the remaining of :

Waves

Chapters 13,14

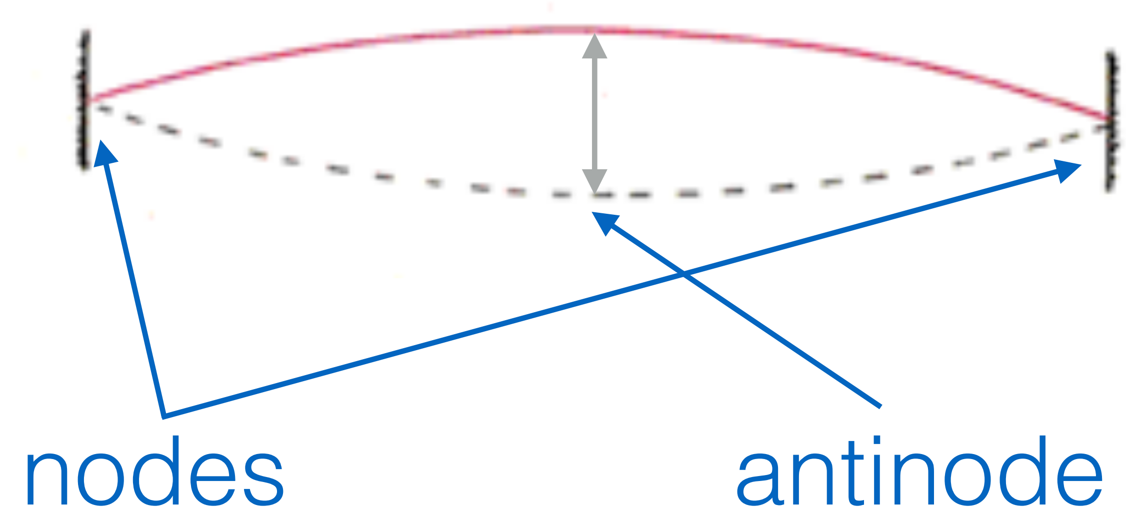
Lecture Physics 1A

January 18, 2017

Teun Huijben (3rd year NB)

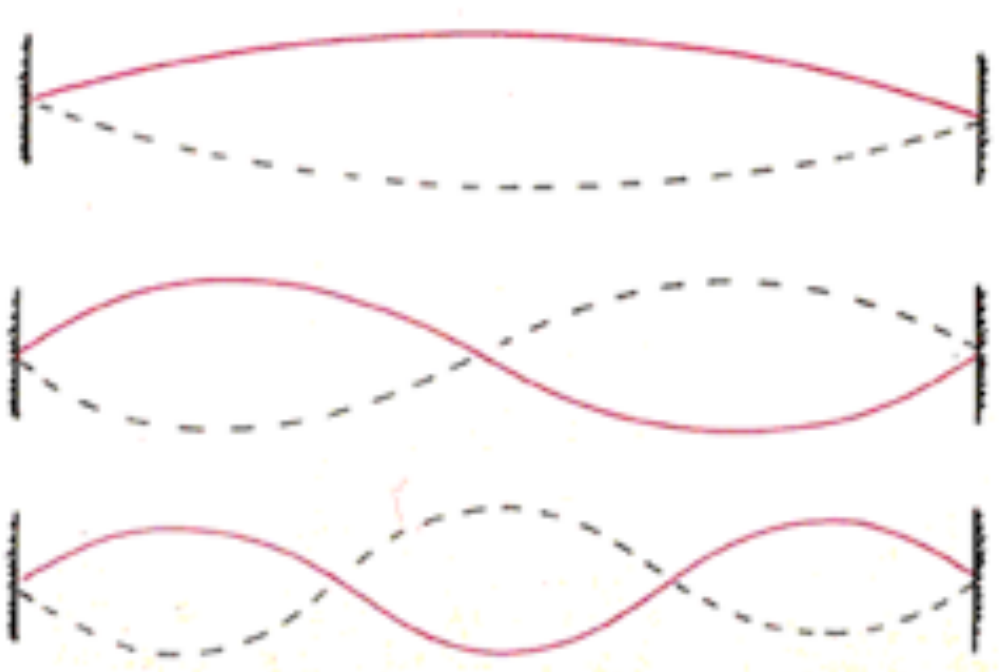
Standing waves

$$y(x,t) = 2A \cdot \sin(kx) \cdot \sin(\omega t)$$



- no propagating, it is 'standing'
- maximum amplitude depending on x-position
- fixed number of wavelengths between walls

Standing waves



L = λ/2

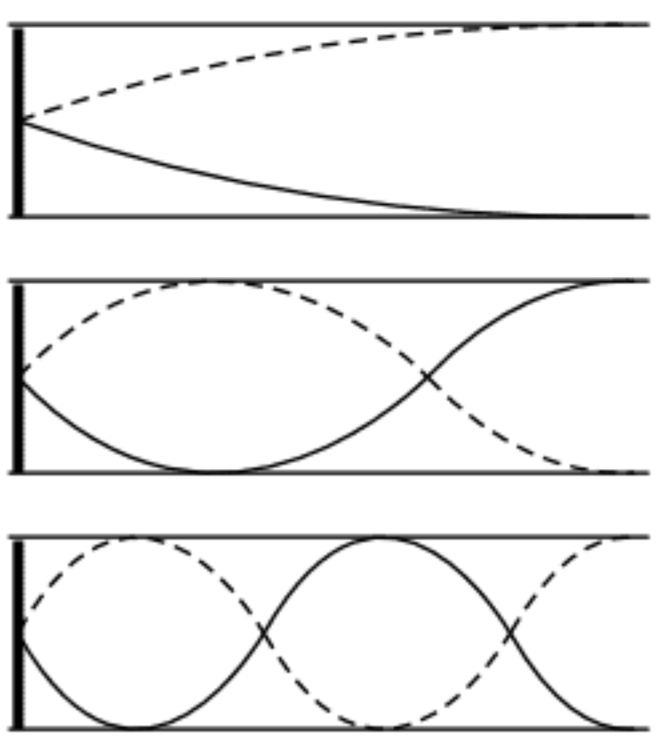
L = λ

L = 3λ/2

2 fixed ends:

$L = m \cdot (\lambda/2)$

m=1,2,3, …



L = λ/4

L = 3λ/4

L = 5λ/4

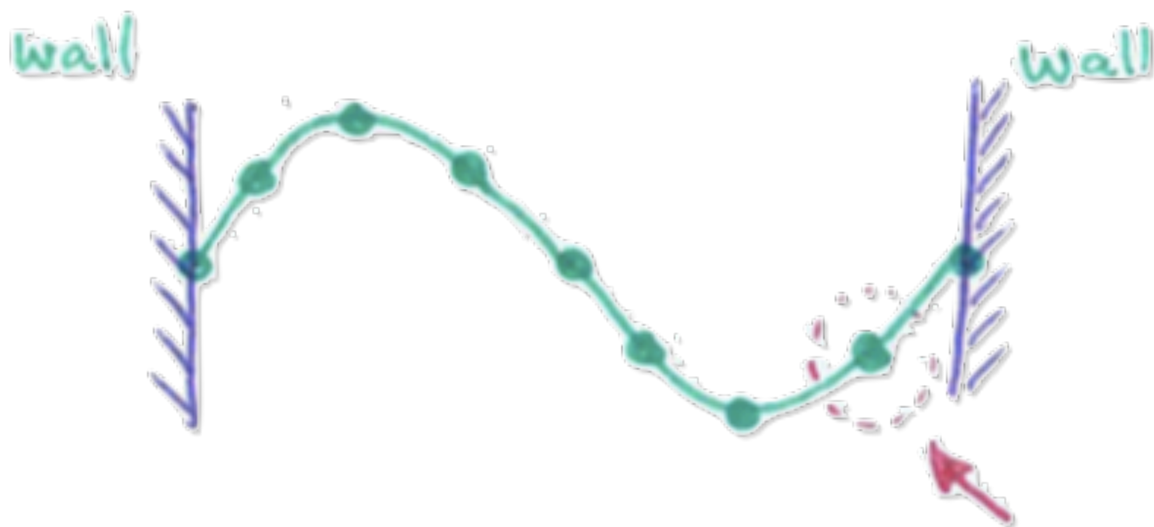
1 open+1 fixed end:

$L = (2n-1) \cdot (\lambda/4)$

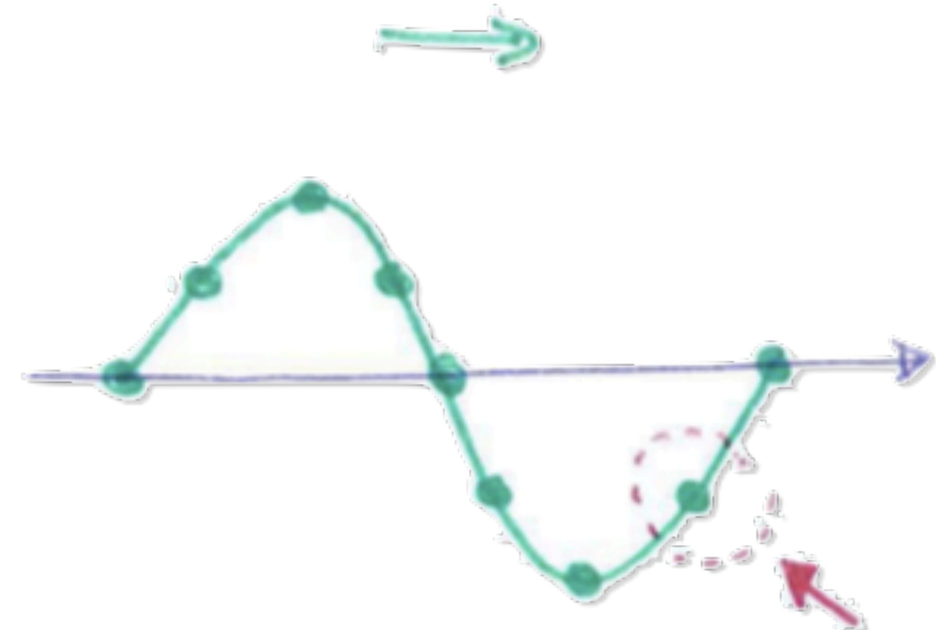
n=1,2,3, …

Standing waves

Different displacement between the marked marbles?



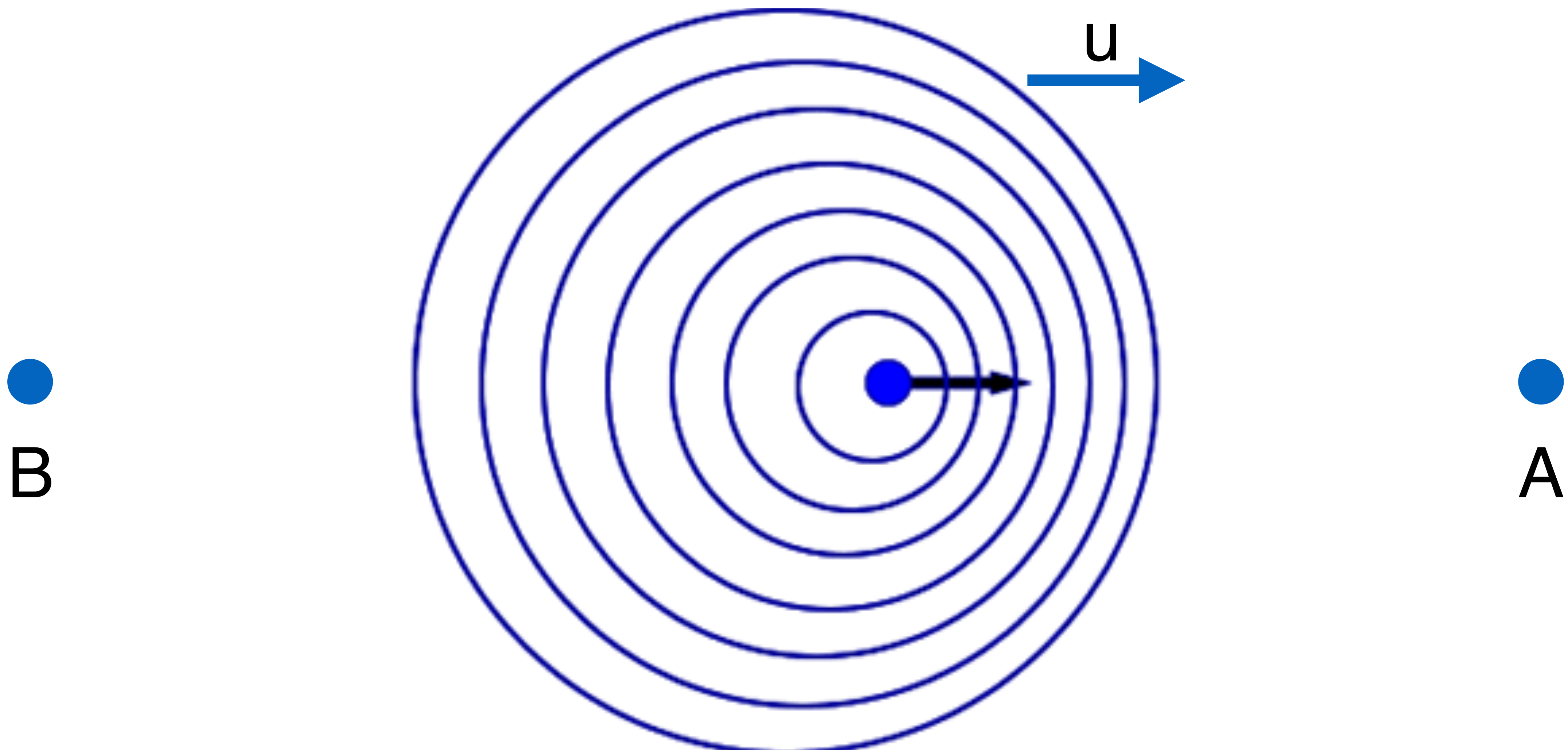
standing wave



transverse wave

Doppler effect

moving source:



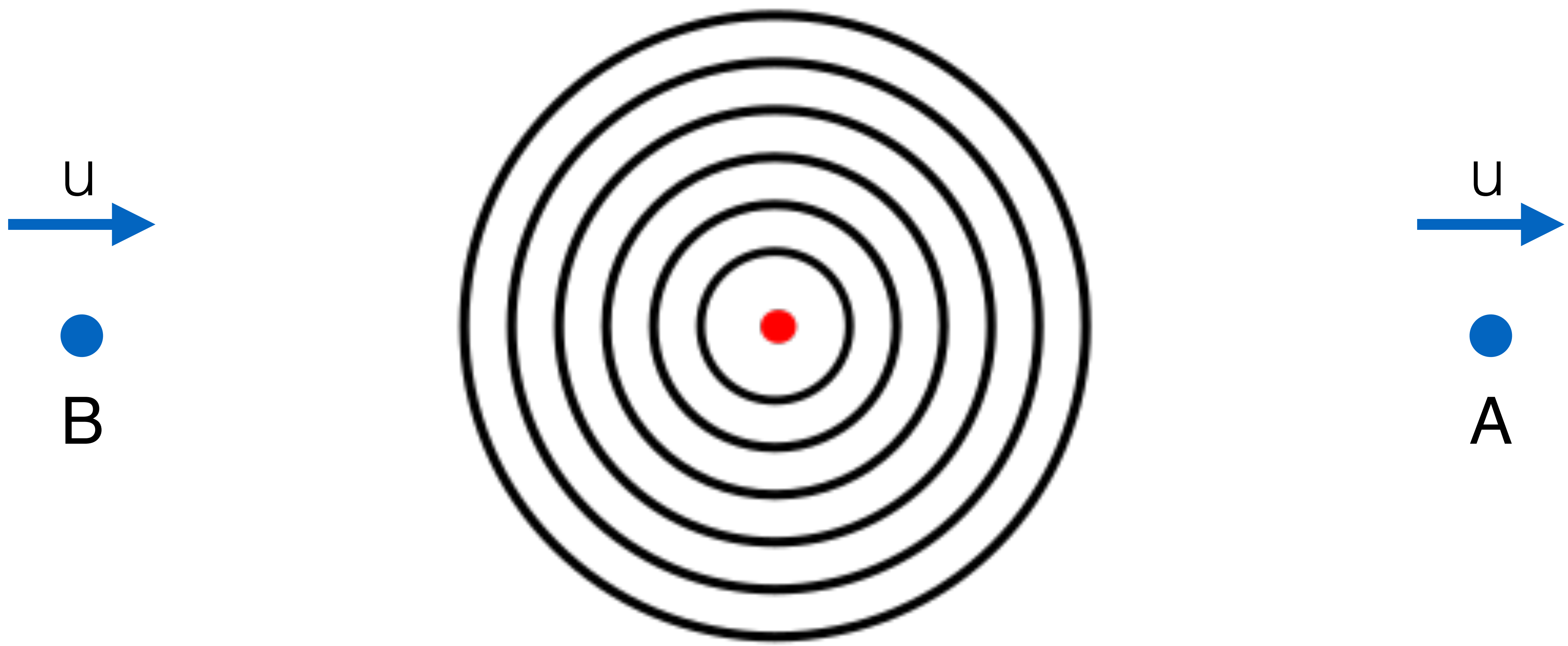
longer λ
lower f

shorter λ
higher f

$$f' = \frac{f}{\left(1 \pm \frac{u}{v}\right)}$$

Doppler effect

moving observer:



shorter λ
higher f

$$f' = f \cdot \left(1 \pm \frac{u}{v}\right)$$

longer λ
lower f

Temperature and Heat

Chapter 16

Temperature

The **temperature** of a system is the average amount of **kinetic energy**.

- measured in scales: °C, K, F, …

$$[T] = K$$

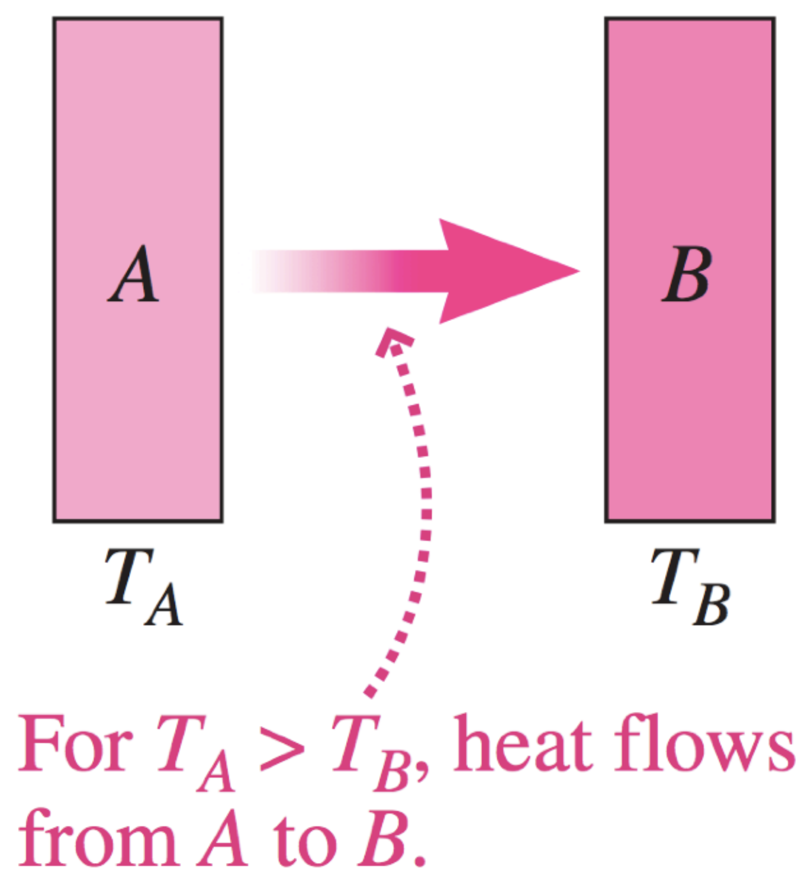
$$T_C = T - 273.15$$

$$T_F = 9/5 T_C + 32$$

Temperature ↔ Heat

The **temperature** of a system is the average amount of **kinetic energy**

Heat is the transferred energy between two objects wit a **different T**



Heat

Heat is the transferred energy between two objects wit a **different T**

- $Q = \mathbf{C} \cdot \Delta T$

$[Q] = J$
C = **heat capacity** (of object)
$[C] = J \cdot K^{-1}$

- $Q = \mathbf{m} \cdot \mathbf{c} \cdot \Delta T$

c = **specific heat** (of material)
$[c] = J \cdot K^{-1} \cdot kg^{-1}$

example:

Shower

The temperature in the water heater is 18°C. If the heater holds 150 kg of water, how much energy will it take to bring it up to 50°C? If the energy is supplied by a 5.0-kW electric heating element, how long will that take?

$c_{water} = 4184\ J \cdot kg^{-1} \cdot K^{-1}$

example:

Aluminium in water

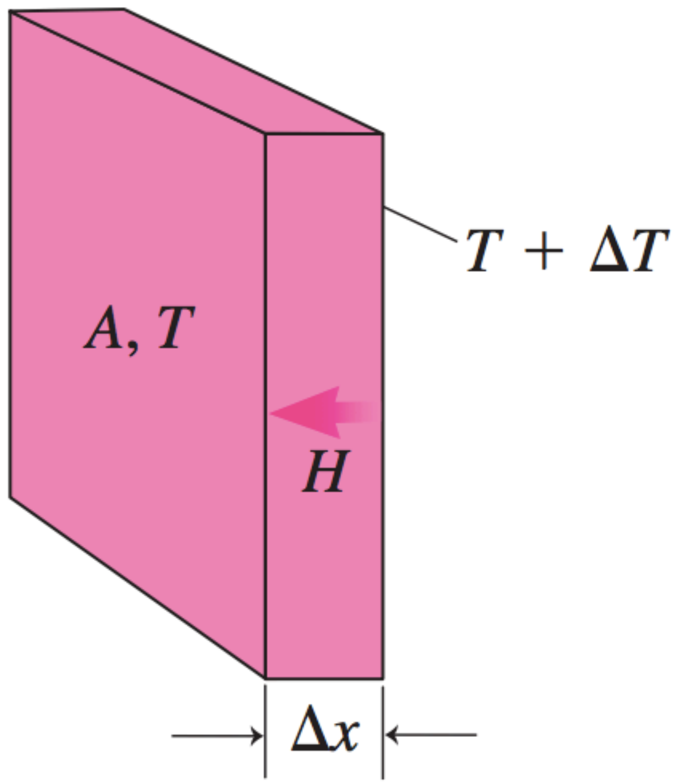
An aluminum frying pan of mass m_P is at temperature T_P when it's plunged into a sink containing m_W kg of water at temperature T_W. Assuming that none of the water boils and that no heat is lost to the surroundings, find the equilibrium temperature of the water and pan.

Heat transfer

- **Conduction** = direct physical contact

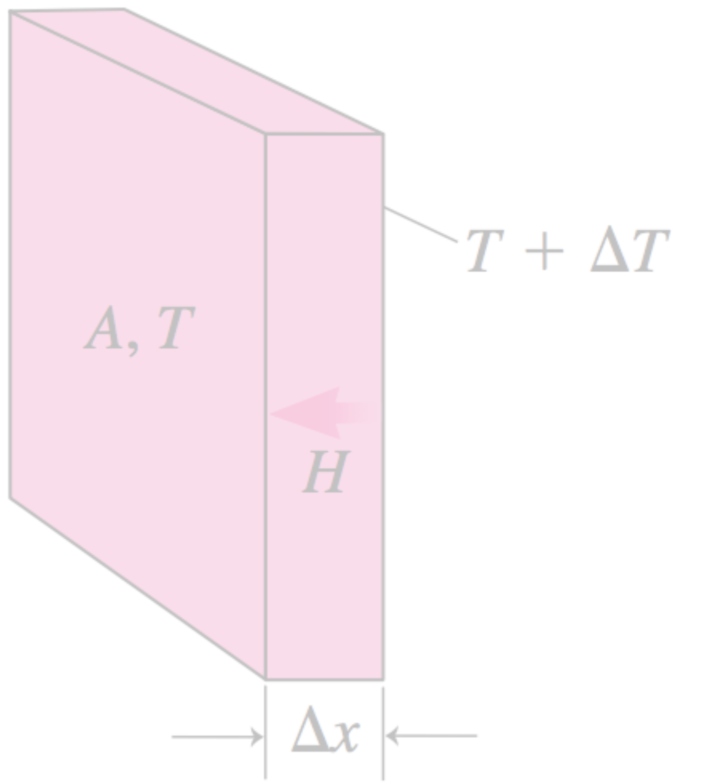
$$H = -k \cdot A \cdot \frac{\Delta T}{\Delta x} = -\frac{\Delta T}{R}$$

H = heat flow in W
k = thermal conductivity in $W \cdot m^{-1} \cdot K^{-1}$
R = thermal resistance in $K \cdot W^{-1}$



Heat transfer

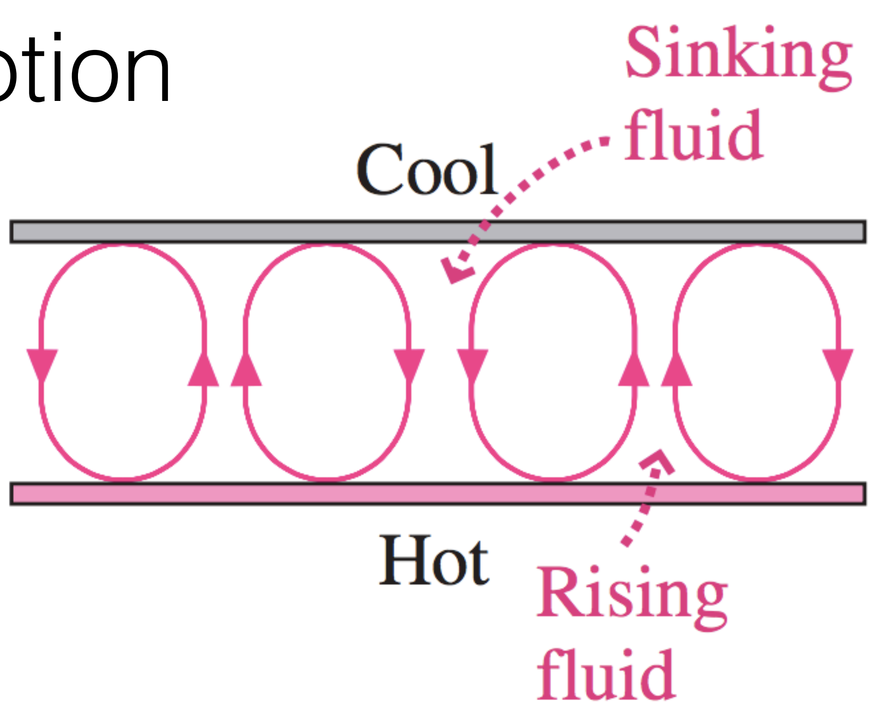
- **Conduction** = direct physical contact



$$H = -k \cdot A \cdot \frac{\Delta T}{\Delta x} = -\frac{\Delta T}{R}$$

H = heat flow in W
k = thermal conductivity in W·m^{-1}·K^{-1}
R = thermal resistance in K·W^{-1}

- **Convection** = transfer by fluid motion



Heat transfer

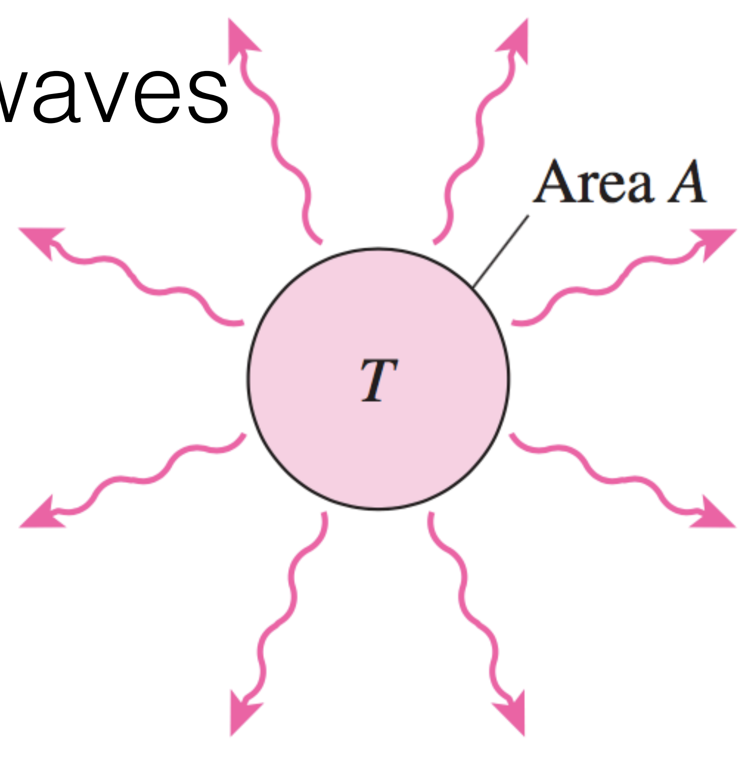
- **Conduction** = direct physical contact

$$H = -k \cdot A \cdot \frac{\Delta T}{\Delta x}$$

- **Convection** = transfer by fluid motion

  → heated fluid gets less dense and rises

- **Radiation** = emitting electromagnetic waves



Heat transfer

- **Conduction** = direct physical contact

$$H = -k \cdot A \cdot \frac{\Delta T}{\Delta x}$$

- **Convection** = transfer by fluid motion

  → heated fluid gets less dense and rises

- **Radiation** = emitting electromagnetic waves

$$P = e\sigma A T^4$$

P = radiation power in W
e = emissivity [0,1]
σ = Stefan-Boltzman constant
($5.67 \cdot 10^{-8}$ $W \cdot m^{-2} \cdot K^{-4}$)

Heat transfer

- **Conduction** = direct physical contact

$$H = -k \cdot A \cdot \frac{\Delta T}{\Delta x}$$

- **Convection** = transfer by fluid motion

→ heated fluid gets less dense and rises

- **Radiation** = emitting electromagnetic waves

$$P = e\sigma A T^4$$

$$P = e\sigma A\left(T_{surface}^4 - T_{surrounding}^4\right)$$

Thermal behaviour of Matter

Chapter 17

Ideal gas law

$$\boxed{\mathbf{pV = nRT}} = nN_AkT = \mathbf{NkT}$$

R = gas constant in $J \cdot K^{-1} \cdot mol^{-1}$

$$= N_A \cdot k_b = (6.022 \cdot 10^{23}) \cdot (1.38 \cdot 10^{-23}) = 8.13\ J \cdot K^{-1} \cdot mol^{-1}$$

Avogadro number

Boltzman constant

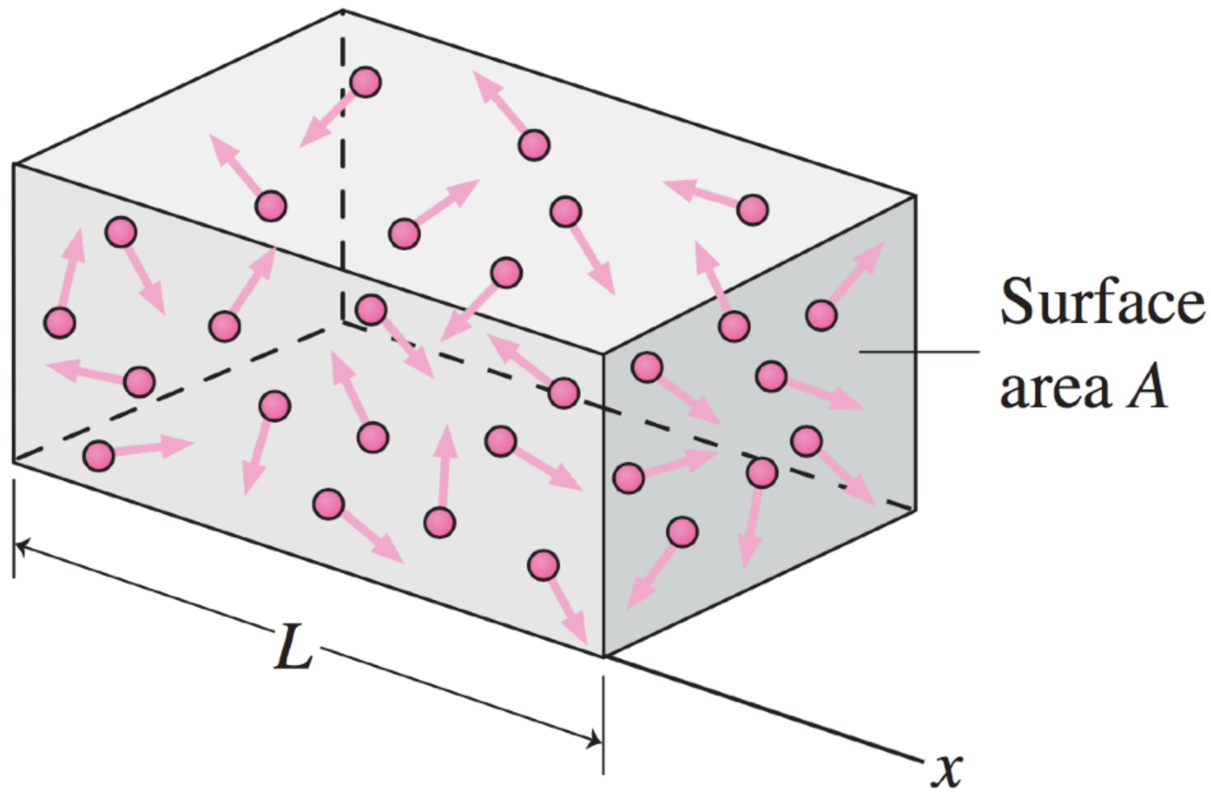
Ideal gas law

$$PV = nRT$$

assumptions:

- molecules have neligible size → no collisions
- no attraction/repulsion between molecules
- randomly move in all directions
- collisions with the wall are elastic

Kinetic theory of ideal gas



$$\frac{1}{2}m\overline{v^2} = \frac{3}{2}kT$$

The **temperature** of a system is the average amount of **kinetic energy**

example:

Speed nitrogen molecule

Find the average kinetic energy of a molecule with mass m in air at room temperature and determine its speed.

Phase changes

L = Heat of **transformation** ($J \cdot kg^{-1}$)

L_f = Heat of fusion (solid ↔ liquid)

L_v = Heat of vaporation (liquid ↔ gas)

L_s = Heat of sublimation (solid ↔ gas)

$$\mathbf{Q = L \cdot m}$$

example:

Ice in water

When 200 g of ice at -10°C is added to 1.0 kg of water at 15°C, is there enough ice to cool the water to 0°C? If so, how much ice is left in the mixture?

$c_{ice} = 2050\ J{\cdot}kg^{-1}{\cdot}K^{-1}$

$c_{water} = 4184\ J{\cdot}kg^{-1}{\cdot}K^{-1}$

$L_F = 334\ kJ{\cdot}kg^{-1}$

Thermal expansion

volume:

$$\beta = \frac{\Delta V / V}{\Delta T}$$

β = coefficient of volume expansion (K^{-1})

length:

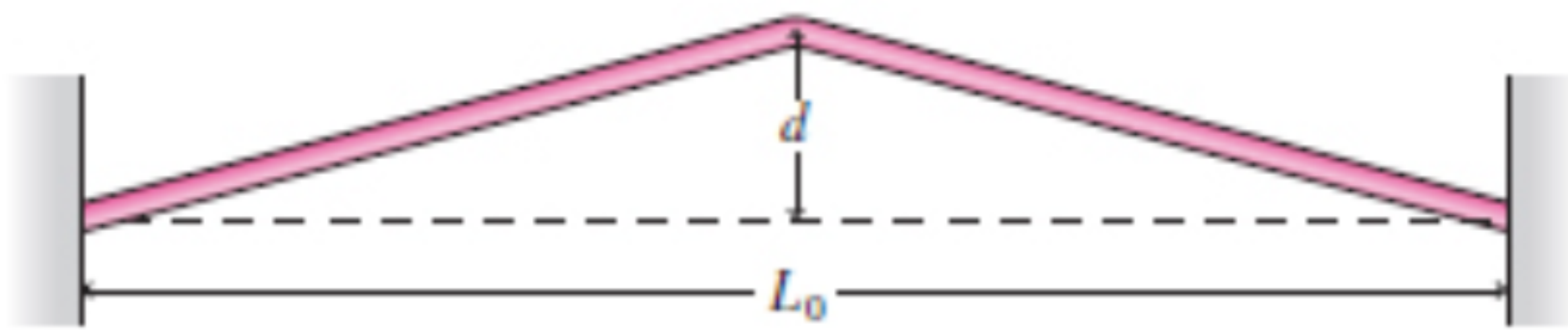
$$\alpha = \frac{\Delta L / L}{\Delta T}$$

α = coefficient of linear expansion (K^{-1})

β = 3α

example:

Linear expansion



Express the distance d in terms of L_0 , ΔT , and the linear expansion coefficient α