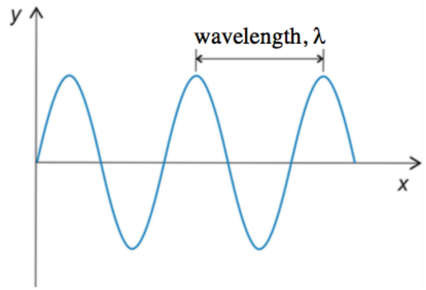
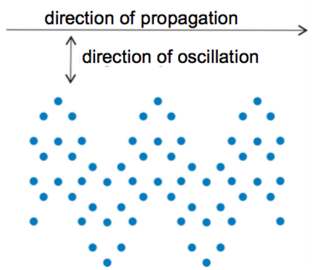
# Waves

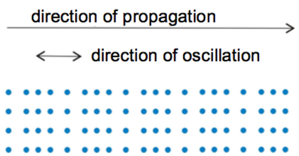


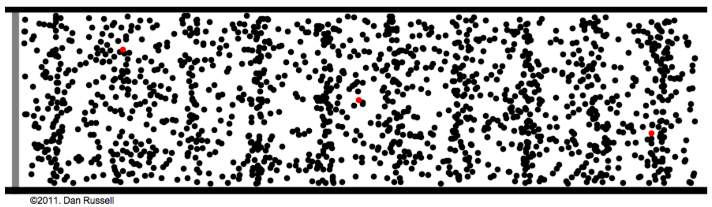

$$c = \frac{\lambda}{T} = \lambda \cdot \frac{1}{T} = \lambda \cdot f$$

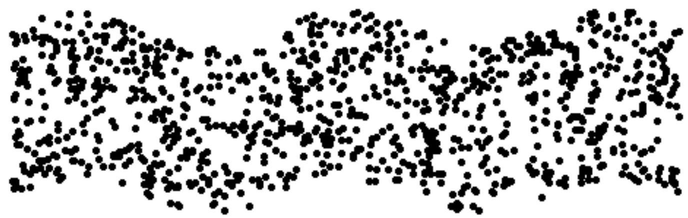
**Transverse wave:**

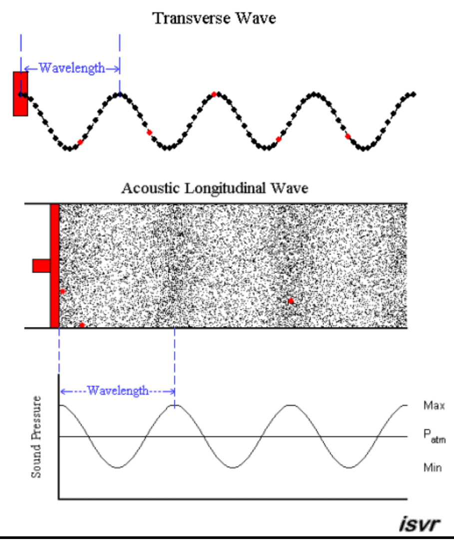


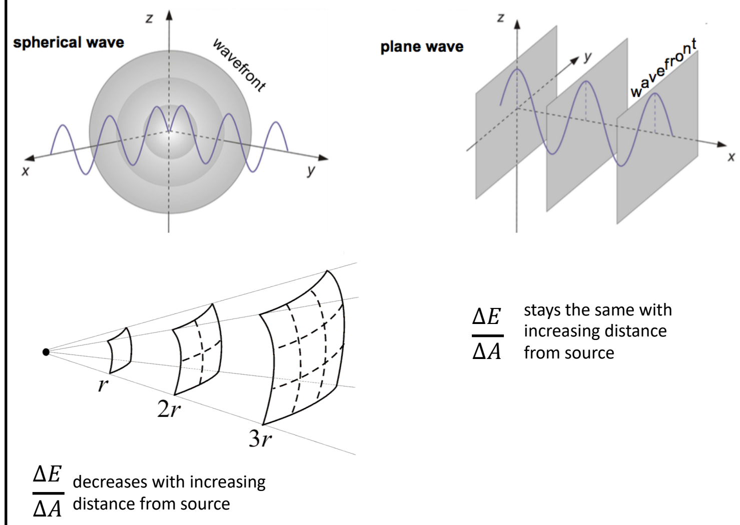

**Longitudinal wave:**



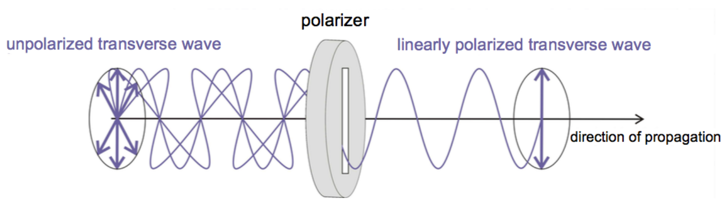



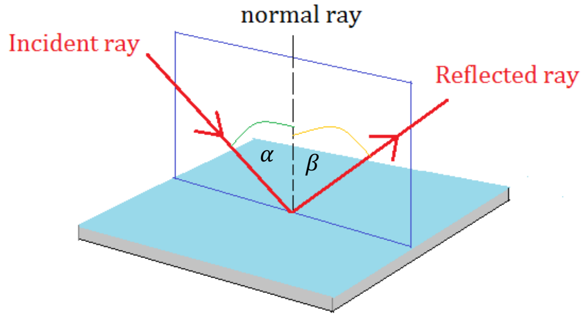


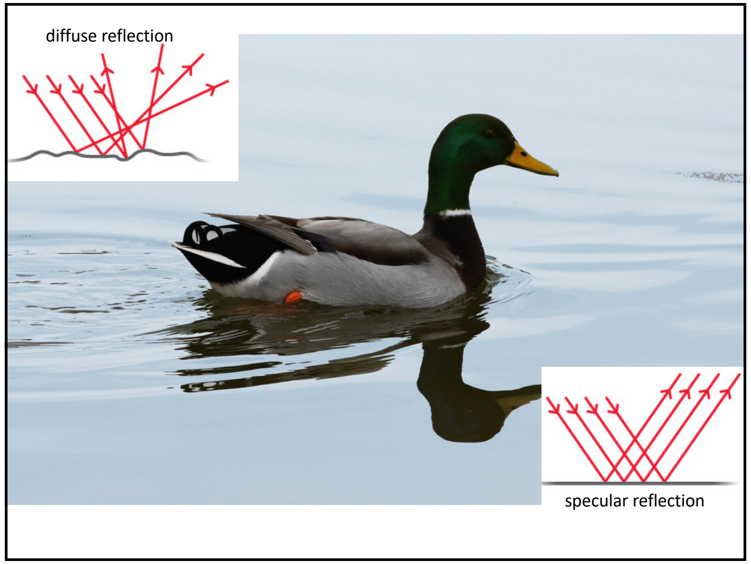

## Polarization



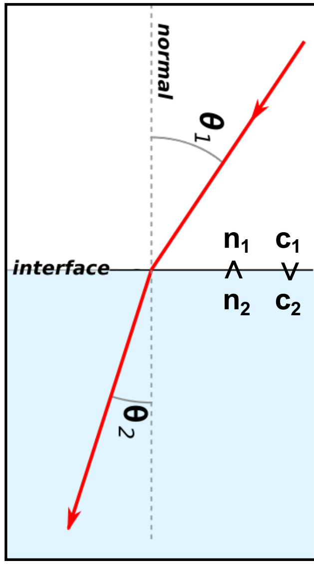

## Reflection




$$\alpha = \beta$$

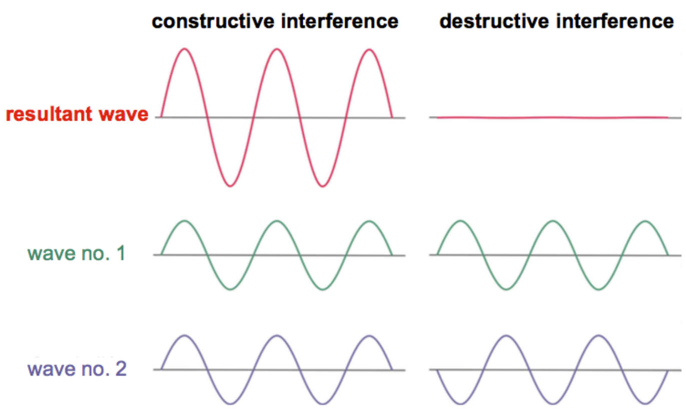



# Refraction

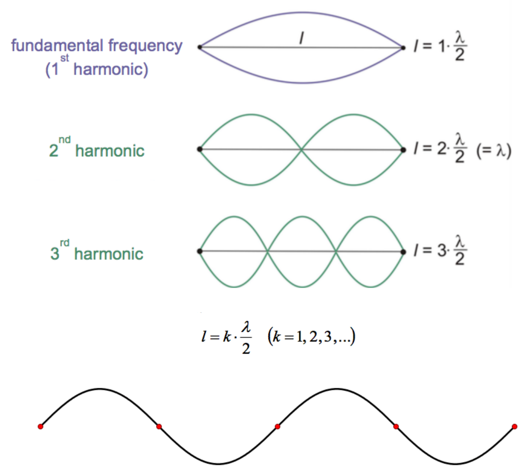



$$\frac{\sin\alpha}{\sin\beta} = \frac{c_1}{c_2}$$

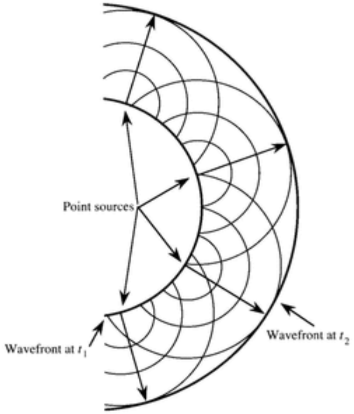
$$\sin\alpha \cdot n_1 = \sin\beta \cdot n_2$$




**standing waves**



# Huygens–principle




# Soundwaves

**Range of sounds**

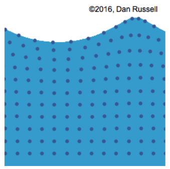
| sound range | infrasound | audible sound | ultrasound | hypersound |
|---|---|---|---|---|
| frequency (Hz) | < 20 | 20–20 000 | 20 000–$10^9$ | $10^9$ < |

**Speed of sound in various media**

| medium | $c_{sound}$ (m/s) |
|---|---|
| air (0ºC, 101 kPa) | 330 |
| helium gas (0ºC, 101 kPa) | 965 |
| water (20ºC) | 1483 |
| fatty tissue | 1470 |
| muscle | 1568 |
| bone (compact) | 3600 |
| iron | 5950 |

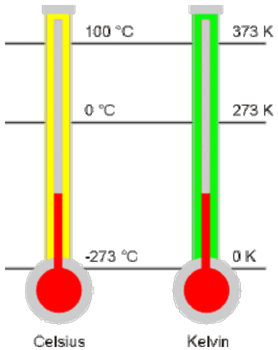
# Problems: 8/4 and 8/10

**4.** Waves are propagating on the surface of water towards the shore with a velocity of 1.5 m/s. The distance between two neighboring crests is six meters. There is a piece of wood somewhere further in the water that turns up and disappears periodically as the water waves when you are looking at it from the shore. Calculate the time interval between two turn-ups.

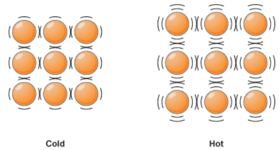



**10.** A sound wave arrives from air (0ºC) at the water surface (20ºC). Angle of incidence is 10º. Calculate the angle of refraction!

# Termodynamics




$$\frac{T}{\mathrm{K}} = \frac{t}{°\mathrm{C}} + 273 \qquad \frac{t}{°\mathrm{C}} = \frac{T}{\mathrm{K}} - 273.$$



## Heat capacity (C) and specific heat capacity(c)

$$C = \frac{Q}{\Delta T} = \left[\frac{J}{K}\right] \qquad c = \frac{C}{m} = \left[\frac{J}{kg \cdot K}\right]$$

$$Q = c \cdot m \cdot \Delta T$$

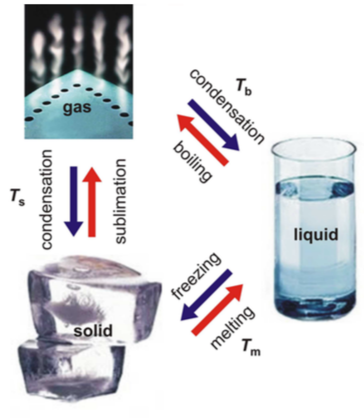
**The specific heat capacity of some materials**

| material | c (J/(kg·K)) |
|---|---|
| silver | 234 |
| glass | 840 |
| water | 4180 |
| body tissue (average) | 3500 |

## Phase transitions

Specific latent heat

$$L = \frac{Q}{m} = \left[\frac{J}{kg}\right]$$




## Gas Laws

Boyle's Law $pV = constant_I$

Charle's Law. $\frac{V}{T} = constant_{II}$

Gay-Lussac's Law $\frac{p}{T} = conatsnt_{III}$

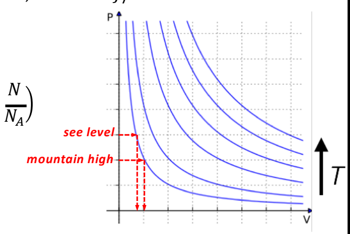
Avogadro's Law $\frac{V}{N} = constant_{IV}$


$$\frac{p}{T} \cdot \frac{V}{N} = k_{III} \cdot k_{IV} \qquad k_{III} \cdot k_{IV} = k_B = 1{,}38 \cdot 10^{-23}\ J/K$$

$$pV = Nk_BT \qquad pV = \frac{N}{N_A} k_B N_A T$$

$$(k_B \cdot N_A = R) \qquad \left(n = \frac{N}{N_A}\right)$$

$$\boxed{pV = nRT}$$




**isobaric** process – **pressure** stays constant

**isothermal** process – **temperature** stays constant

**isochoric** process – **volume** stays constant

# Problems: 9/7 and 9/12

7. We throw a 20 g 0 °C ice cube into a glass (2 dl) of warm (30 °C) water. What will be the final temperature after the ice melts? Conditions are same as in problem #6.

**The specific heat capacity of some materials**

| material | *c* (J/(kg·K)) |
|---|---|
| silver | 234 |
| glass | 840 |
| water | 4180 |
| body tissue (average) | 3500 |

**Specific latent heat of some materials**

| material | *L* (kJ/kg) |
|---|---|
| gold — *heat of fusion* | 67 |
| aluminum — *heat of fusion* | 396 |
| table salt (NaCl) — *heat of fusion* | 517 |
| ice — *heat of fusion* | 334.4 |
| water — *heat of vaporization (at 30 °C and 101 kPa)* | 2400 |
| water — *heat of vaporization (at 100 °C and 101 kPa)* | 2257 |

12. A metal gas container is left lying under the shining Sun. The initial pressure of the ideal gas inside is 50 bar. Its temperature increases as a result of the sunshine from 12 °C to 72 °C. What will be the final pressure?