PHY 121 Mechanics *S.G. Rajeev*

Lecture 24

Thermodynamics

• *Thermodynamics* is the study of heat. To begin with it was thought of as a separate branch of physics with its own fundamental laws. But it was discovered later that the laws of thermodynamics can be derived from those of mechanics using statistical arguments.

•We all have an intuitive idea of when a body is 'hot' or 'cold'. It turns out that *heat is a form of energy*, transfered between systems in contact with each other.

Heat

•Heat can be converted into kinetic energy (as in an engine). Or friction might convert kinetic energy into heat.

•A body can also transfer heat to another. Two bodies are in *thermal equilibrium* if they are in contact with each other, yet no heat is transfered between them.

•Before it was realized that heat is a form of energy, it was measured in a unit of its own called *calories*. Now we *define* a calorie to be *4.186 J*.

Temperature

•The 'zeroth law of thermodynamics' (due to Saha) states when two bodies are in thermal equilibrium:

> *There is a quantity (called* temperature*), such that two bodies at the same temperature are in thermal equilibrium.*

•It is called the zeroth rather than the first law because it was discovered after the other three laws. It is more basic than than even the first law so it was given the number zero.

•There is a lowest possible temperature, but there is no upper limit to temperature.

•Heat flows from a body of higher

temperature to a body of lower temperature.

Measuring Temperature

- There are some properties such as the volume of a liquid (e.g., mercury) at constant pressure that grow with temperature. The pressure of a gas at constant volume also increases with temperature. These are helpful in making instruments that measure temperature: *thermometers*.
- The fundamental unit of temperature is *Kelvin* or K for short.
- The lowest possible temperature is defined to be at $0K$.
- There is a temperature at which water is in equilibrium with water vapor and ice (the triple point of water). We define the temperature

at this point to be $273.16K$.

- We can measure temperature by a constant volume gas thermometer. The pressure of any gas at constant volume (at not too high pressures) is proportional to temperature.
- Practical units of temperatures are *Celsius* and *Fahrenheit*.

$$T_C = T_K - 273.15^\circ, \quad T_F = \frac{9}{5}T_C + 32^\circ$$

- Trivia question: at what temperature does the above scales coincide?
- Answer: -40.

Heat Expansion

- As you heat a body, the random motions of the molecules that make up the body increase. Hence the average distance between molecules increases. This shows up as an expansion of the body in all directions.
- Liquids expand more than solids and gases more than liquids.
- For a solid, the change in the length ΔL is proportional to the original length L and to the change in temperature Δ

$$\Delta L = \alpha L \Delta T.$$

- The constant α is a property of the body, called *coefficient of*

linear expansion

- Since a body expands in all directions, its volume V increases as well. A bit of calculus (along with the fact that $V = L^3$) gives

$$\Delta V = 3\alpha V \Delta T$$