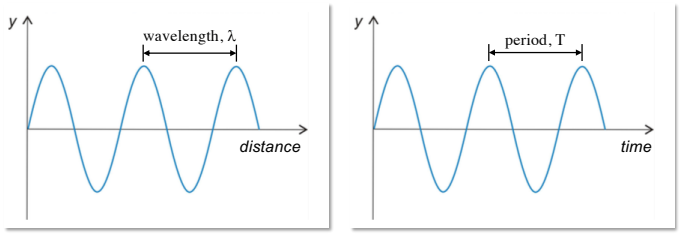
Waves

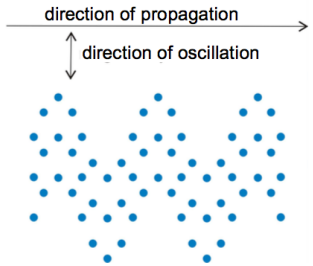
1



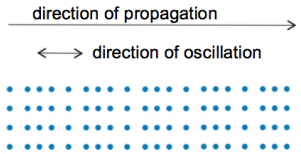
$$c = \frac{\lambda}{T} = \lambda \cdot \frac{1}{T} = \lambda \cdot f$$

2

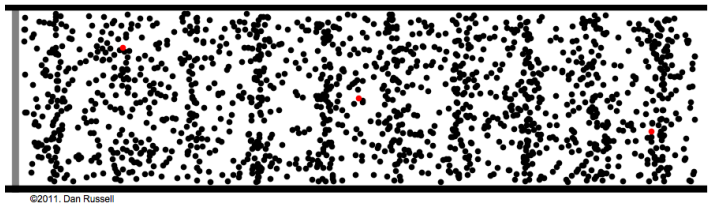
Transverse wave:

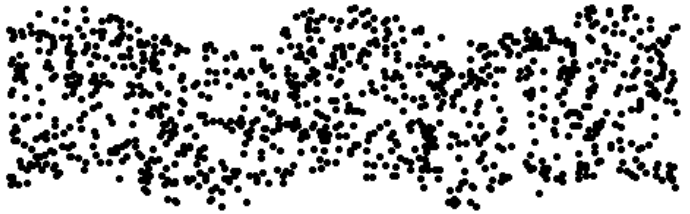


Longitudinal wave:

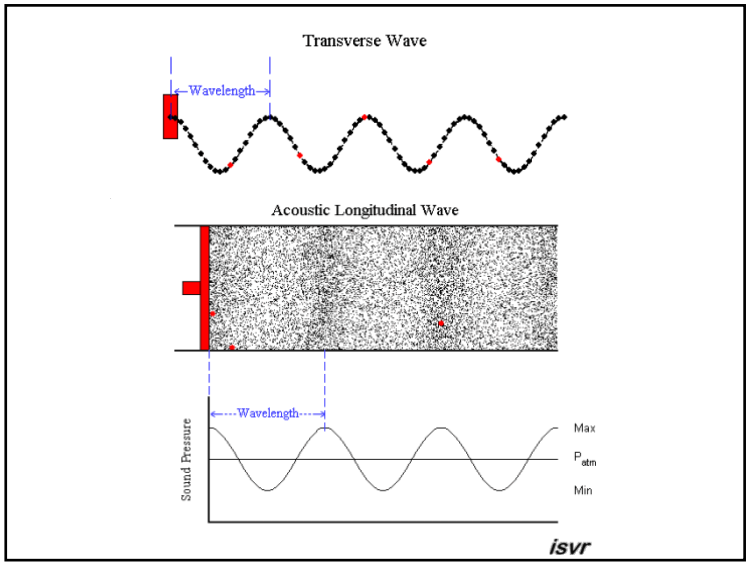


3

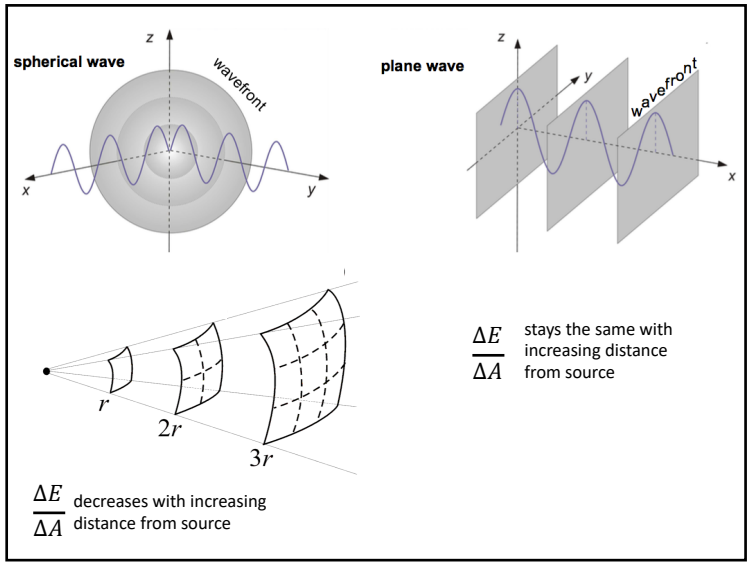




4

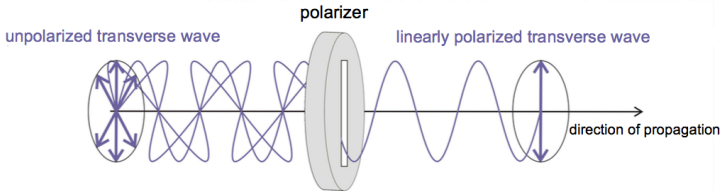


5



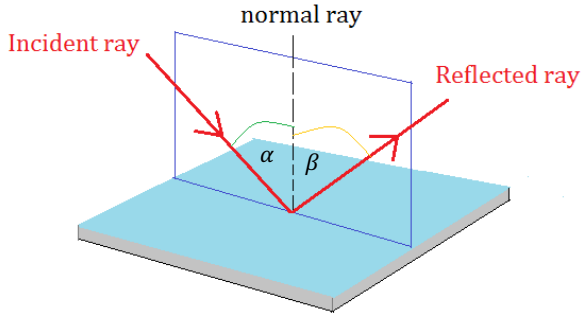
6

Polarization



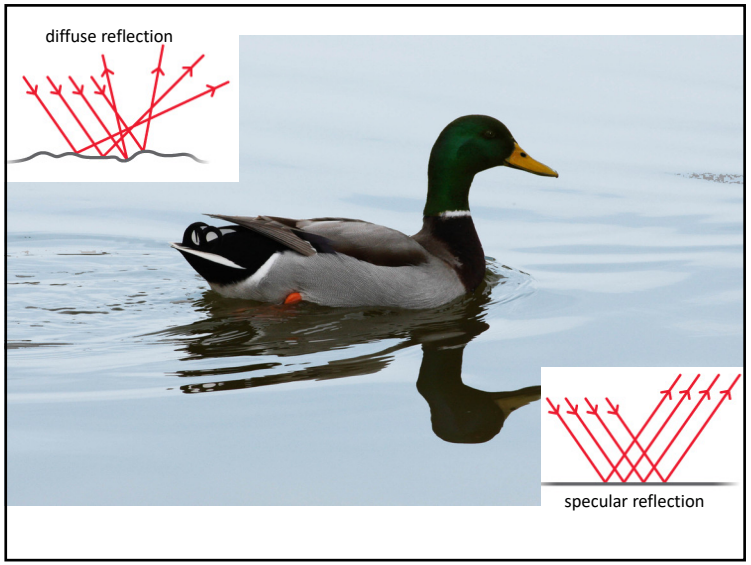
7

Reflection

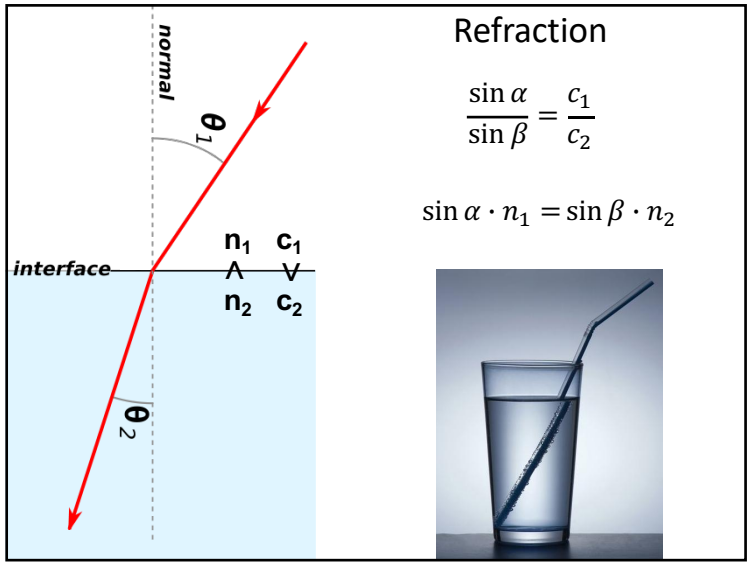


$\alpha = \beta$

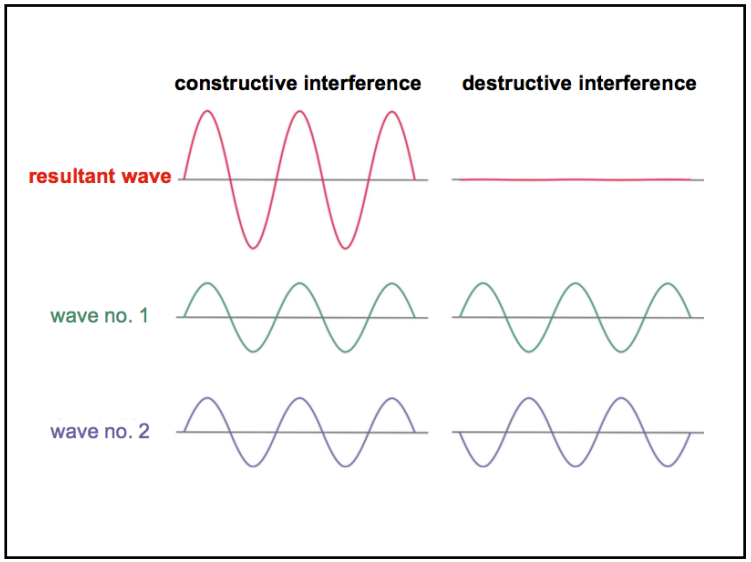
8


diffuse reflection
specular reflection

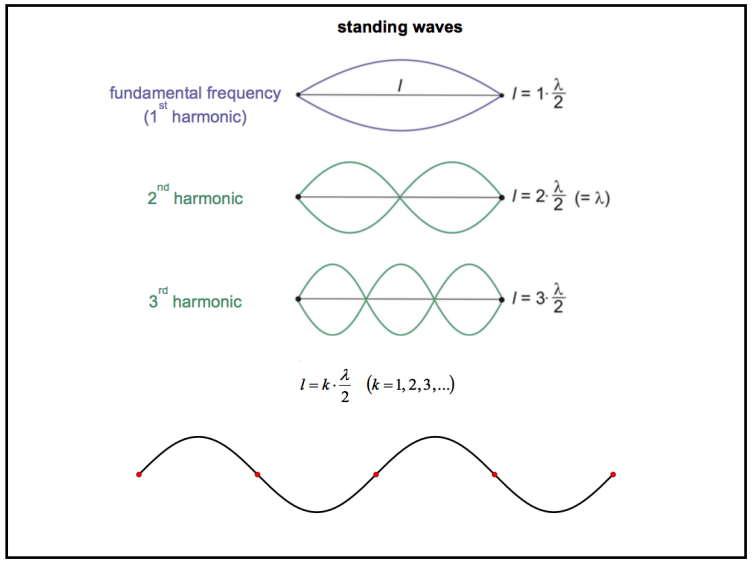
9


Refraction
normal
θ 1
θ 2
interface
n1 c1
n2 c2
sin α / sin β = c1 / c2
sin α · n1 = sin β · n2

10


constructive interference
destructive interference
resultant wave
wave no. 1
wave no. 2

11


standing waves
fundamental frequency
(1st harmonic)
l = 1·λ/2
2nd harmonic
l = 2·λ/2 (= λ)
3rd harmonic
l = 3·λ/2
l = k·λ/2 (k = 1, 2, 3, ...)

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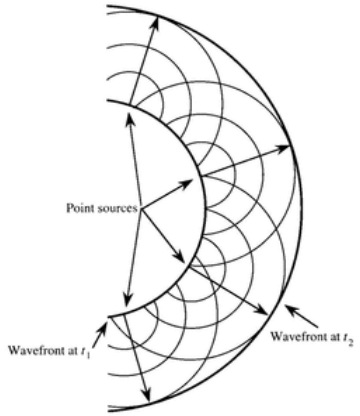
Huygens–principle



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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 (0°C, 101 kPa)	330
helium gas (0°C, 101 kPa)	965
water (20°C)	1483
fatty tissue	1470
muscle	1568
bone (compact)	3600
iron	5950

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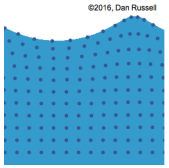
Problems: 8/4 and 8/10

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 (0°C) at the water surface (20°C). Angle of incidence is 10°. Calculate the angle of refraction!

Speed of sound in various media

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

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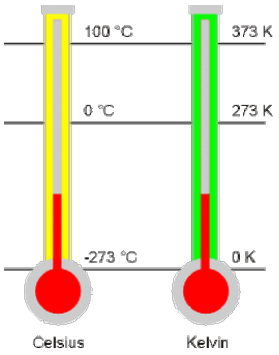
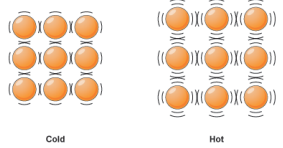
Termodynamics



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



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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

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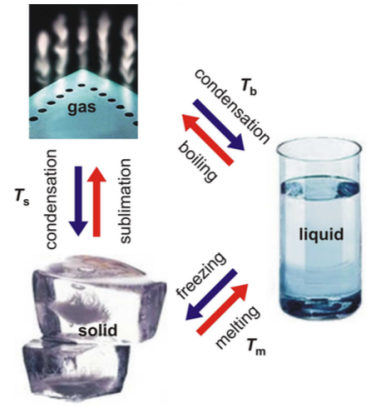
Phase transitions

Specific latent heat

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



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Gas Laws

Boyle's Law $pV = constant_I$

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

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

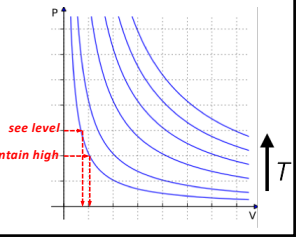
Avogadro's Law $\frac{V}{N} = constant_{IV}$

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

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

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

$\boxed{pV = nRT}$



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isobaric process – **pressure** stays constant

isothermal process – **temperature** stays constant

isochoric process – **volume** stays constant

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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?

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