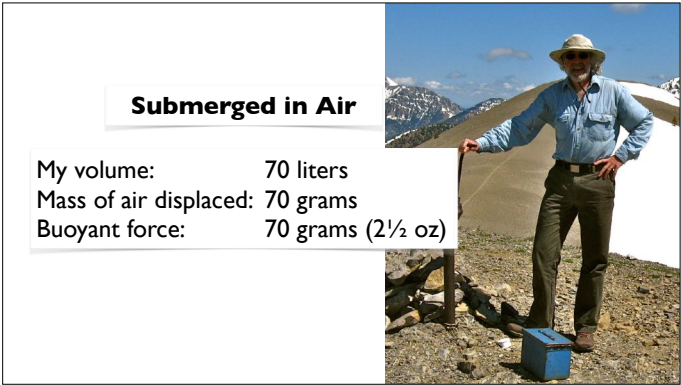
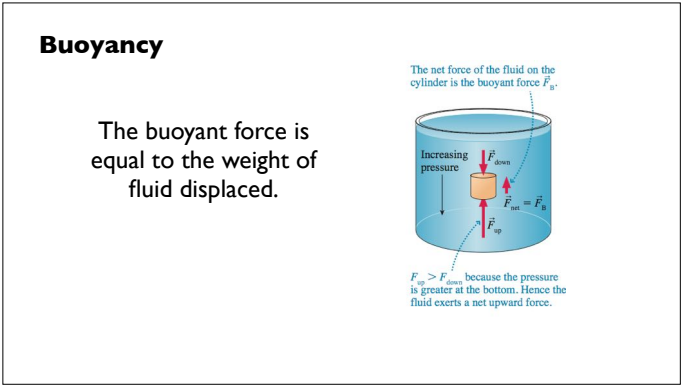
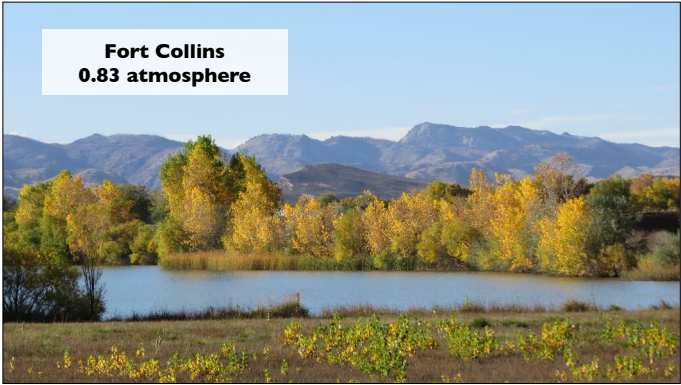
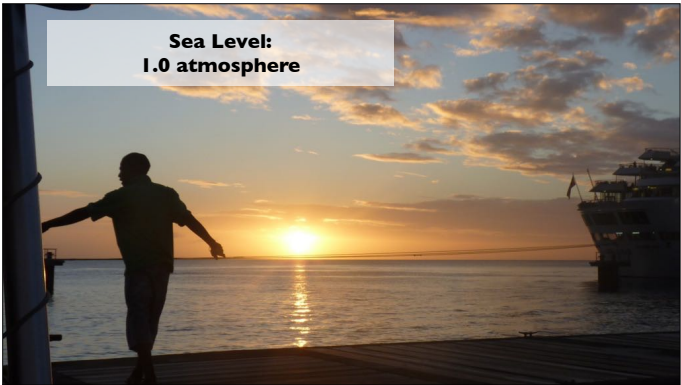
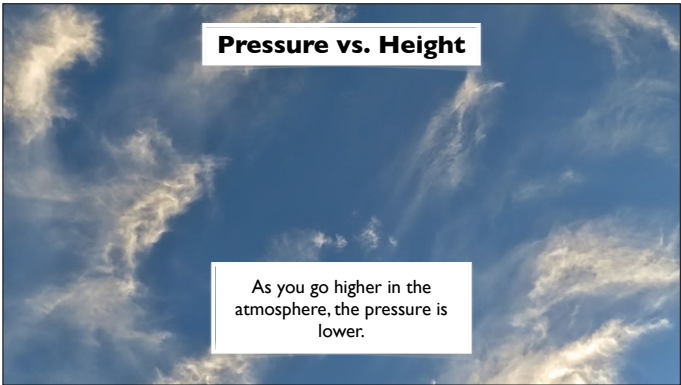


**Pressure**

The air at the earth's surface supports the weight of all the air above it: That's the source of atmospheric pressure.

We define the pressure at sea level as **1 atmosphere**.





My mass: 70 kilograms  
 My volume: 70 liters  
 Mass of water displaced: 70 kilograms  
**Buoyant force equals weight force!**

**Submerged in Water**



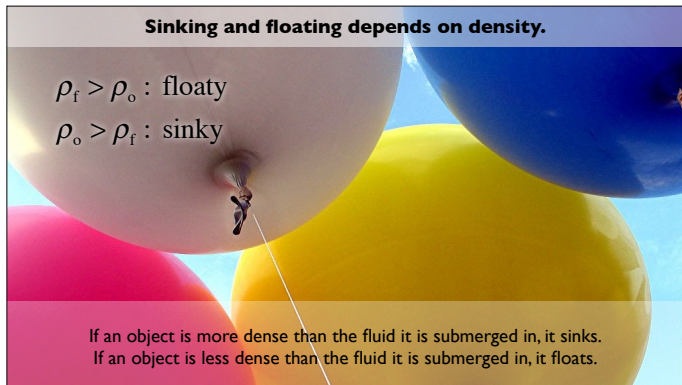
Balloon volume: 12 liters  
 Mass of air displaced: 12 grams  
 Mass of balloon: 1 g  
 Mass of helium in balloon: 2 grams  
 Total lift: 9 grams (1/3 oz)



**Sinking and floating depends on density.**

$\rho_f > \rho_o$  : floaty  
 $\rho_o > \rho_f$  : sinky

If an object is more dense than the fluid it is submerged in, it sinks.  
 If an object is less dense than the fluid it is submerged in, it floats.



### Physics Topic #2: Energy

The universal currency for making things happen.



**Energy comes in many different forms.**

Mechanical energy:



Thermal energy:



Other forms include:



$E_{\text{chem}}$

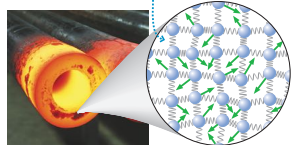
$E_{\text{nuclear}}$

### Forms of Energy

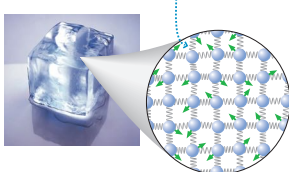
|                                |                                                                                                           |
|--------------------------------|-----------------------------------------------------------------------------------------------------------|
| Kinetic energy                 | Energy of motion. If something is moving, it has kinetic energy. Moving faster means more kinetic energy. |
| Gravitational potential energy | If something is up high, it has a lot; if something is down low, it doesn't.                              |
| Radiant energy                 | The energy of light and other waves, like microwaves.                                                     |
| Thermal energy                 | When something is hot, it has a lot; when it is cold, it has a little.                                    |

### Thermal Energy

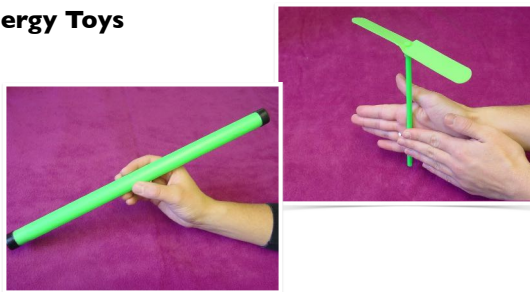
Hot object: Fast-moving atoms have lots of kinetic and elastic potential energy.



Cold object: Slow-moving atoms have little kinetic and elastic potential energy.



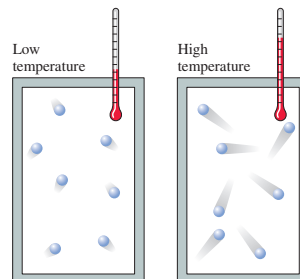
### Energy Toys



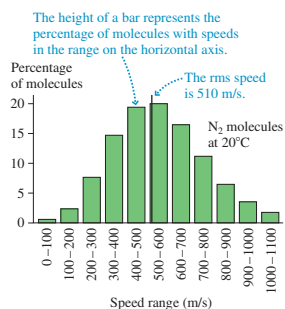
Explain the operation in terms of energy transformation.



## Thermal Energy and Gases



## Speedy!



When the temperature goes up, when thermal energy increases, the atoms move faster and spread out, so the density goes down. So: **Hot air rises.**



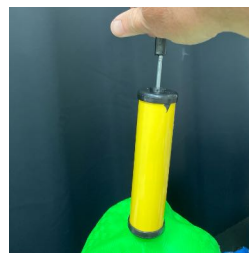
## Warming and Cooling Air I



### Observations & Explanations

- Compress the syringe, and watch the temperature change. (Position the thermal camera's cursor on a spot on the syringe.)
- Where does the energy come from to warm up the air in the syringe?
- Now, let the air expand. What happens to the temperature?
- Where did the energy go?

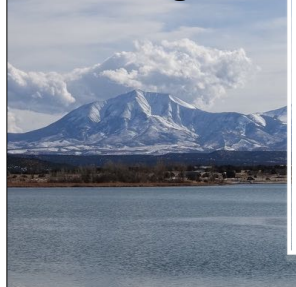
## Warming and Cooling Air II



### Observations & Explanations

- Pump air into the ball until it is pretty firm. As you pump, watch how the temperature changes using the thermal camera.
- Where does the energy come from to warm up the air in the ball?

## Trading Heat for Height



### Question

- As air rises, it expands and cools. **Explain this in terms of energy transformations.**
- As air falls, it compresses and warms. **Explain this in terms of energy transformations.**
- Finally: **If hot air rises, why is it cold in the mountains?**

## Lapse Rate



For dry air, rising air will cool by  $5.5^\circ F$  per 1000 ft.

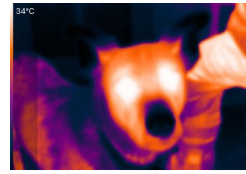
## Wish Paper



### Observations & Explanations

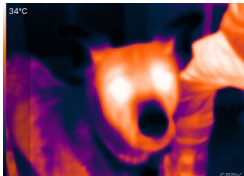
- What happens to the lit paper?
- Explain why the paper rises **in terms of buoyancy**.
- Explain why the paper rises **in terms of energy transformations**.
- Why, at some point, does the paper stop rising?

## Thermal Radiation



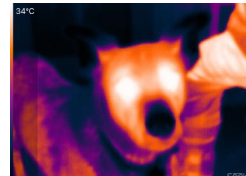
The atoms in your body are always moving around, because you are warm. This means that they emit electromagnetic waves.

## Thermal Radiation



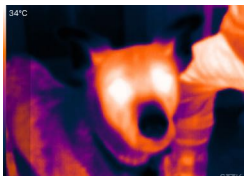
You are emitting about 800 W of thermal radiation. You are absorbing about 700 W of thermal radiation from the environment.

## Thermal Radiation



The main determinant of how warm or cold you feel isn't the temperature of the air in the room. *It's the temperature of the walls.*

## Thermal Cameras



Use the thermal camera to look around the room. ***You are seeing the radiation that people are emitting.***

## Thermal Radiation

### Observations

- Can the thermal camera “see through” glass?
- Can the thermal camera “see through” a balloon?

## Thermal Radiation

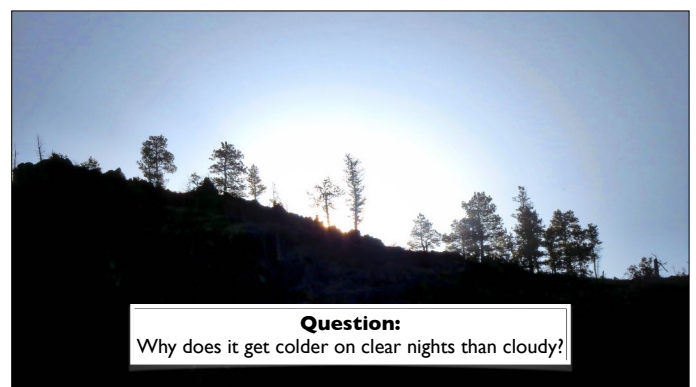
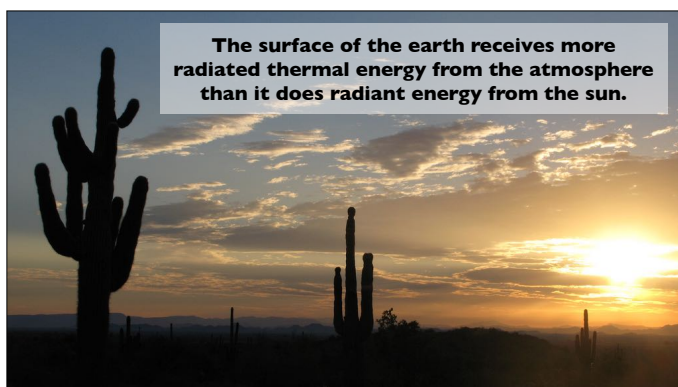
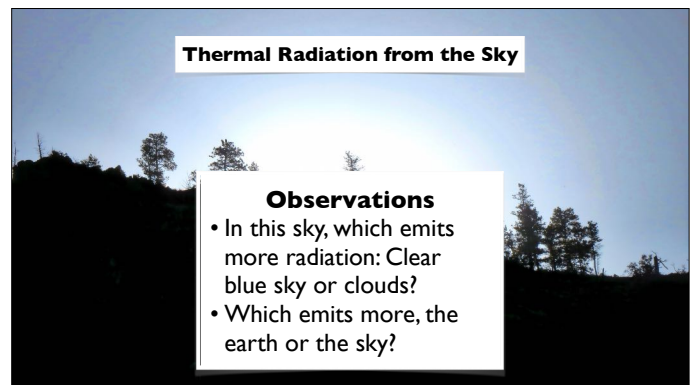
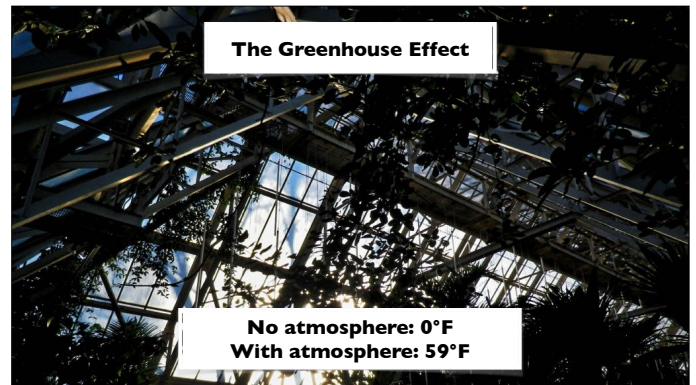
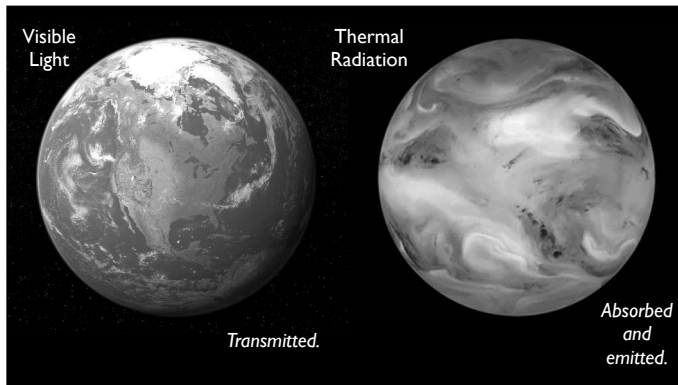
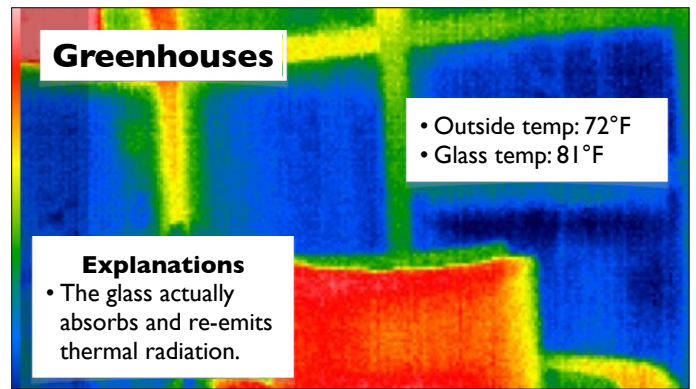
### Explanations

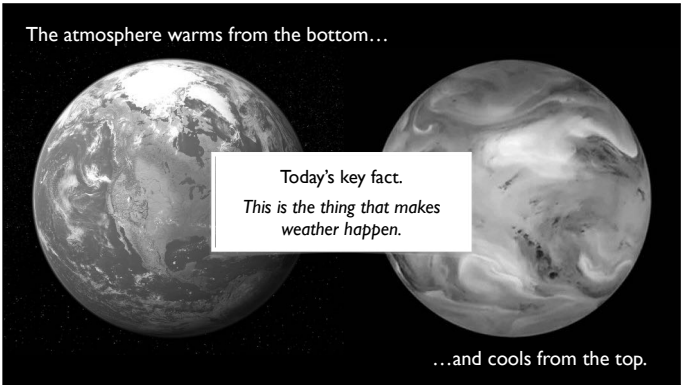
- Glass absorbs thermal radiation.
- Glass passes visible light.

## Greenhouses

### Questions

- What sort of radiation shines on the greenhouse to warm it up?
- What sort of radiation do surfaces in the greenhouse emit to cool off?





## Stable Atmosphere

In the morning, the air tends to be cooler near the surface.

### Remember

For dry air, rising air will cool by 5.5 °F per 1000 ft.

|           |       |
|-----------|-------|
| 4000 feet | 58 °F |
| 3000 feet | 56 °F |
| 2000 feet | 54 °F |
| 1000 feet | 52 °F |
| 0 feet    | 50 °F |

## Unstable Atmosphere

The atmosphere warms from the bottom.  
When the air warms near the surface, the atmosphere can become unstable.

### Remember

For dry air, rising air will cool by 5.5 °F per 1000 ft.

|           |       |
|-----------|-------|
| 4000 feet | 58 °F |
| 3000 feet | 56 °F |
| 2000 feet | 54 °F |
| 1000 feet | 52 °F |
| 0 feet    | 60 °F |

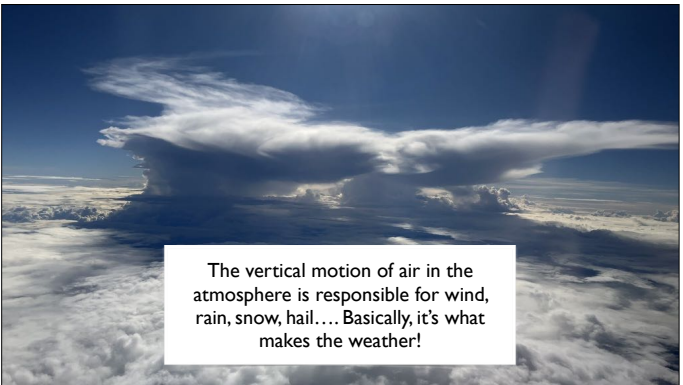
## Unstable Atmosphere

Early in the morning, it tends to be still. As the earth warms up, air starts to move, and the wind starts to blow.

### Remember

For dry air, rising air will cool by 5.5 °F per 1000 ft.

|           |       |
|-----------|-------|
| 4000 feet | 58 °F |
| 3000 feet | 56 °F |
| 2000 feet | 54 °F |
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| 0 feet    | 60 °F |



### Remember:

## Miso Soup

### Explanations

You can see the soup rising and falling.  
What causes this motion?



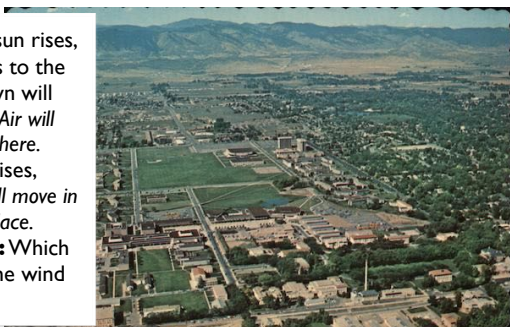
## The same motions happen in the atmosphere.

### Explanations

Clouds mean rising air,  
Clear sky means falling air.



- When the sun rises, the foothills to the west of town will warm first. *Air will start to rise here.*
- As the air rises, cooler air will move in to take its place.
- **Question:** Which way does the wind blow?



- When the sun rises, the foothills to the west of town will warm first. *Air will start to rise here.*
- As the air rises, it cools. **Clouds often form over the foothills first.**



- When the sun sets, the foothills to the west of town will cool first. *Air will start to sink here.*
- As the air sinks, it will move to replace rising air over still-warm areas.
- **Question:** Which way does the wind blow?

