Welcome to Physics 182

Today, we're going to go over:

- **The Objectives and Policies for the Course (very much the same as PHY181)**

- **Textbook Options and How to Register and Access:**

  - **the homework site, MasteringPhysics with Learning Catalytics**
    Use the MasteringPhysics link and course ID on our Canvas site and follow directions

- **Get started on Thermodynamics and Chapter 18.**

- **Your assignment for Monday is to read Chapter 18, get registered for MasteringPhysics, do the Introductory homework assignments, and the HW 18-1 and 18-2 (assigned after Thursday makeup class) on MP.**

- **If you weren't in PHY181 last semester and you have some questions, please feel free to hang around after class and get some answers to any of your questions.**

Introduction to Thermodynamics

The first part of PHY182 covers the science of **Thermodynamics.**

Note: students majoring in Engineering and Physics will likely take an entire course in Thermodynamics; Chemistry majors will take Physical Chemistry where Thermodynamics is covered extensively.

What is **Thermodynamics**?

Dynamics implies motion, forces, momentum, energy, etc.
From PHY181, we're experts at this!

Thermo implies something to do with **Heat**. **But, what is Heat?**

Something to do with **Temperature**? **But, what is Temperature?**

The point is: we really don't yet know what Heat and Temperature are, and we won't have good descriptions and definitions for a few chapters.

The history of thermodynamics is closely tied to the development of the steam engine in the 19th century. This reveals that it was a fairly well-developed science long before anyone could precisely define many of its fundamental quantities! We will somewhat follow this historical treatment.

Introduction to Thermodynamics

Where do we begin our study of thermodynamics?

Where did we begin our study of physics in PHY181?

We began with the observation that: **"Everything Moves"**

We developed kinematics and dynamics to describe and explain that motion.

Although it's not completely historically accurate, we can begin our study of **Thermodynamics** with the observation that:

"Everything is composed of invisible particles (atoms or molecules) that are always in random motion. The science of Thermodynamics is the study of this random motion – especially in terms of energy."

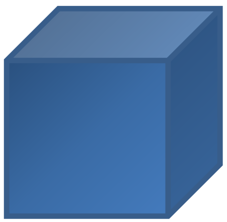
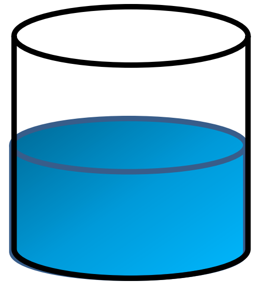
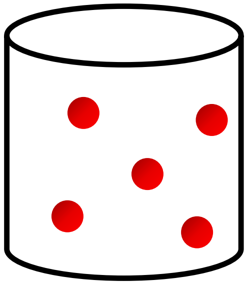
But remember: this idea was not well established when many of the basic relations and laws of thermodynamics were discovered in the 19th century.

So, let's get going with Chapter 18

Phases of Matter

Almost all substances can come in three different **Phases**:

PhET
States of Matter

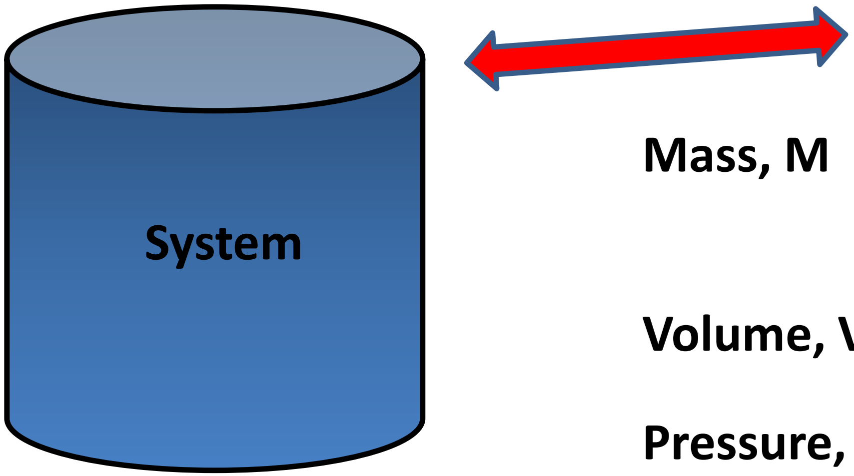
Solid		Liquid		Gas
	melt → ← freeze		vaporize → ← condense	
Atoms/molecules are bound by strong long range forces Definite shape		Atoms/molecules have weak long range forces		Atoms/molecules interact only during collisions
		[Take shape of container and can flow]		
Incompressible (Volume = constant)		Incompressible (to a good approximation)		Compressible (Volume ≠ constant)

PhET
States of Matter

(other motions?)

Macroscopic State Variables

In Thermodynamics, as in other areas of physics, we must first define our **"System"** as the object or collection of objects that we are studying. *It is almost always possible to visualize this as a gas in a container*.



State Variables:

Mass, M (use upper case M for mass of system, lower case m for mass of particle)

Volume, V

Pressure, P
Temperature, T
(more about these two soon)

(There are others, but this will get us started)

Also, **Mass Density**: $\rho = \frac{M}{V} \quad \left[\text{MKS Units}: \frac{\text{kg}}{\text{m}^3} \right]$

Whiteboard Problem 18-1

What is the diameter of a Copper sphere that has the same mass as a 10 cm X 10 cm X 10 cm cube of Aluminum? (LC)

Where are you going to find the densities?

TABLE 18.1 Densities of materials

Substance	ρ (kg/m^3)
Air at STP*	1.29
Ethyl alcohol	790
Water (solid)	920
Water (liquid)	1000
Aluminum	2700
Copper	8920
Gold	19,300
Iron	7870
Lead	11,300
Mercury	13,600
Silicon	2330

$*T = 0°C, p = 1$ atm

Whiteboard Problem 18-2

The nucleus of a Uranium atom has a diameter of 1.5 X 10^{-14} m and a mass of 4.0 X 10^{-25} kg.

What is the density of the nucleus? (LC)

$$\text{Answer: } \rho \sim 10^{17}\ kg/m^3\ !$$

What is the densest thing that you have ever encountered? Look at Table 18-1.

Probably Gold. How does this nuclear density compare to the density of gold?

Does matter exist at such high densities in macroscopic quantities anywhere in the Universe?

Yes, in objects called Neutron Stars?

Roughly, what is weight of a thimble of neutron star material on Earth? ***(LC)***

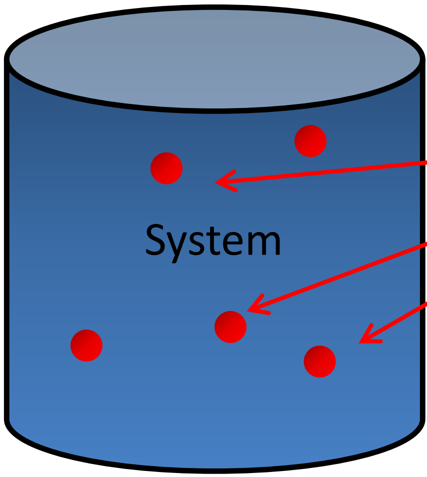
What's a thimble – Google it!

TABLE 18.1 Densities of materials

Substance	**ρ (kg/m^3)**
Air at STP*	1.29
Ethyl alcohol	790
Water (solid)	920
Water (liquid)	1000
Aluminum	2700
Copper	8920
Gold	19,300
Iron	7870
Lead	11,300
Mercury	13,600
Silicon	2330

*$T = 0°C$, $p = 1$ atm

Other Ways of Specifying the Mass



M = system mass

N particles, each of mass m

So, M = Nm

So, **Number Density**, $\frac{N}{V}$ Units $= [\frac{\text{particles}}{m^3} = m^{-3}]$

(Note, your author uses the ratio N/V as the symbol for number density.)

And, $$\frac{N}{V} = \frac{\rho}{m}$$

Also, we will frequently do as the chemists do and work with **Moles**:

$$1 \text{ mole of a substance} = N_A \text{ number of particles}$$

$$\text{where: } N_A = \text{Avagadro's Number} = 6.02 \times 10^{23}\ mol^{-1}$$

So, the number of moles, n, in the system is: $n = \frac{N}{N_A}$

Relating Moles and Mass

Define: $\text{mass of one } {}^{12}C \text{ atom} = 12.0 \text{ u}$ (u = *atomic mass unit*)

Mass number (number of protons and neutrons)

$$\text{Note: } 1\ u = 1.66 \times 10^{-27}\ kg$$

Now, to a good approximation* for an atomic species X with mass number A

$$\text{mass}({}^{A}X) = A\ u$$ (i.e. A atomic mass units)

And for a molecule, we just add up the masses of the individual atoms:

$$e.g.\ \ m(H_2O) = 2 \times (1\ u) + 16\ u = 18\ u$$

Define:

$$\text{Molar Mass, } M_{mol} = \text{mass of one mole of the substance, Units} = [\frac{kg}{mol}]$$

$$\text{So: } M_{mol}\left(\frac{kg}{mol}\right) = \frac{\text{atomic or molecular mass in u}}{1000}$$

$$e.g.\ \ M_{mol}(He) = 0.004\ kg/mol \text{ and } M_{mol}(H_2O) = 0.018\ kg/mol$$

This gives us another way to determine the number of moles; for M = system mass:

$$\text{Number of moles, } n = \frac{M}{M_{mol}}$$

*ignoring the small mass of the electrons and any nuclear binding energies.

Whiteboard Problem 18-3

What is the number density of Lead? (LC)

Here, we are to assume that we know the mass densities from Table 18-1 and atomic mass numbers from Table 18-2:

TABLE 18.1 Densities of materials

Substance	ρ (kg/m^3)
Air at STP*	1.29
Ethyl alcohol	790
Water (solid)	920
Water (liquid)	1000
Aluminum	2700
Copper	8920
Gold	19,300
Iron	7870
Lead	11,300
Mercury	13,600
Silicon	2330

*$T = 0°C$, $p = 1$ atm

TABLE 18.2 Some atomic mass numbers

Element		A
^{1}H	Hydrogen	1
^{4}He	Helium	4
^{12}C	Carbon	12
^{14}N	Nitrogen	14
^{16}O	Oxygen	16
^{20}Ne	Neon	20
^{27}Al	Aluminum	27
^{40}Ar	Argon	40
^{207}Pb	Lead	207

Hint: Look at the units of the quantities that you have and the units of what you want.

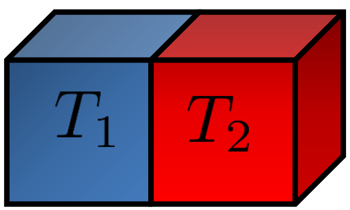
Temperature

Temperature is a very difficult physical quantity to define, but we have a pretty good idea of what it means:

Stick your hand in a bucket of ice water, and then in a pot of boiling water – you'll experience different temperatures!

But, what physical quantity does temperature actually measure?

We'll find this out in Chap 20; for now, we'll just say that for two systems:



If: $T_1 \neq T_2$

Then: thermal energy flows between the systems.

Temperature Scales

We will use several different temperature scales that you should have seen:

	Fahrenheit °F	°C Celsius	K Kelvin*
Water boils	212	100	373
Normal body temp	99	37	310
Room temperature	68	20	293
Water freezes	32	0	273
CO_2 sublimates	−109	−78	195
Nitrogen boils	−321	−196	77
Absolute zero	−460	−273	0

From water freezes to water boils: 180°F; 100°C; 100 K

Conversions:

$$T_K = T_C + 273$$

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

*Note: the Kelvin scale is an absolute scale which means that the zero is at absolute zero.

Whiteboard Problem 18-4

The lowest and highest natural temperatures ever recorded on Earth were in Antarctica and Libya.

a) **The low in Antarctica was -127^{o}F.**
 What is this temperature in Celsius? (LC)

b) **The high in Libya was 136^{o}F.**
 What is this temperature in Kelvin? (LC)

Conversions:

$$T_K = T_C + 273$$

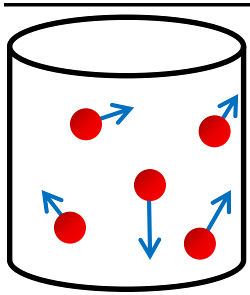
$$T_F = \frac{9}{5}T_C + 32$$

Pressure

Pressure is an important property of fluids (gases and liquids) that will be used in all of thermodynamics. It is introduced in Chap 14 (sections 14.2 and 14.3). There are two types of pressure that we will see:

1. **Gas Pressure** When the particles collide with the wall, they exert a force

PhET
Gas Properties



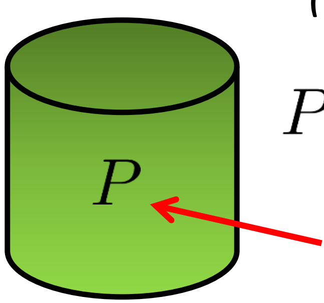
$$\text{Pressure, } P = \frac{\text{force on the wall}}{\text{Area}}$$

$$\text{MKS Units: } 1\ \frac{N}{m^2} \equiv 1\ Pascal\ (Pa)$$

e.g. Atmospheric Pressure: $P_{\text{atm}} = 1.013 \times 10^5\ Pa = 14.7\ \frac{pounds}{in^2}$

The ***atmosphere*** is another common unit of Pressure: $P_{\text{atm}} = 1.0 \text{ atmospheres}$

Gauge Pressure* is the pressure relative to the atmospheric pressure
(because that's what a pressure gauge measures)



P_{atm}

Absolute Pressure, P

$$P_{\text{gauge}} = P - P_{\text{atm}}$$

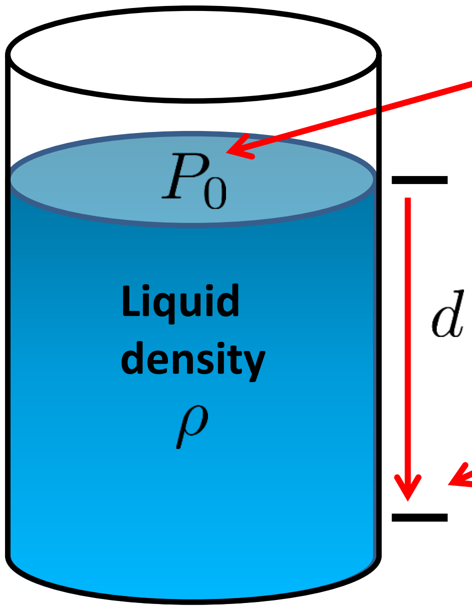
***in most of our calculations, absolute pressure must be used.**

Pressure

2. **Hydrostatic Pressure** is a contribution to the pressure in a fluid in a gravitational field. It is caused by the weight of the fluid above that point.

(if *you* have been to the bottom of the dive well at the Rec *Center*, you've felt hydrostatic pressure. Where do you feel it?) *In your ears!*

e.g. in a liquid:



P_0: pressure at the surface (atmospheric pressure if the container is open to the atmosphere)

Pressure at depth d is:

$$\mathrm{P(at\ d)} = P_0 + \rho g d$$

where g is the acceleration of gravity, $g = 9.8\ m/s^2$

Whiteboard Problem 18-5

a) **What is the pressure in atmospheres at the bottom of the 18 foot dive well pool at the Rec Center? (LC)**

b) The deepest point in the ocean is 11 km below sea level, deeper than Mt. Everest is tall. **What is the pressure in atmospheres at this depth? (LC)**

$$\rho_{\text{water}} = 1000\ kg/m^3$$

When I teach about pressure, this song keeps running through my head?

What's the song and Who's the Artist?

"Under Pressure" by David Bowie and Freddie Mercury with Queen