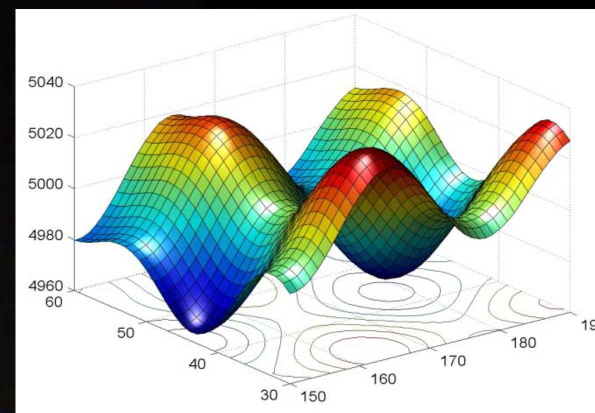
Satellites, Weather and Climate Module 33:

Atmospheric sciences and the mathematics common core standards



$$\sum F = ma$$

Dr. Janel Hanrahan

SWAC

LYNDON
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NSF

VERMONT

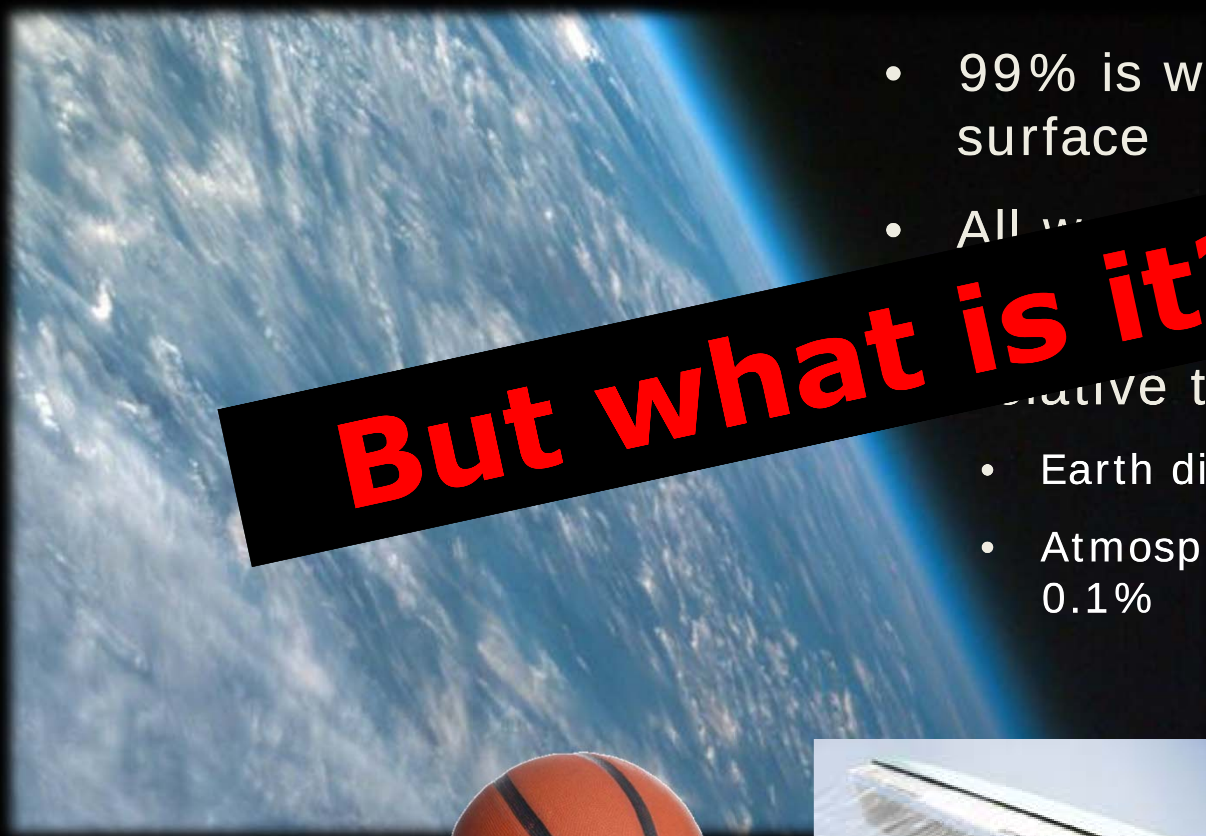
Satellites, Weather and Climate Module 33:

Atmospheric sciences and the mathematics common core standards

High School

CCSS.Math.Content.HSF-BF.A.1c Compose functions. For example, if T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t)) is the temperature at the location of the weather balloon as a function of time.

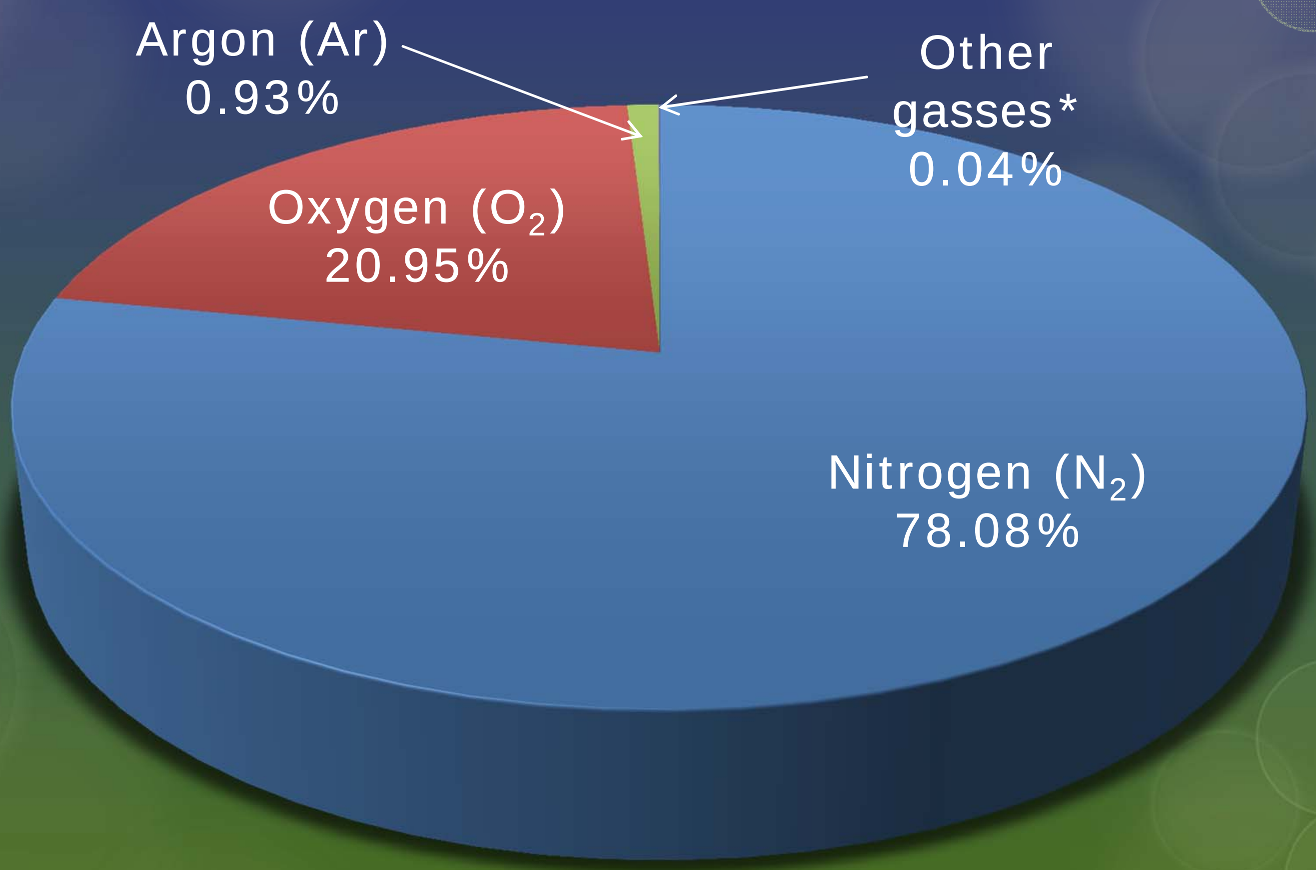
The Atmosphere



- 99% is within 20 miles of surface
- All w…
- …ative thickness:
  - Earth diameter: 7,900 miles
  - Atmosphere is 7/7900 or 0.1%

But what is it????

Composition of Earth's atmosphere



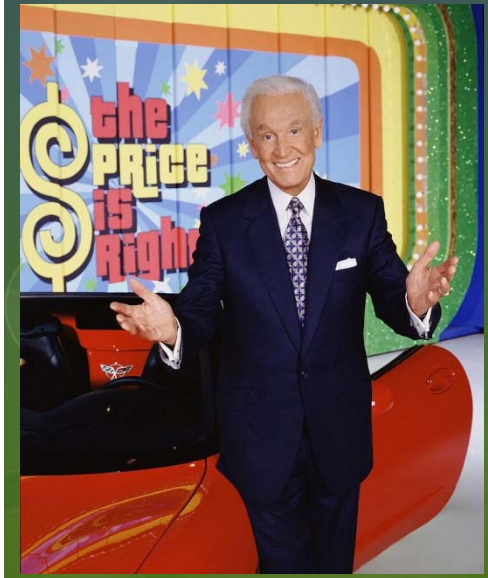
*including water vapor, carbon dioxide, neon, helium, methane, krypton, hydrogen, nitrous oxide, carbon monoxide, xenon, ozone, nitrogen dioxide, iodine, and ammonia

Question

How much does the air in our room weigh???

Question

How much does the air in our room weigh???



The person with the closest guess without going over gets a NEW CAR!!!*

***Well, not really. But it is fun to guess right?**

The weight of our atmosphere

Dr. Janel Hanrahan
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Many people do not consider that the Earth's atmosphere has weight. Indeed, our atmosphere is made up of various gasses, the most abundant of which are Nitrogen (78.08%), Oxygen (20.95%) and Argon (0.93%). These and the remaining 0.04% of atmospheric gases and particles, all have mass, and therefore have weight. For this activity, we will compute the weight of the air in this room.

Question: How much does the air in our room weigh?

Required values	Equations	Conversions and constants
W = ____________ lbs W = ____________ N	$F = m \cdot a$	$1\ \text{lb} = 4.448\ \text{N}$ $T_K = 273 + T_C$ $1\ \text{mb} = 100\ \text{Pa}$ $g = 9.8\ \text{m s}^{-2}$ $R_d = 287\ \text{J} \cdot \text{K}^{-1} \cdot \text{kg}^{-1}$

Putting it all together

Solution:

Common Core Standards addressed:

Newton's second law of motion

$$F = ma$$

force

acceleration

mass

Newton's second law of motion

$$W = mg$$

weight
(force due to gravity)

mass

gravitational
acceleration

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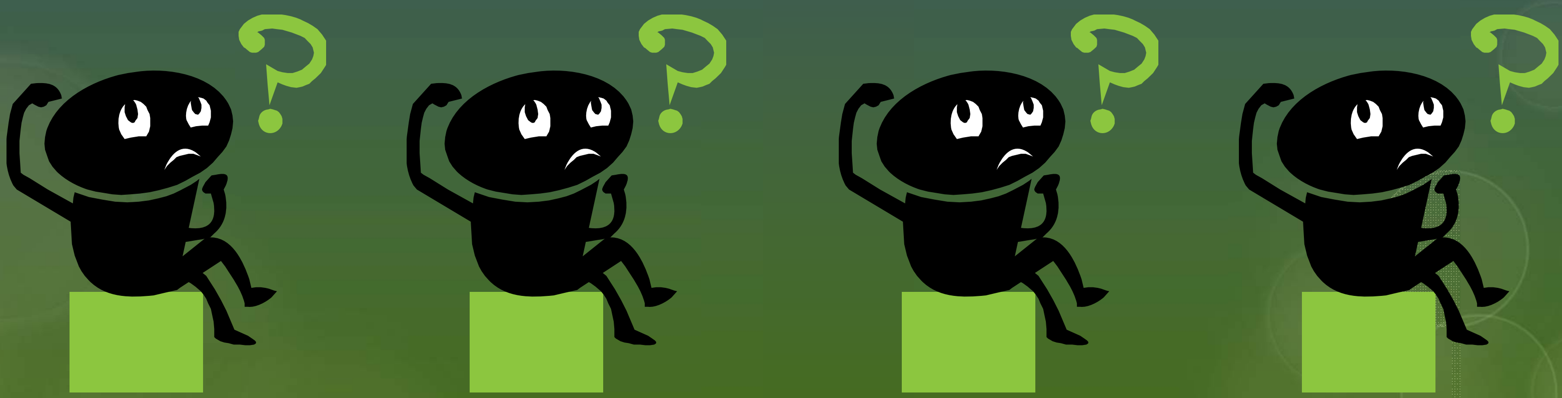
		$R_d = 287\ \text{J} \cdot \text{K}^{-1} \cdot \text{kg}^{-1}$
		$1\ \text{ft} = 0.3048\ \text{m}$

Question

What is the mass of the air in our room?



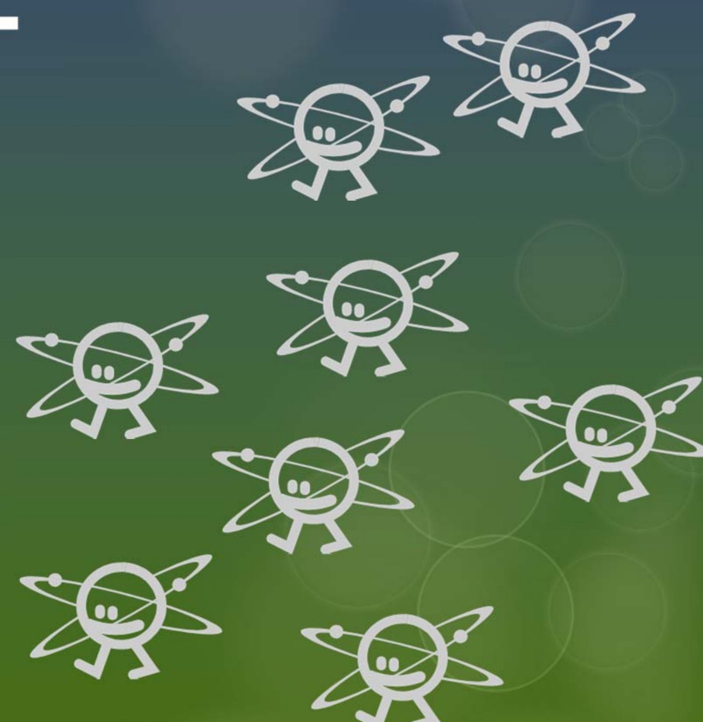
Density

mass

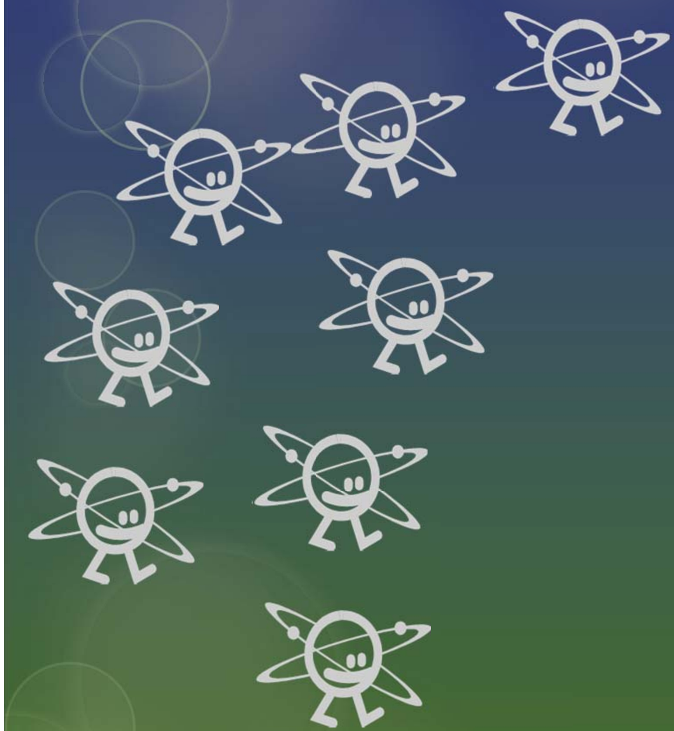
density

$$\rho = \frac{m}{V}$$

volume



Density



$$\rho = \frac{m}{V}$$

volume

$$m = \rho V$$

mass

density

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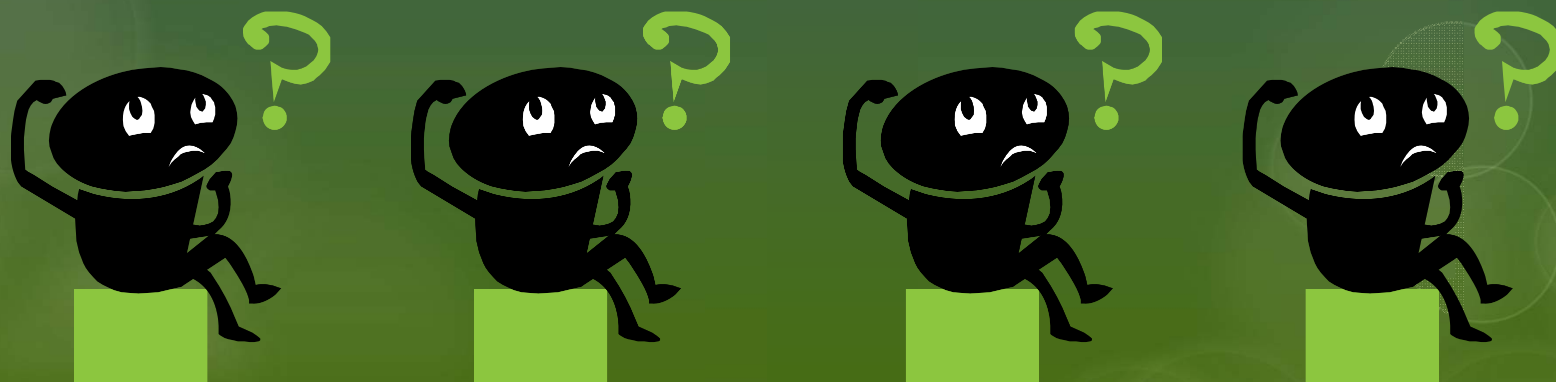
ρ = ________ kg/m³		$R_d = 287\ \text{J} \cdot \text{K}^{-1} \cdot \text{kg}^{-1}$
V = ________ m³		$1\ \text{ft} = 0.3048\ \text{m}$

Questions

What is the volume of our room?

What is the density of the air in our room?



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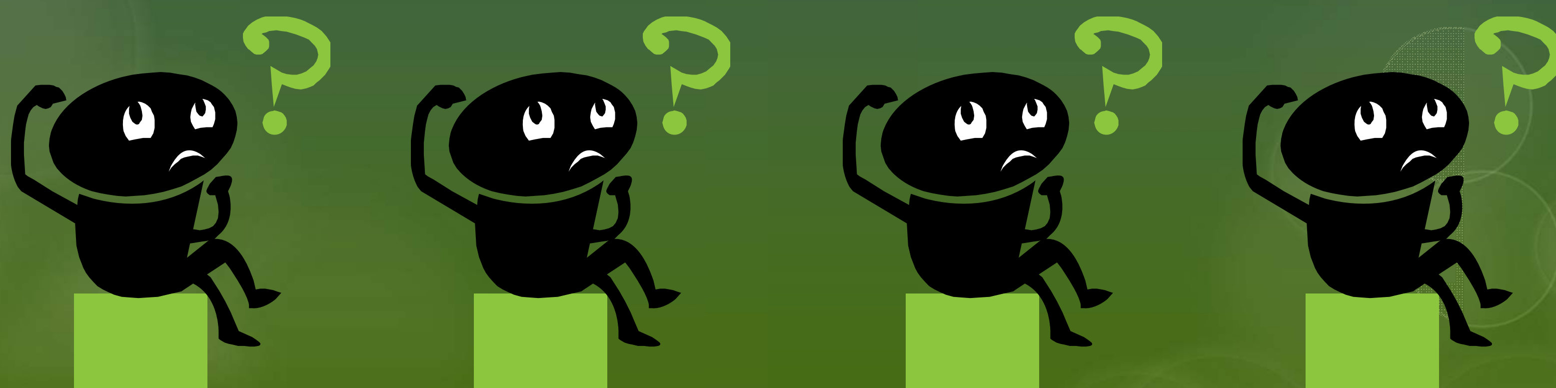

Volume

volume height

$$V^{*} = lwh$$

length width

*Assuming that the room is a rectangular prism

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L = ________ m		
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h = ________ m		

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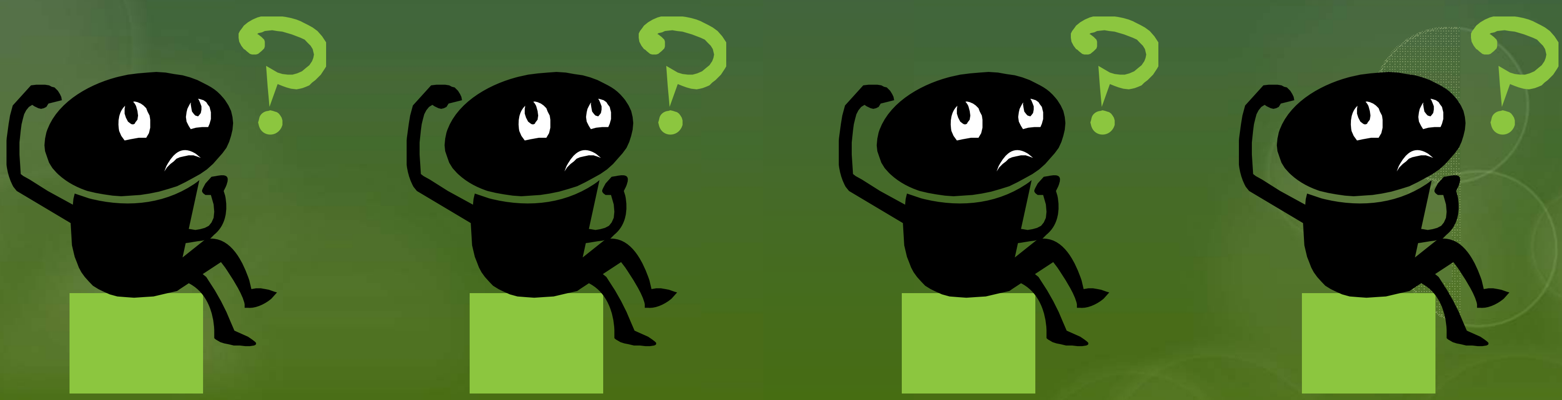

The Ideal Gas Law

density

$$\rho = \frac{P}{RT}$$

pressure

gas constant

temperature

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ρ = ________ kg/m³	$\rho = P/(R \cdot T)$	$R_d = 287\ \text{J} \cdot \text{K}^{-1} \cdot \text{kg}^{-1}$
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L = ________ m		
w = ________ m		
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R_d = 287 J/kkg		
P = ________ Pa		
T = ________ K		

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L = ________ m		
w = ________ m		
h = ________ m		
$R_d = 287\ J/kkg$		
P = ________ Pa		
T = ________ K		

Now we just need to measure volume, pressure and temperature.

The rest can be computed!

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L = ____ m		
w = ____ m		
h = ____ m		
$R_d = 287\ J/kkg$		
P = ____ Pa		
T = ____ K		

Question

How much does the air in our room weigh???

Answer:

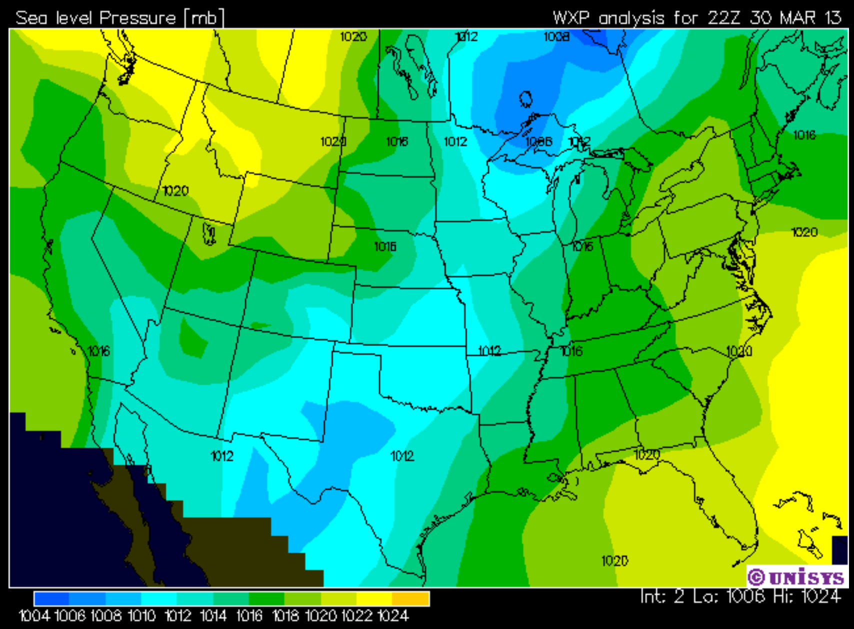
[redacted]

Question

How much does the air in <u>your classroom</u> weigh???

What if I don't have fancy instruments?

- Typical sea-level pressure = 100,000 Pa (1,000 mb)
- Unisys Weather plotter: weather.unisys.com

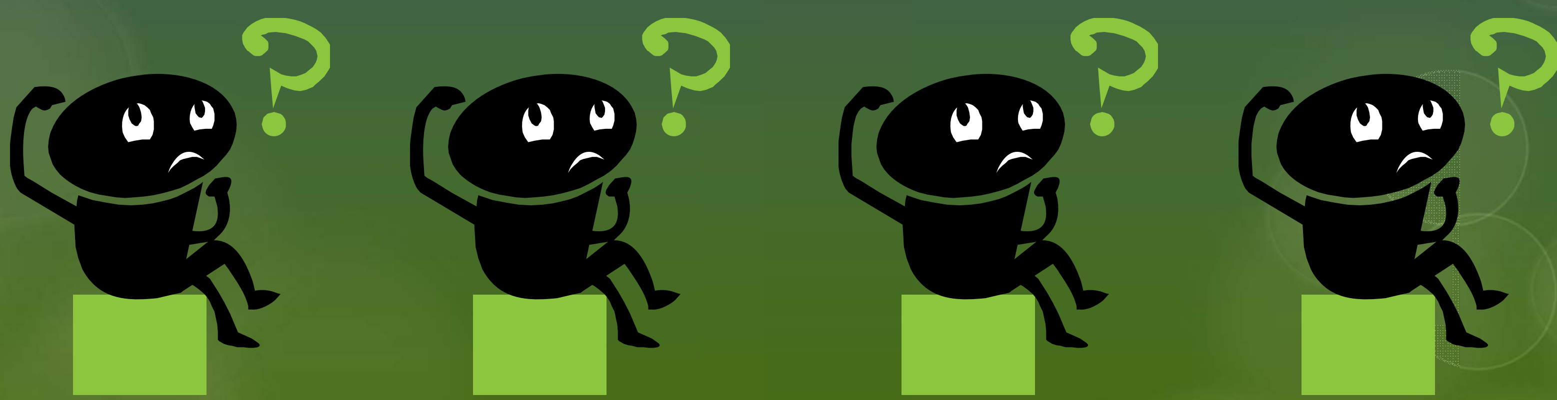


$$\rho = \frac{P}{RT}$$

- Typical sea-level density = 1.2 kg/m^3

Question

What math common core standards are addressed with this activity?



Common Core Standards

Grade 6

- **CCSS.Math.Content.6.RP.A.3d** Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

$$m = \rho \cdot V$$

If density is in kg/m^3, and mass is in kg, what units must be used when we measure the volume of the room?

RP: Ratios and Proportional Relationships

Question

What <u>other</u> math common core standards can be addressed with this activity?

www.corestandards.org/Math

Email me:
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Take a break!

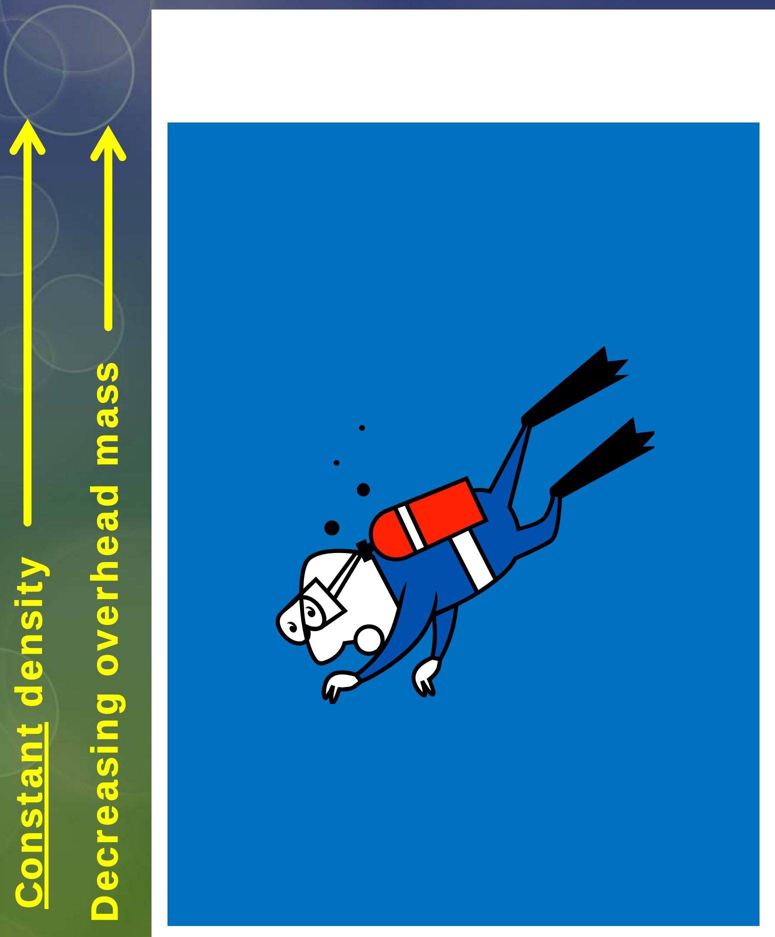
The atmosphere is a fluid… Really!

fluid

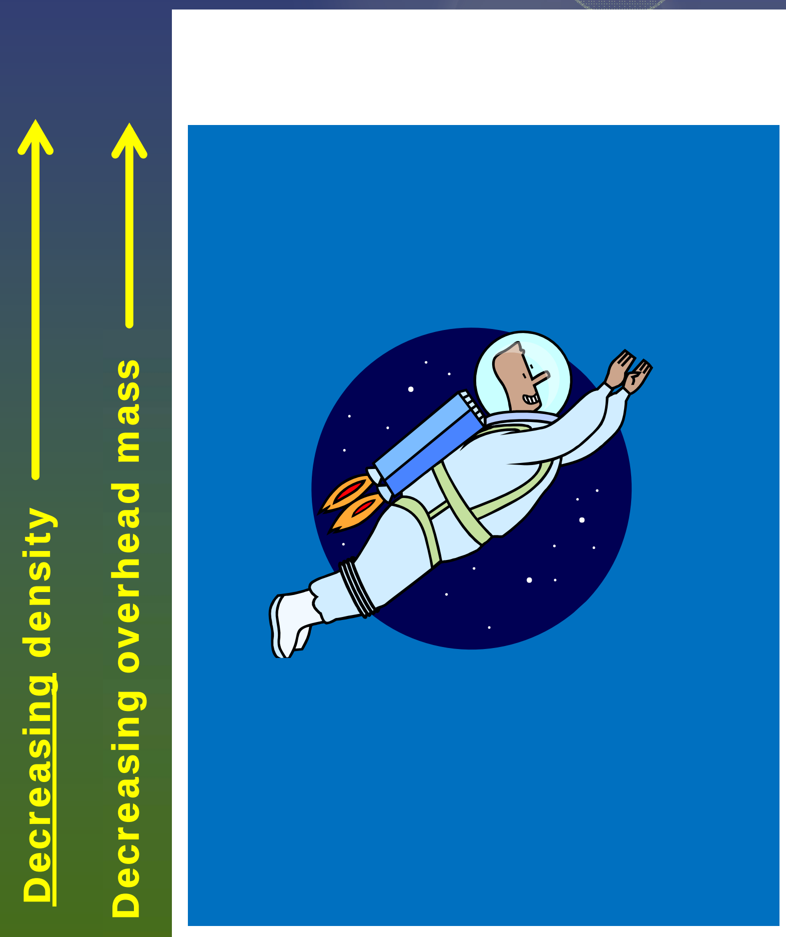
flu·id *n.*
A continuous, amorphous substance whose molecules move freely past one another and that has the tendency to assume the shape of its container; a liquid or gas.

What's the difference?

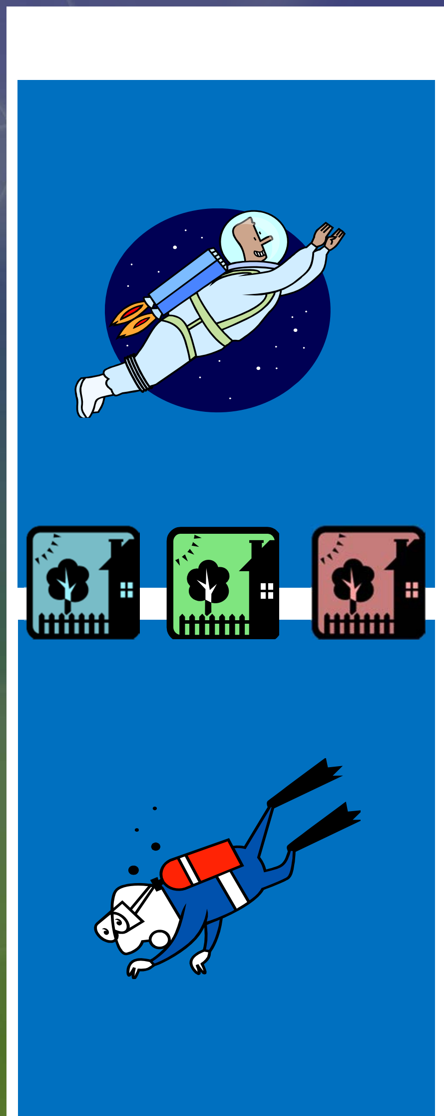
Liquid: not easily compressed



Gas: easily compressed



Where
we live



Pressure

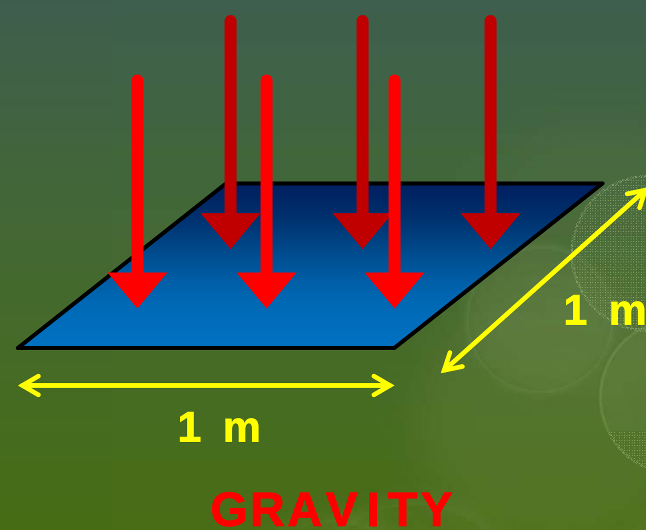
Net force per unit area

Weight

Net force due to gravity

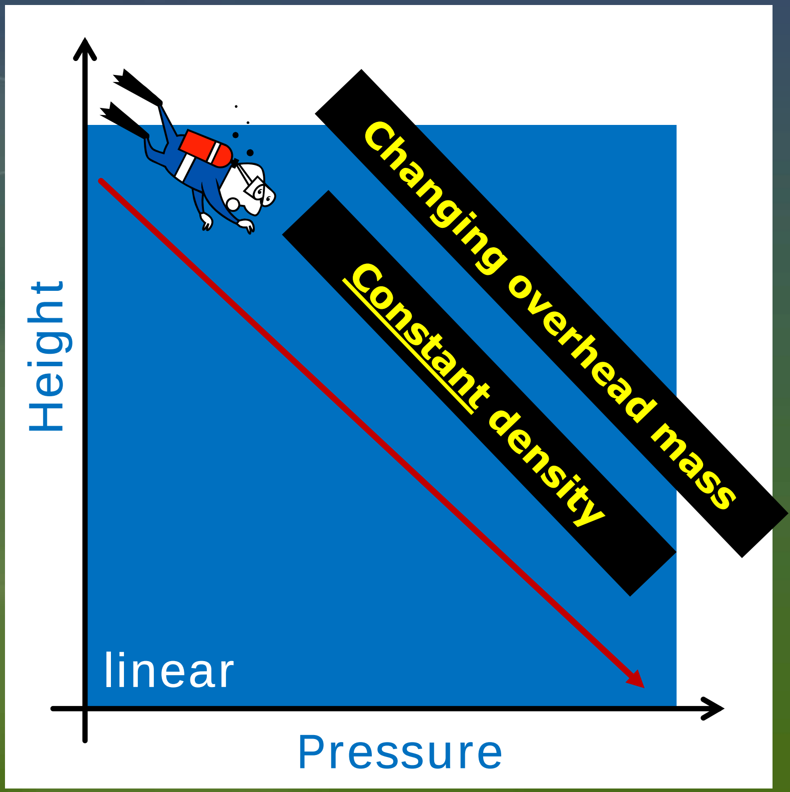
Atmospheric Pressure

Weight per unit area

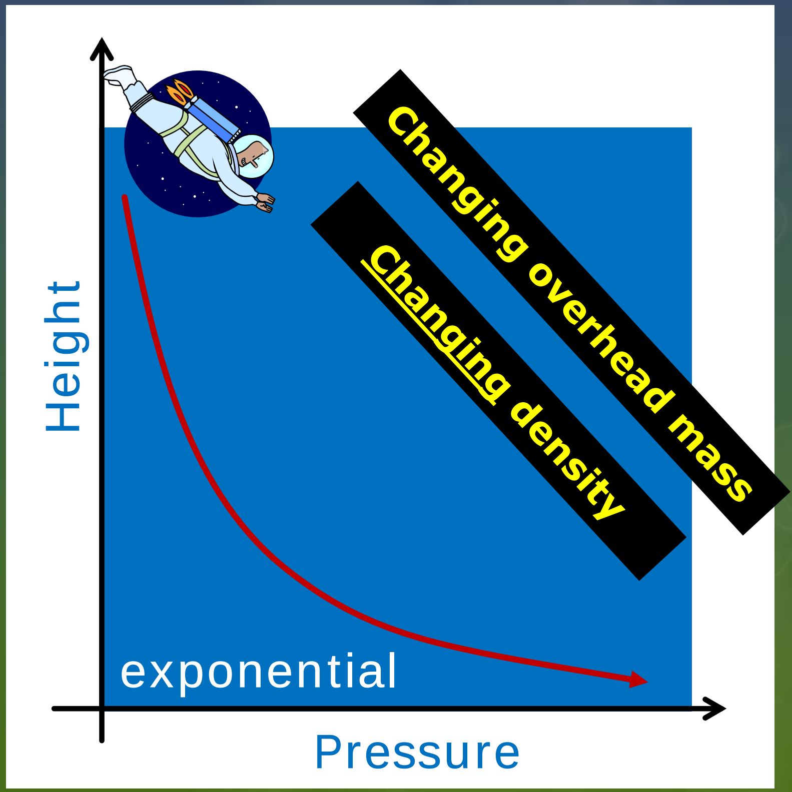


How does pressure change with height?

Liquid: not easily compressed



Gas: easily compressed



Pressure decreases exponentially with height

$$P \approx P_o e^{-Z/H}$$

pressure

sea-level pressure (z = 0)

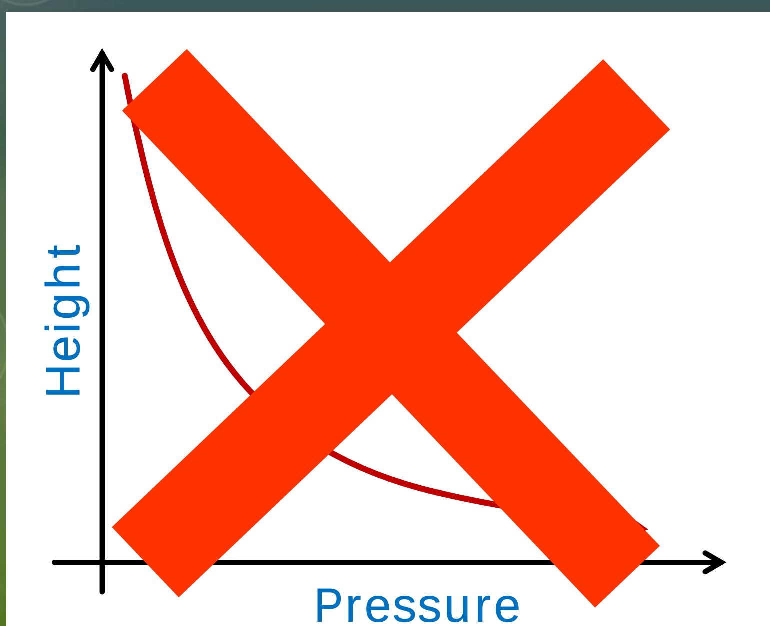
height

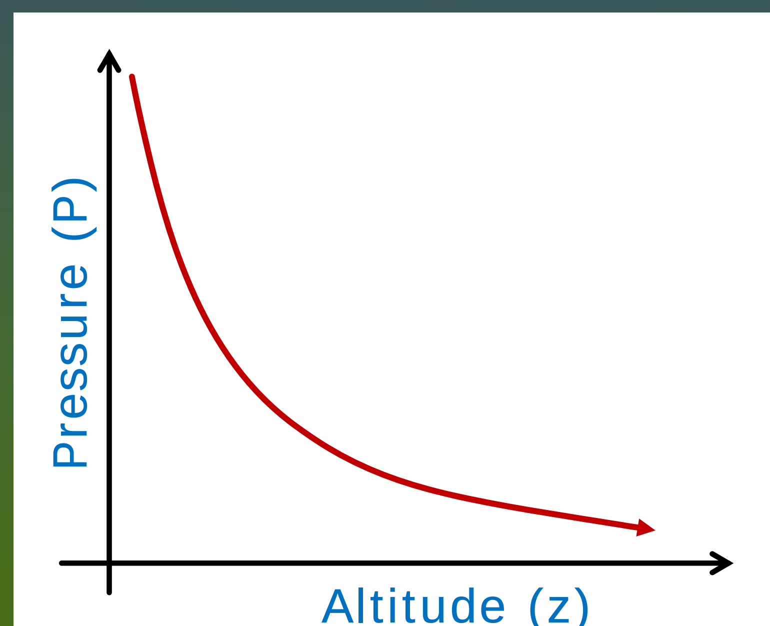
e-folding depth (scale height)

Pressure decreases exponentially with height

dependent independent

$$P \approx P_o e^{-Z/H}$$





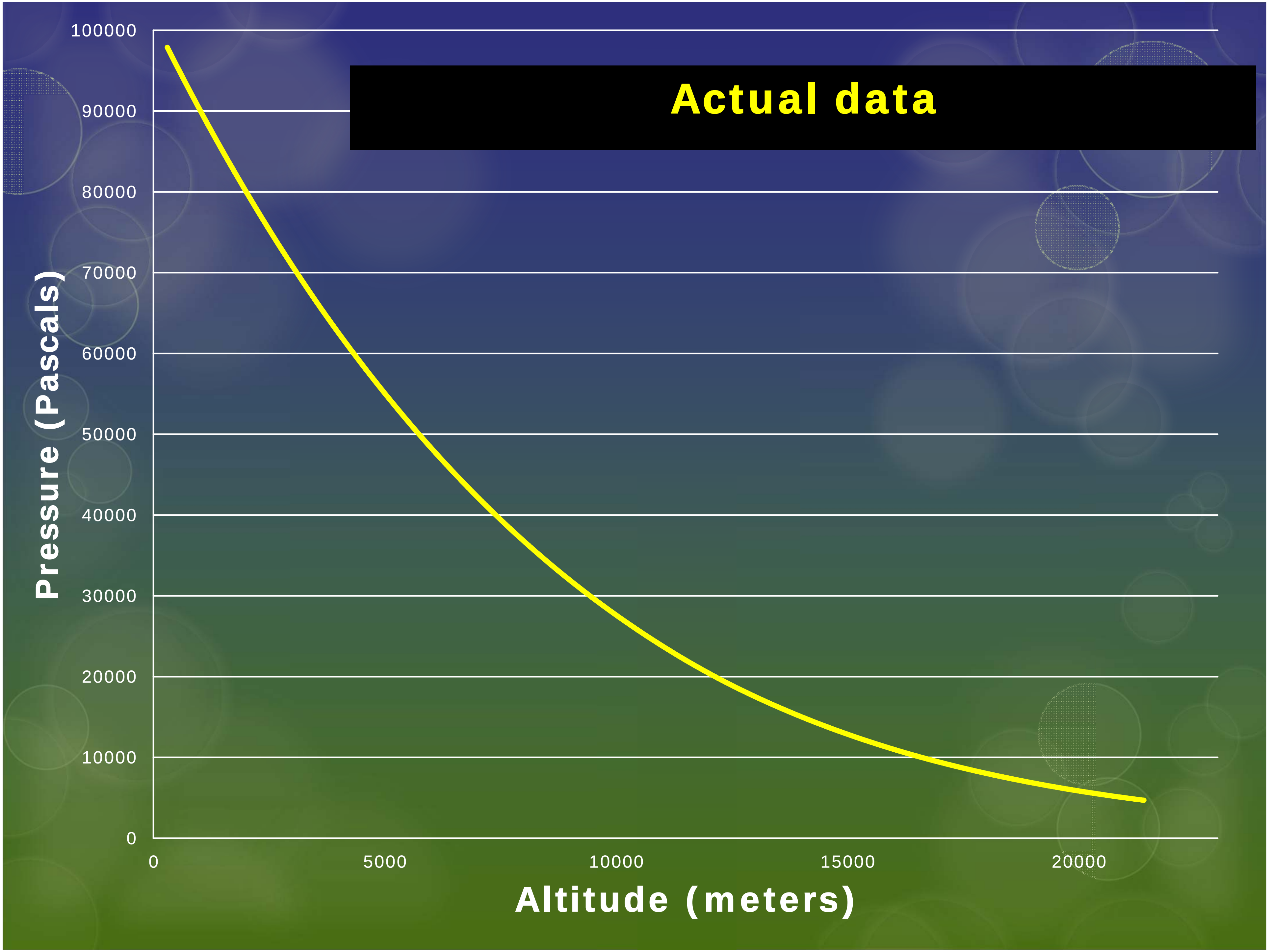
Balloon data activity

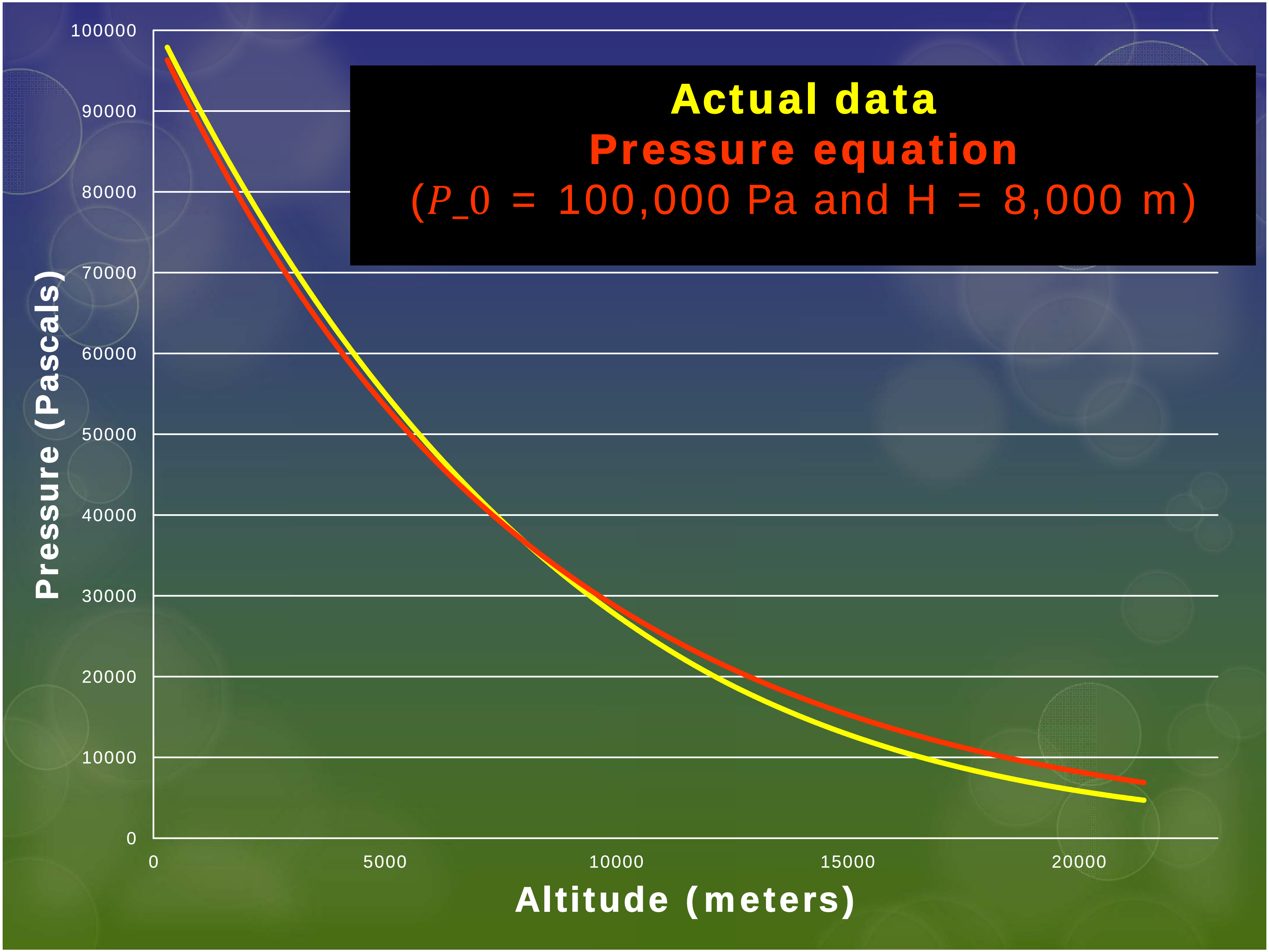
$$P \approx P_o e^{-Z/H}$$

- Plot pressure as a function of height
- Estimate P_0
- Compute *H*

$$\text{let } P_0 = 100{,}000 \text{ Pa}$$

$$H \approx \frac{-Z}{ln(P) - ln(P_0)}$$


Actual data
Pressure (Pascals)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
5000
10000
15000
20000
Altitude (meters)


Actual data
Pressure equation
(P_0 = 100,000 Pa and H = 8,000 m)
Pressure (Pascals)
100000
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
0
5000
10000
15000
20000
Altitude (meters)

Common core standards

High School

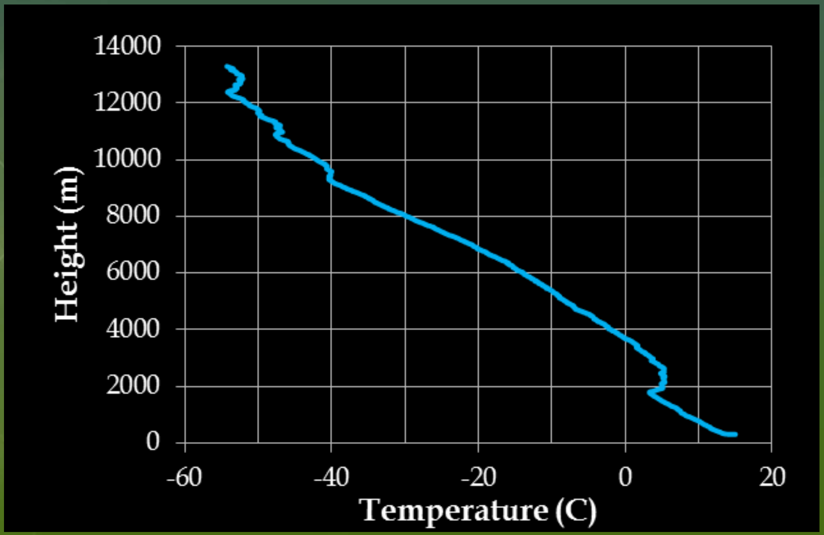
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-LE.A.4** For exponential models, express as a logarithm the solution to $ab^{ct} = d$ where a, c, and d are numbers and the base b is 2, 10, or e; evaluate the logarithm using technology.

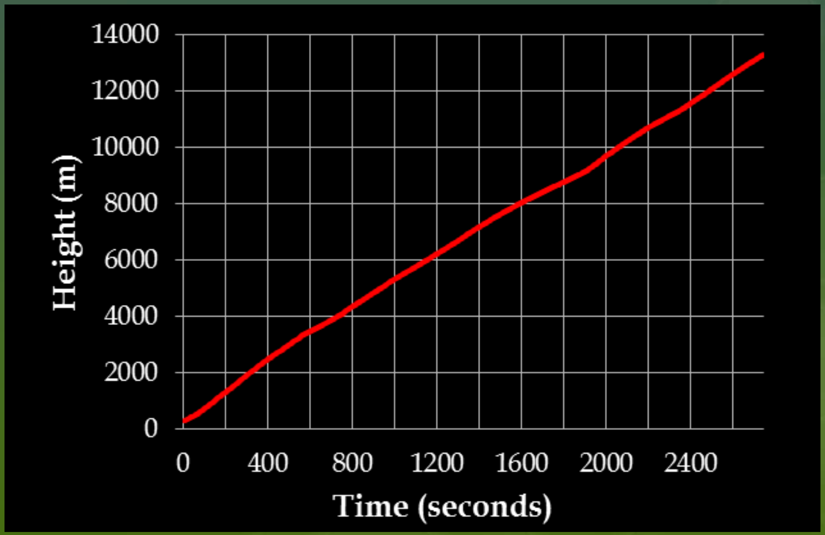
HSF-LE: High School Functions – Linear, Quadratic, & Exponential models

Other activities with balloon data

High School

- **CCSS.Math.Content.HSF-BF.A.1c** Compose functions. For example, if T(y) is the temperature in the atmosphere as a function of height, and h(t) is the height of a weather balloon as a function of time, then T(h(t)) is the temperature at the location of the weather balloon as a function of time.





Question

What other math common core standards can be addressed with this activity?

www.corestandards.org/Math

Balloon data

- Time
- Height
- Pressure
- Temperature
- Dewpoint temperature
- Relative humidity
- Wind speed
  (1 knot = 0.51 m/s = 1.15 mph)
- Wind direction
  (0 degrees: from the north)
  (180 degrees: from the south)



Thank you!