Recap: Bernoulli's Principle

❖ **"The sum of pressure plus kinetic energy per unit volume of a flowing fluid is constant."**

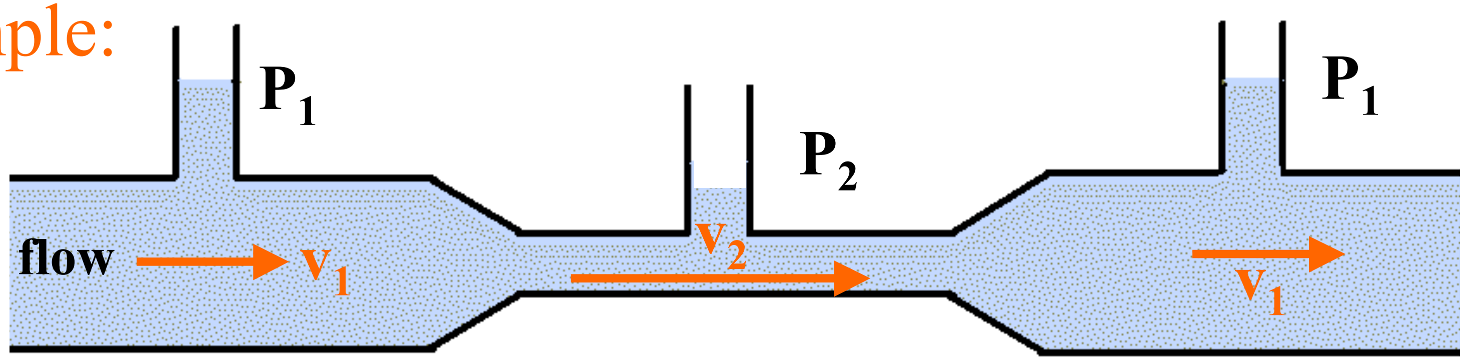
$$P + \underbrace{\tfrac{1}{2}\rho v^2}_{\text{K.E. per unit volume}} = \text{constant}$$

pressure ↗

($\rho = \frac{\text{mass}}{\text{vol}}$)

Result: Relates pressure variations to changes in fluid speed.

Example:



- Intuitively expect pressure in constriction region to be higher.

Not True – Exact opposite !

- **Speed of liquid is greater in constriction which by Bernoulli's equation indicates lower pressure.**

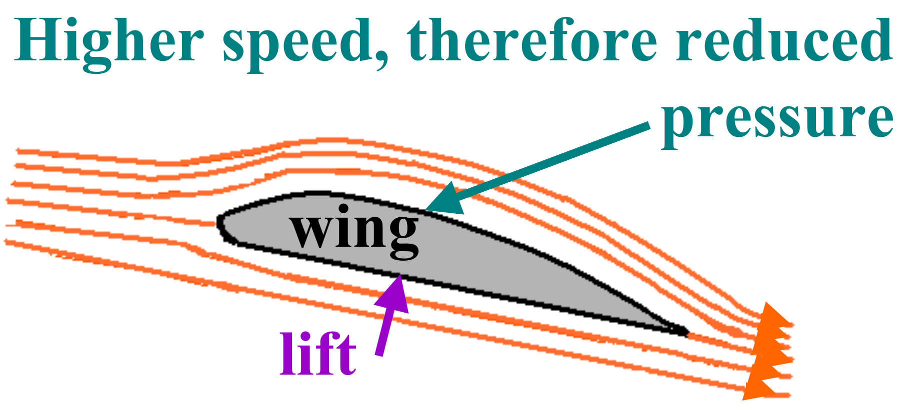
Thus: **High pressure** is **not** associated with **high velocity**. (Against intuition).

Example: Garden hose – a restriction causes **velocity** of water to **increase** but pressure at nozzle is **less** than further back in pipe where velocity of flow is lower.

(The large force exerted by water exiting hose is due to its velocity and not to pressure in pipe).

Bernoulli's Principle and Flight

- Bernoulli's principle applies to an **incompressible fluid** (i.e. density ρ constant)
- However it can be **extended** qualitatively to **help explain** motion of **air** and other **compressible fluids**.



Shape /tilt of wing causes the air flow over wing to have **higher speed** than **air flowing** underneath it (greater distance).

- **Reduced pressure** above the wing **results** in a net **upward force** due to pressure change called **"lift".** (Demo: paper leaf)
- A **biker** also has swollen jacket when going fast due to low external pressure!
- In aircraft design have shape of wing and "angle of attack" variations that effect total lift. (wind tunnel tests).
- **Forward speed** is therefore **critical** for aircraft **lift.** This can be affected by turbulence…
- If air flow over wing changes from laminar to turbulent flow the lift will be reduced significantly!
- In regions of **strong wind shears** lift can also be lost as flow reduces to zero!

Summary:

- A **reduction** in **pressure** causes an **increase** in **flow velocity** (and vice versa).

Temperature and Heat (Chapter 10)

- **What is temperature?**
  - How can we compare one temperature with another?
  - Is there a difference between heat and temperature?
  - What does it mean to say something is **hot** or **cold**?
  - Ask yourself "How do they differ?"
- How can we define "**hot**" or "**cold**"?
- **Senses** – Touch: can be very misleading…
  - **Pain** felt when touching something that is **very hot** or **very cold** can be **difficult** to **distinguish**!
  - **Dissimilar objects** (e.g. wood and metal) can feel **warmer** or **colder** even though **both** are at **room temperature**!
- **Temperature** is really a **comparative measurement** to tell if an object is <u>**hotter**</u> or <u>**colder**</u> than something else.

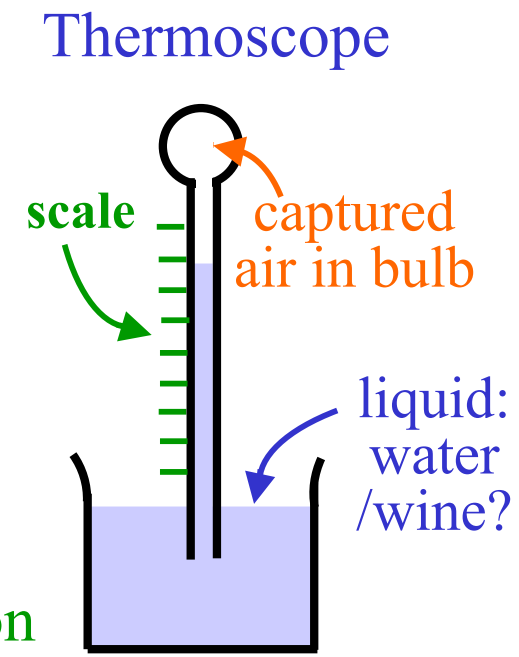
Thermal Equilibrium

- When two objects are in **contact** with each other for a **long period of time,** we say they are in **thermal equilibrium**.

  i.e. they **both** have the **same temperature**.
- This is the basis for temperature (comparative) measurements.

Thermometer

- Invented by Galileo to indicate **"degrees of hotness".**
- As captured air in bulb is **heated** or **cooled** it **expanded** or **contracted** and liquid **level changed** accordingly.
- **Thermometers** tell us whether something is **hotter** or **colder** on an **internationally** recognized **reference scale**.
- **Thermometer use:** - fluid (liquid, gas) expansion
  - electrical resistance change;
  - changes in color…



Temperature Scales

- Thermometers are based on reliable reference points such as **freezing** and **boiling** point of water. **(Stable points as phase transition).**
- Want the reference points to be **far apart** – with uniform scale in between.

Fahrenheit scale (G. Fahrenheit, 18th century)

- He did not want to deal with **negative values**. So he set his **"0" mark** at the coldest temperature he could make in the laboratory (using mixture ice, water and salt).
- He set his upper reference to **human body** temperature and called it **96 º** (for easy division by half, quarter etc.).
- This resulted in scale (still in use in U.S.A.) where **freezing** point of water = 32 ºF and boiling point = 212 ºF (at sea level).
- There are **180 ºF** between these two common reference points.

Celsius scale (A. Celsius, 18th century)

- He used **freezing and boiling point of water** for reference points and then divided the distance between them by **100 equal parts**.
- Strangely, he set the temperature of freezing water to 100 º and boiling water to 0 º!
- Later revision (interchange) resulted in the **centigrade scale** with **100 degrees** between reference points.
- Each Fahrenheit degree is therefore smaller than a centigrade degree:

180 ºF = 100 ºC or 9 ºF = 5 ºC or $1\,^{\circ}F = \frac{5}{9}\,^{\circ}C$

Example: What is room temperature of 68 ºF in ºC?

This is **36 ºF** above freezing point of water (32 ºF).

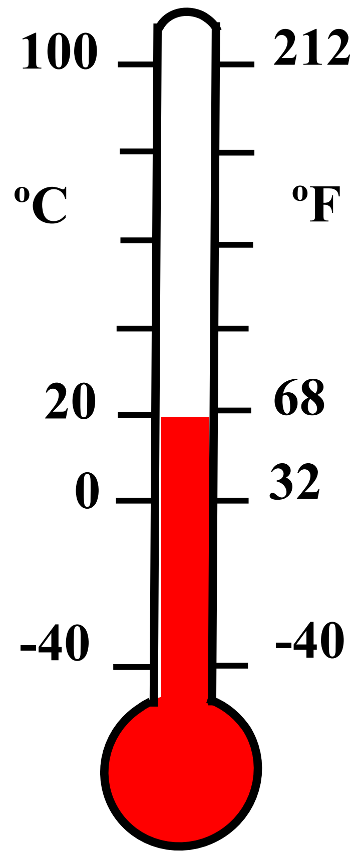
As $1\,^{\circ}F = \frac{5}{9}\,^{\circ}C$ $\quad 36\,^{\circ}F = \frac{5}{9} \times 36\,^{\circ}C = 20\,^{\circ}C$

Thus: 68 ºF = 20 ºC

Conversion Between °F and °C

$$T_c = \frac{5}{9}(T_f - 32) \quad \Rightarrow \quad T_f = \frac{9}{5} T_c + 32$$

- i.e. multiplying T_c by $\frac{9}{5}$ tells us how many degrees Fahrenheit above freezing.



Example: At what temperature do the **Celsius** and **Fahrenheit** scales have the **same value**?

$$T_f = \frac{9}{5} T_c + 32$$

set $T_f = T_c$ to determine value…

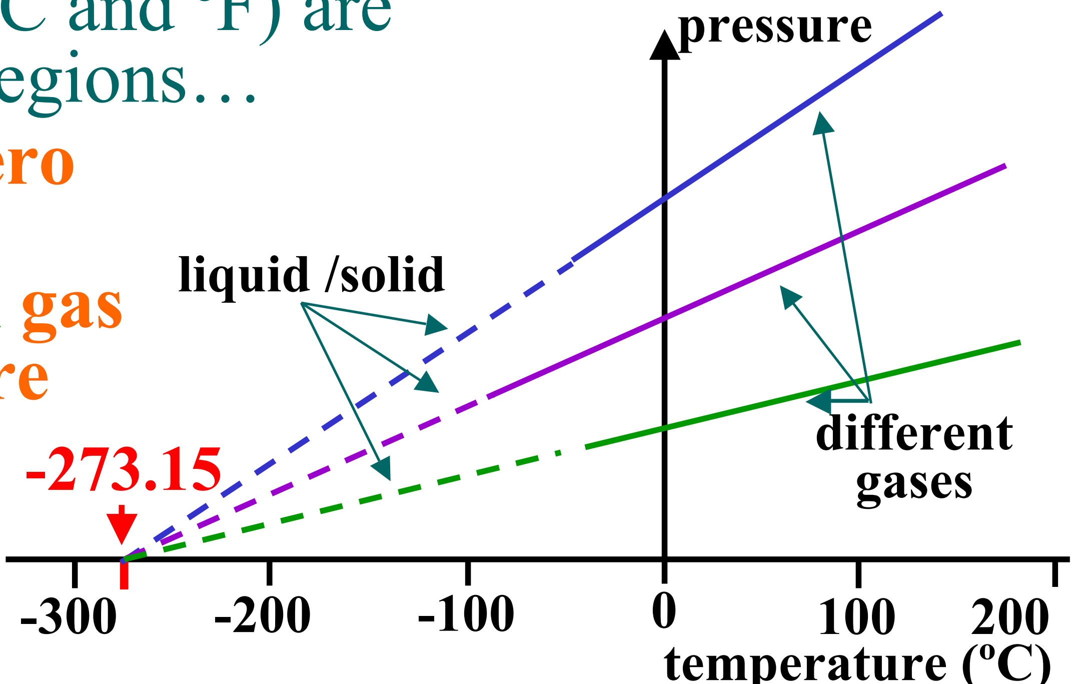
$$T_f = \frac{9}{5} T_f + 32$$

or $T_f = T_c = -40^{\circ}$ (F or C)

- So when the temperature gets close to -40° it **does not matter** which scale to use!
- At **higher** and **lower** values they are quite **different!**

Absolute Zero Temperature

- Choosing the freezing point of water to be 0 ºC is a convenient but arbitrary decision.
- **Negative temperatures** (ºC and ºF) are common in mountainous regions…
- The idea of an **absolute zero** temperature arose from observations of changes in **gas pressure** with **temperature**
- As gas **cools** it **reduces** in **pressure** until it liquefies /solidifies.



- Gas **pressure decreases linearly** with **temperature**.
- Extension of these cooling lines for different gases all **intersected** at **one temperature** at **zero pressure**: **-273.15 ºC**.
- As negative pressure has **no** physical meaning, this indicates that temperature cannot fall below **-273.15 ºC.**

Kelvin Scales (after Lord Kelvin 19th century)

- The Kelvin (or absolute) scale has "0" at -273.15 ºC
- For convenience it uses the **same degree** intervals as **Celsius** scale.
- To convert Celsius to Kelvin simply add 273.15

$$T_k = T_c + 273.15$$

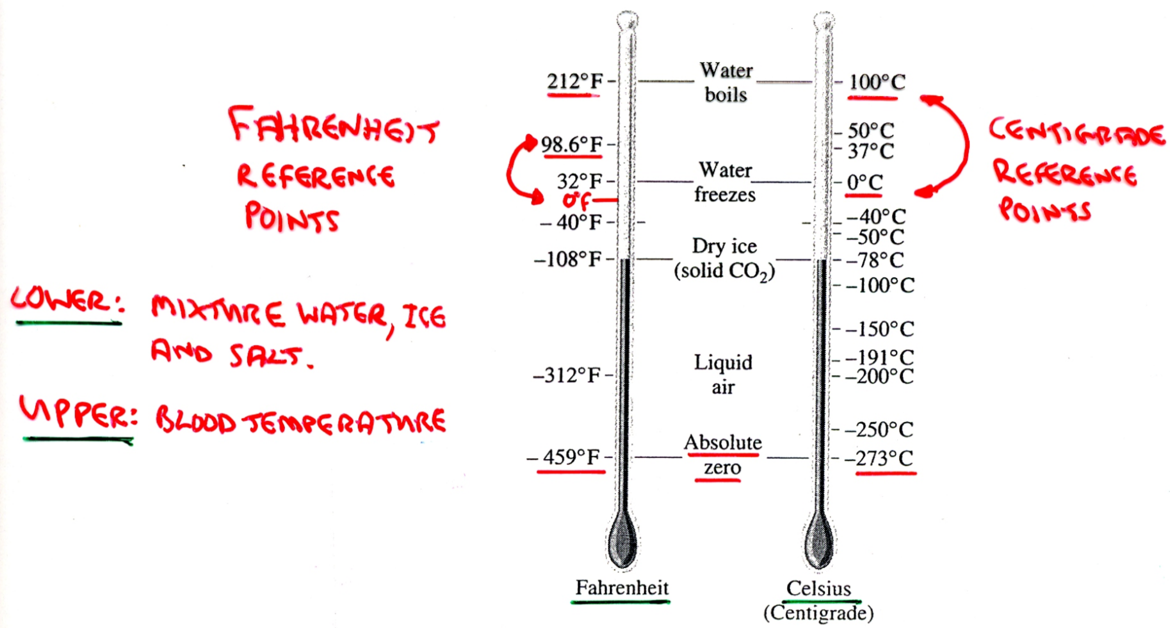
- As **Kelvin** is an **absolute scale**, the comparative **"degree"** symbol is not used.

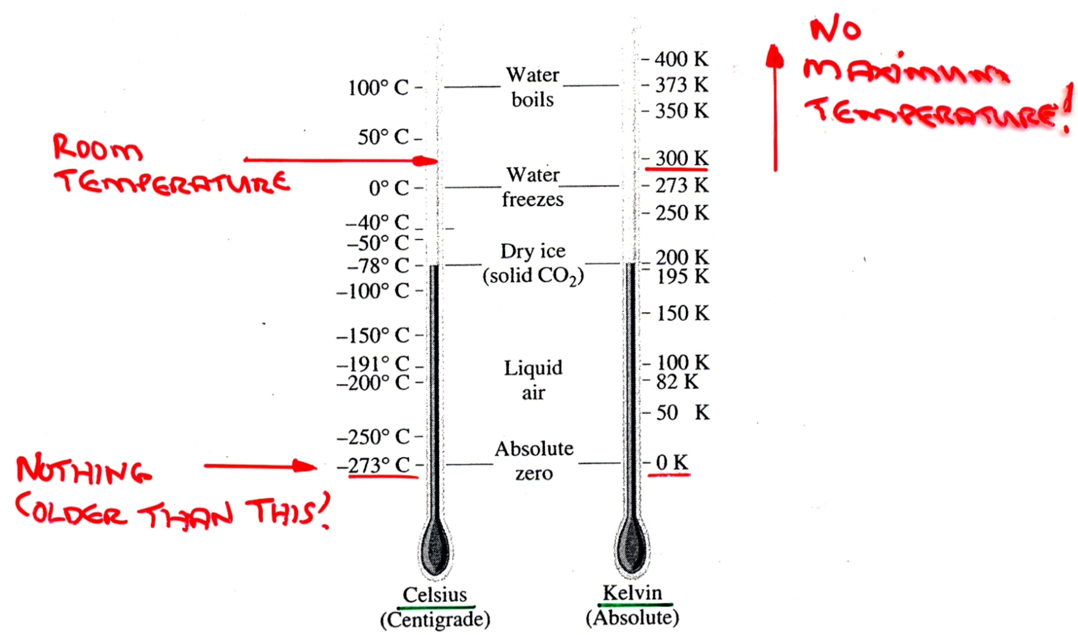
Example: 20 ºC = 293 K

- Incredible range of temperatures in universe!

Temperature Ranges

0 K	Absolute zero	-273.15 ºC
4.25	Liquid He boils	-268.9
20.4	Liquid H boils	-253
77	Liquid N_2 boils	-196
90	Liquid O_2 boils	-183
194	CO_2 (dry ice) freezes	-79
273	Water freezes	0
310	Body temperature	~ 37
1336	Gold melts	1063
5773	Carbon arc	5500
6273	Sun's photosphere	6000
6293	Iron Welding arc	6020


FAHRENHEIT REFERENCE POINTS
LOWER: MIXTURE WATER, ICE AND SALT.
UPPER: BLOOD TEMPERATURE
212°F
98.6°F
32°F
0°F
– 40°F
–108°F
–312°F
– 459°F
Water boils
Water freezes
Dry ice (solid CO_2)
Liquid air
Absolute zero
100°C
50°C
37°C
0°C
–40°C
–50°C
–78°C
–100°C
–150°C
–191°C
–200°C
–250°C
–273°C
CENTIGRADE REFERENCE POINTS
Fahrenheit
Celsius (Centigrade)


ROOM TEMPERATURE
NOTHING COLDER THAN THIS!
NO MAXIMUM TEMPERATURE!
100° C
50° C
0° C
–40° C
–50° C
–78° C
–100° C
–150° C
–191° C
–200° C
–250° C
–273° C
Water boils
Water freezes
Dry ice (solid CO_2)
Liquid air
Absolute zero
400 K
373 K
350 K
300 K
273 K
250 K
200 K
195 K
150 K
100 K
82 K
50 K
0 K
Celsius (Centigrade)
Kelvin (Absolute)