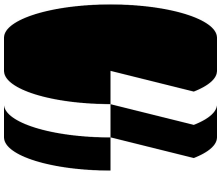
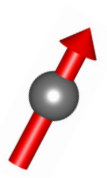
Phonons and sound

ultrasound spectroscopy



Earth

Thomas Young



by Alexander Tsirlin, Leipzig University

Lecture 11: November 15, 2023

Atomic displacements in 1D

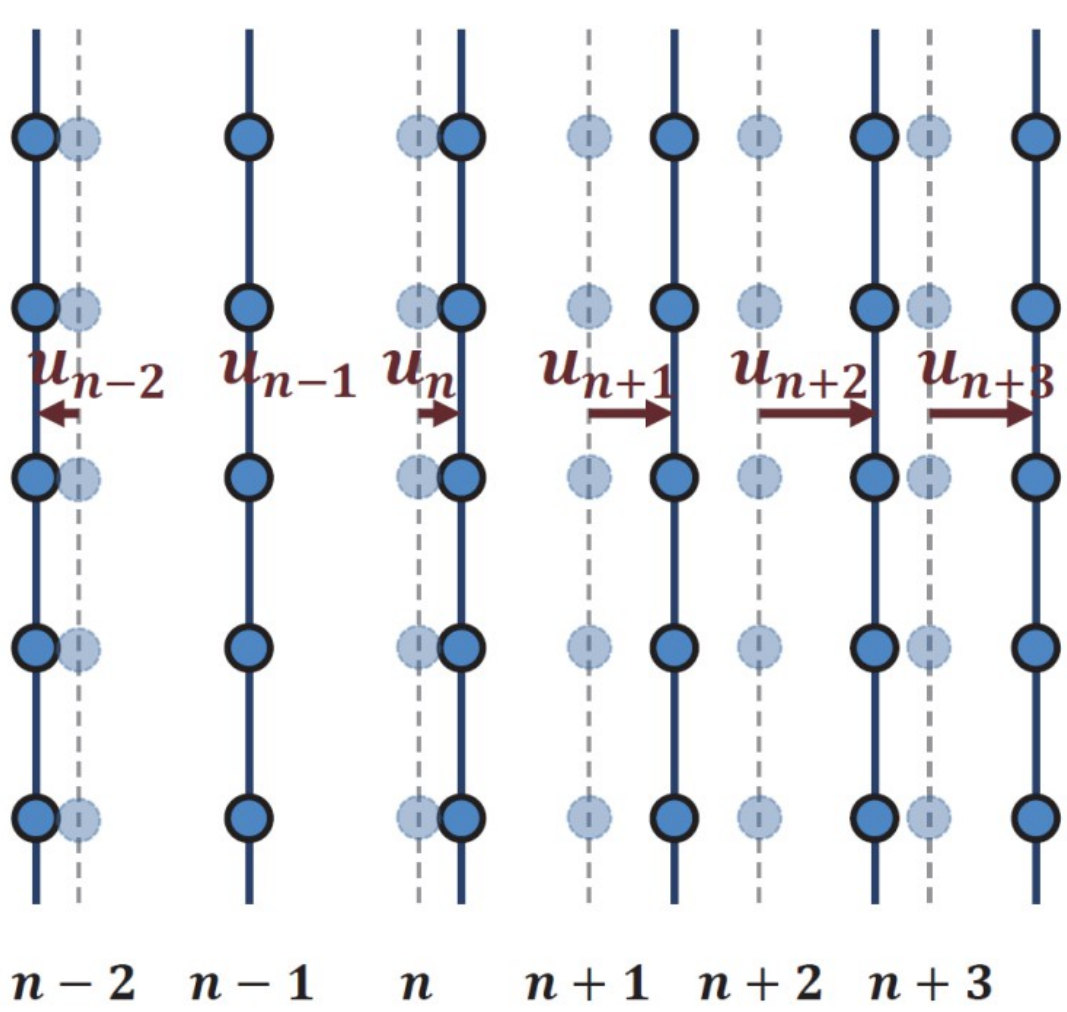
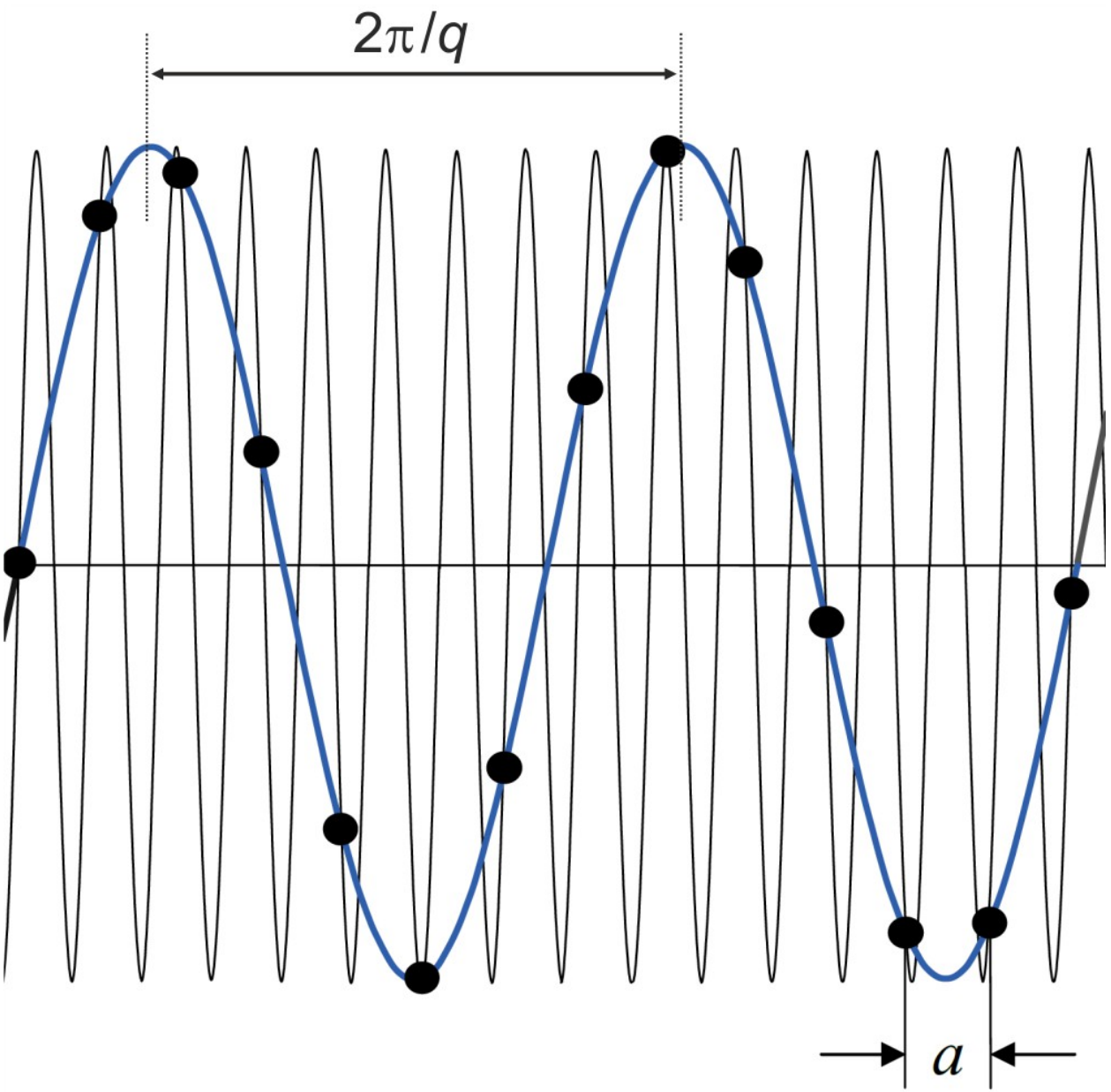


Image credit: Gross and Marx, Festkörperphysik

Displacement wave



q value determines period of the displacement wave

Image credit: Hunklinger, Festkörperphysik

Person

Thomas Young

Thomas Young

Thomas Young
1773 – 1829

"The Last Man who knew everything"

- *Liquids:* contact angle (Young's equation) and capillary phenomena
- *Medicine:* Young's principle (drug dosage for children depending on their age)
- *Languages:* deciphered old Egyptian scripts
- *Music:* Young temperament for tuning musical instruments
- *Solids:* Young's modulus as a material-dependent constant
- *Optics:* double-slit experiment (interference), wave nature of light

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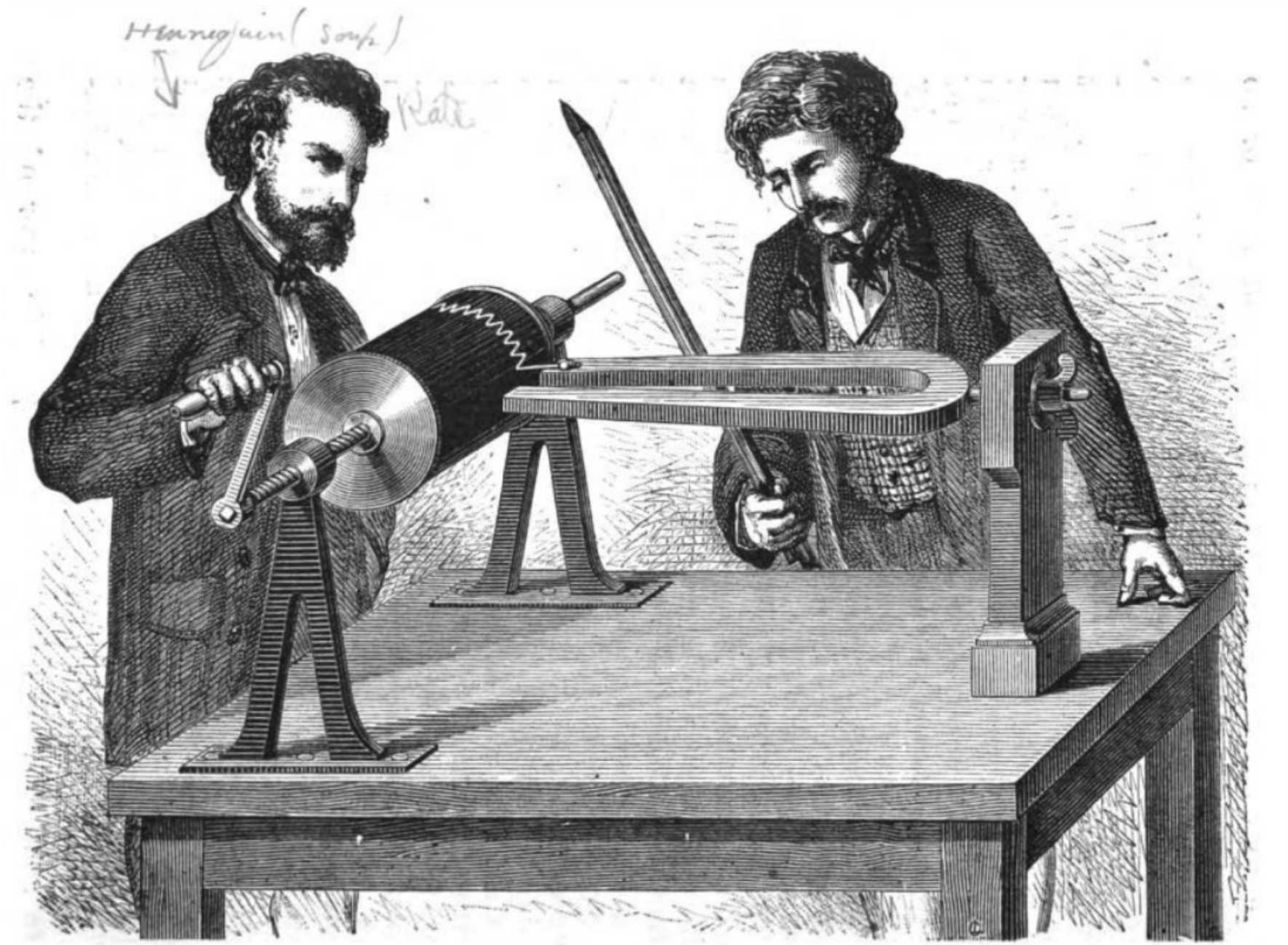
Musical optics

Translating sound into light

Visualization of sound waves



Speed of sound

air (at 25 °C): 343 m/s

water: 1 480 m/s

Image credit: Alvesgaspar, Davide Restivo, Arnoldius, Aom Mahesh vekariya (CC-BY-SA)

Speed of sound

air (at 25 °C): 343 m/s

water: 1 480 m/s

steel: 5 100 m/s

Speed of sound

air (at 25 °C): 343 m/s

water: 1 480 m/s

steel: 5 100 m/s

diamond: 12 000 m/s

Sound transmission

Image credit: Mika Matin and Richard Croft (CC-BY-SA)

Sound transmission

Image credit: Mika Matin and Richard Croft (CC-BY-SA)

Sound insulation

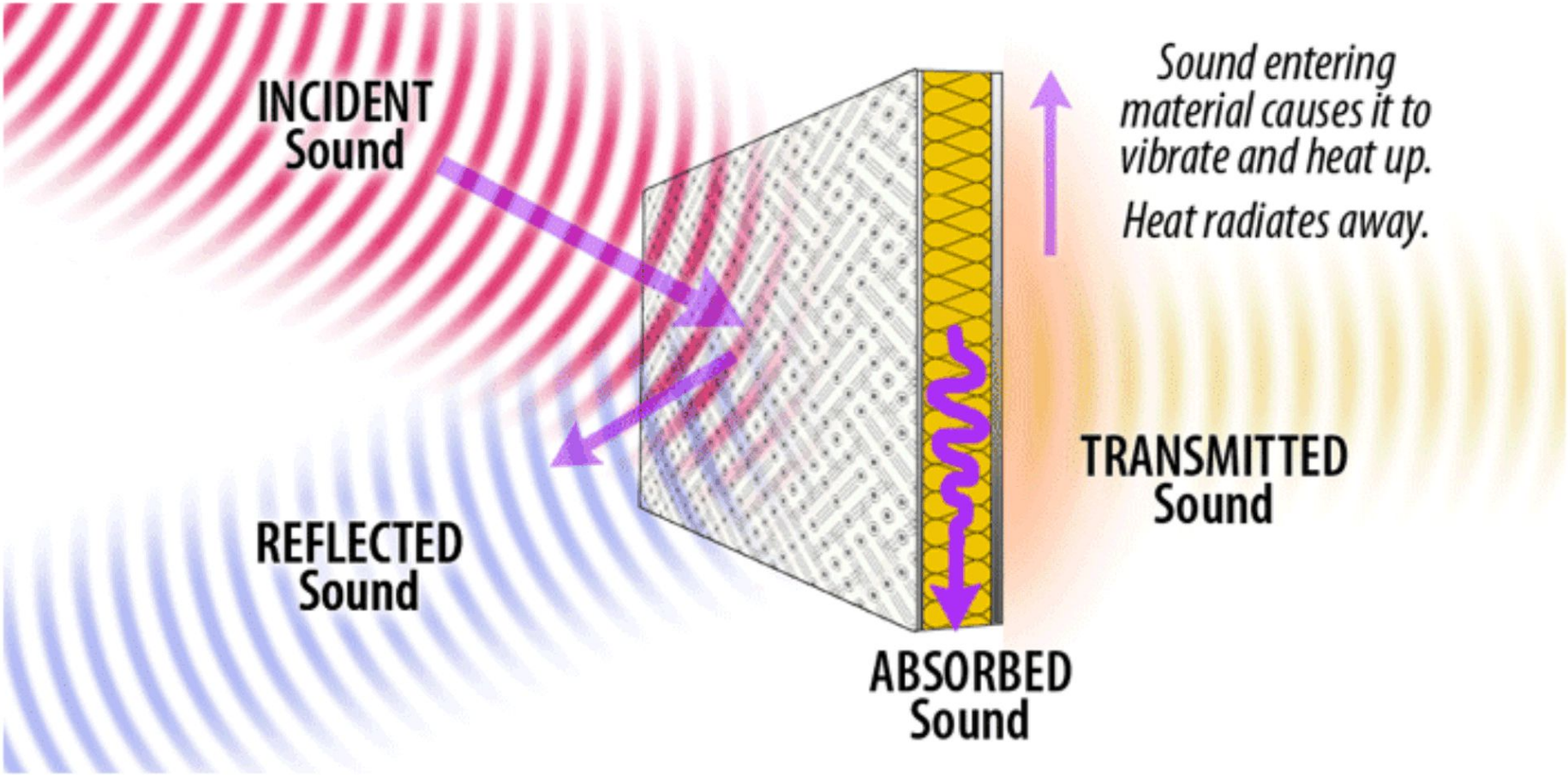
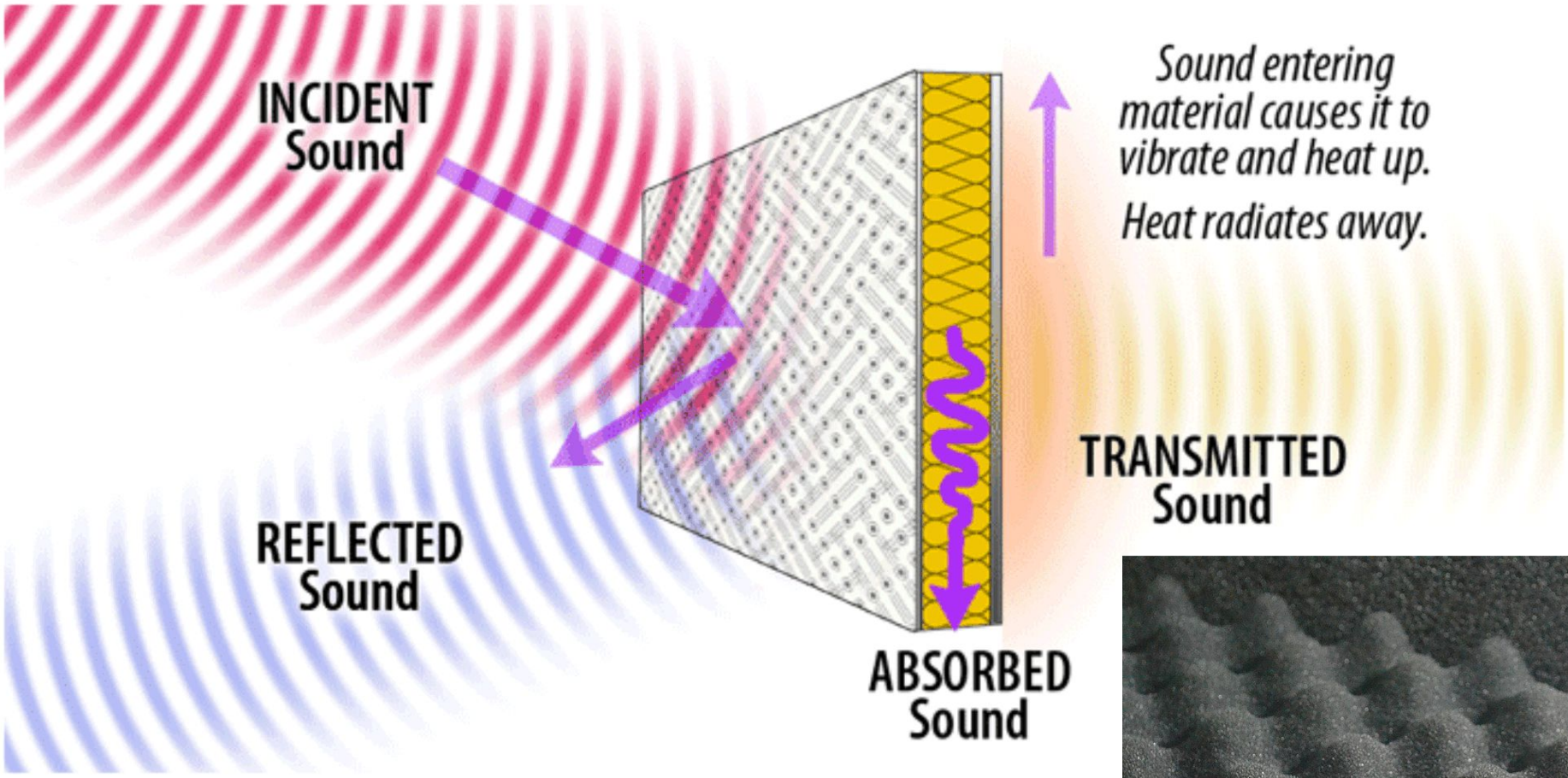


Image credit: Unique Home Guide (fair use)



Most solids reflect sound but do not absorb it

Image credit: Unique Home Guide (fair use) and Chlod Alejandro (CC-BY-SA)

No lecture on 22.11 (public holiday)

No problem sheet this week

Tutorial on 27.11-1.12: discuss any remaining questions

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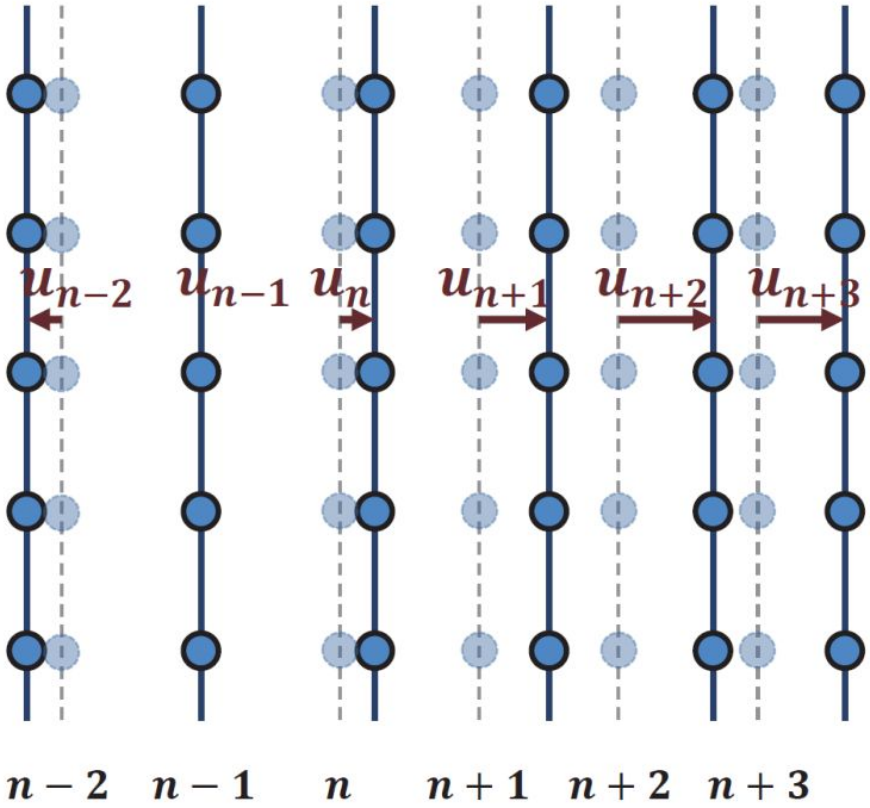
Exam

TP5, written: 15.02.2024

EP5, oral: 5.02-9.02 and 21.02-27.02
earlier slots for volunteers and students from last year,
grades will be in the system by 1.03

registration in January (expect an e-mail from the Study Office)

EP5, second attempt: 25.03-29.03



longitudinal

transverse

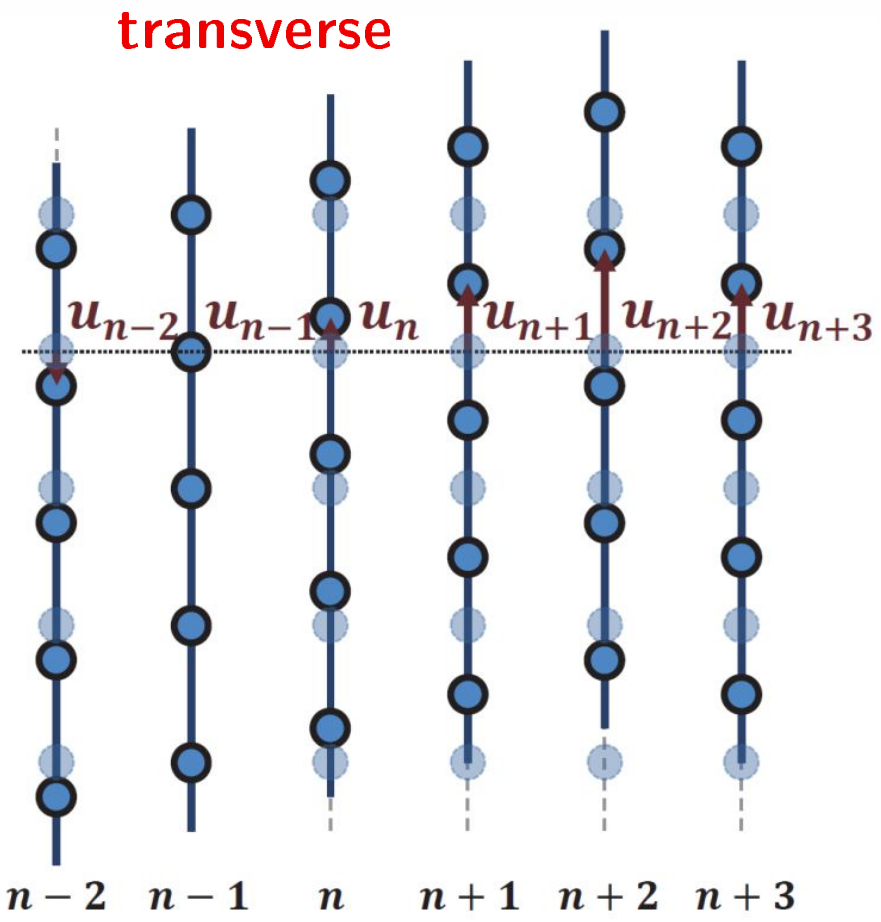
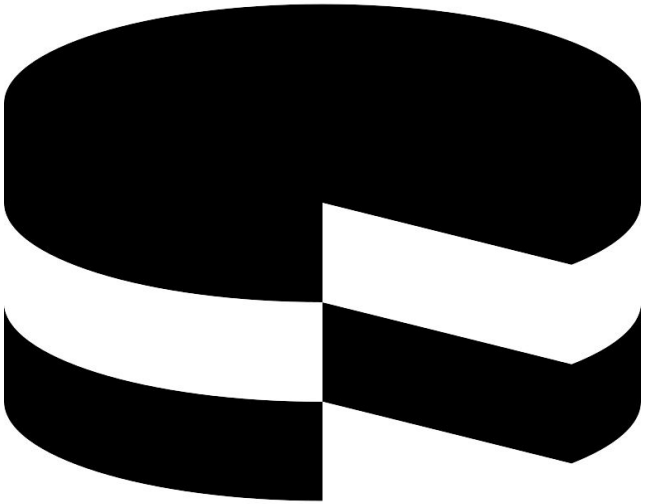


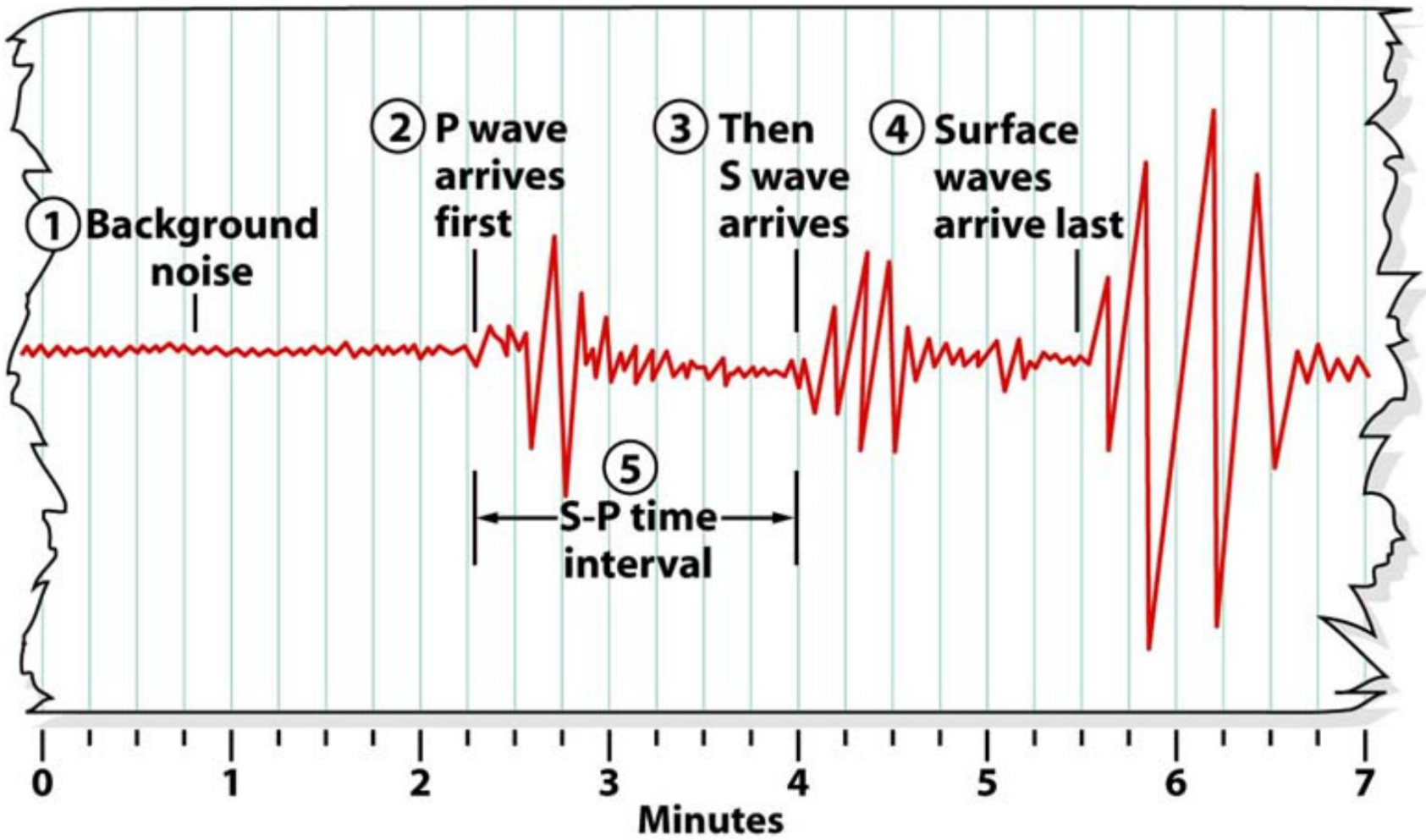
Image credit: Gross, Marx. Festkörperphysik



Material

Earth

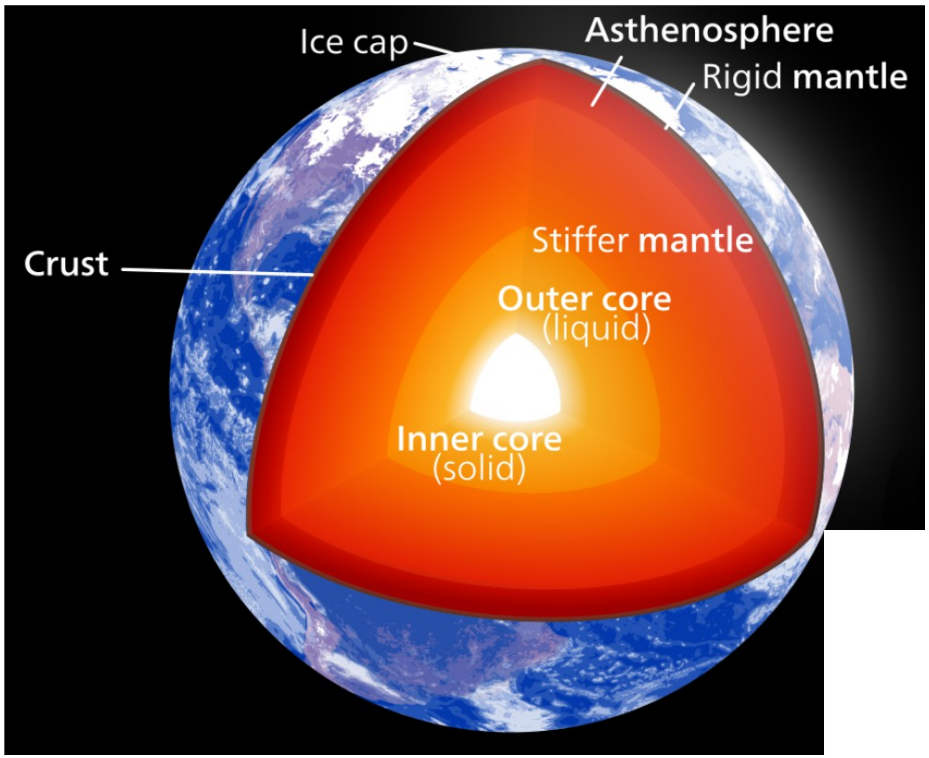
Two types of seismic waves



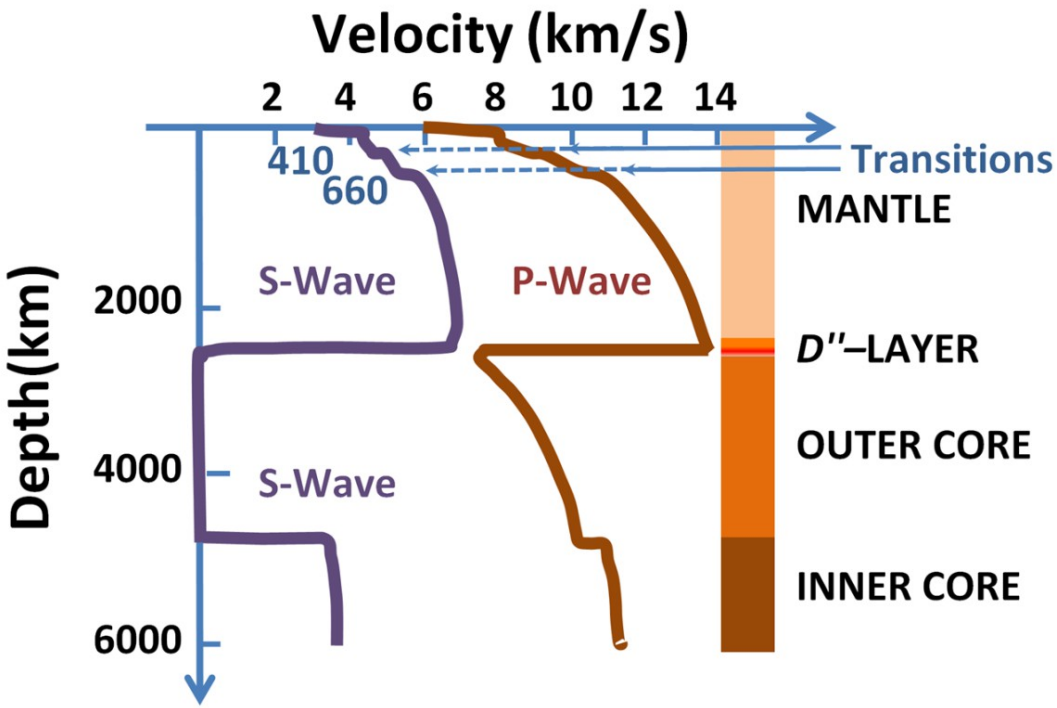
p-**waves:** longitudinal, faster (5 km/s in granite)

s-**waves:** transverse, slower (3 km/s in granite)

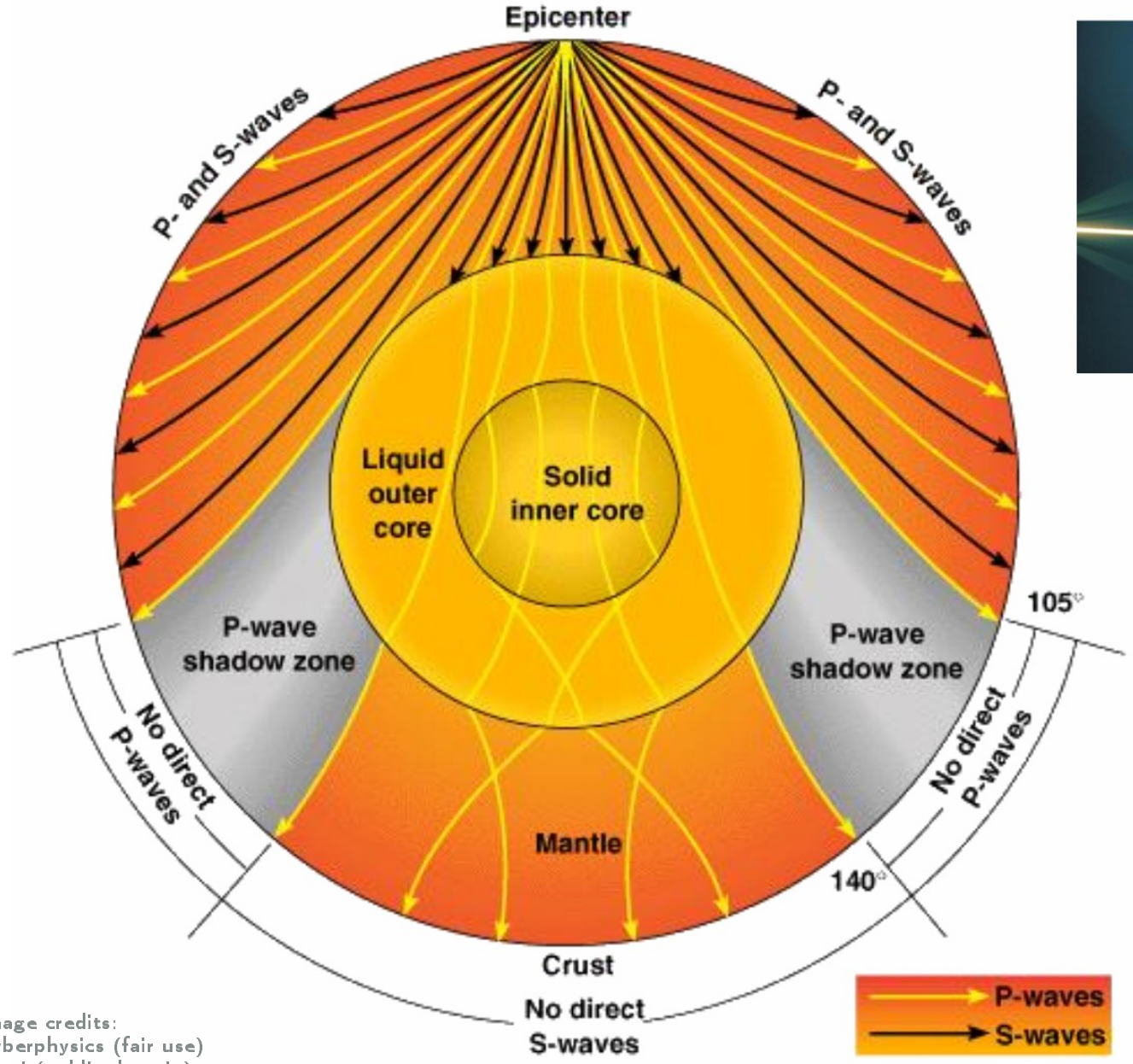
Image credit: Brooklyn College



s-waves do not go
through the center of Earth,
hence there must be liquid



Refraction of seismic waves



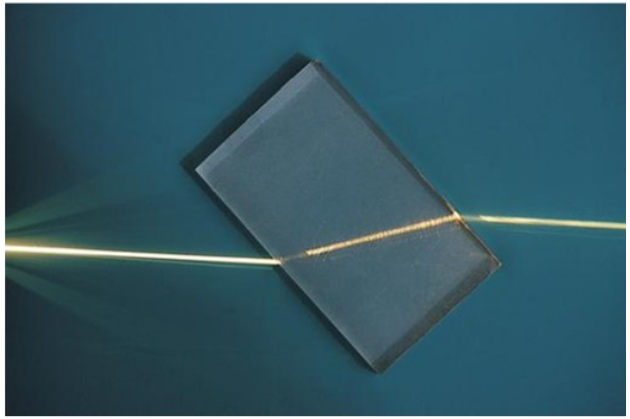


Image credits:
Cyberphysics (fair use)
ajizai (public domain)

Experimental technique

ultrasound spectroscopy

Ultrasound imaging

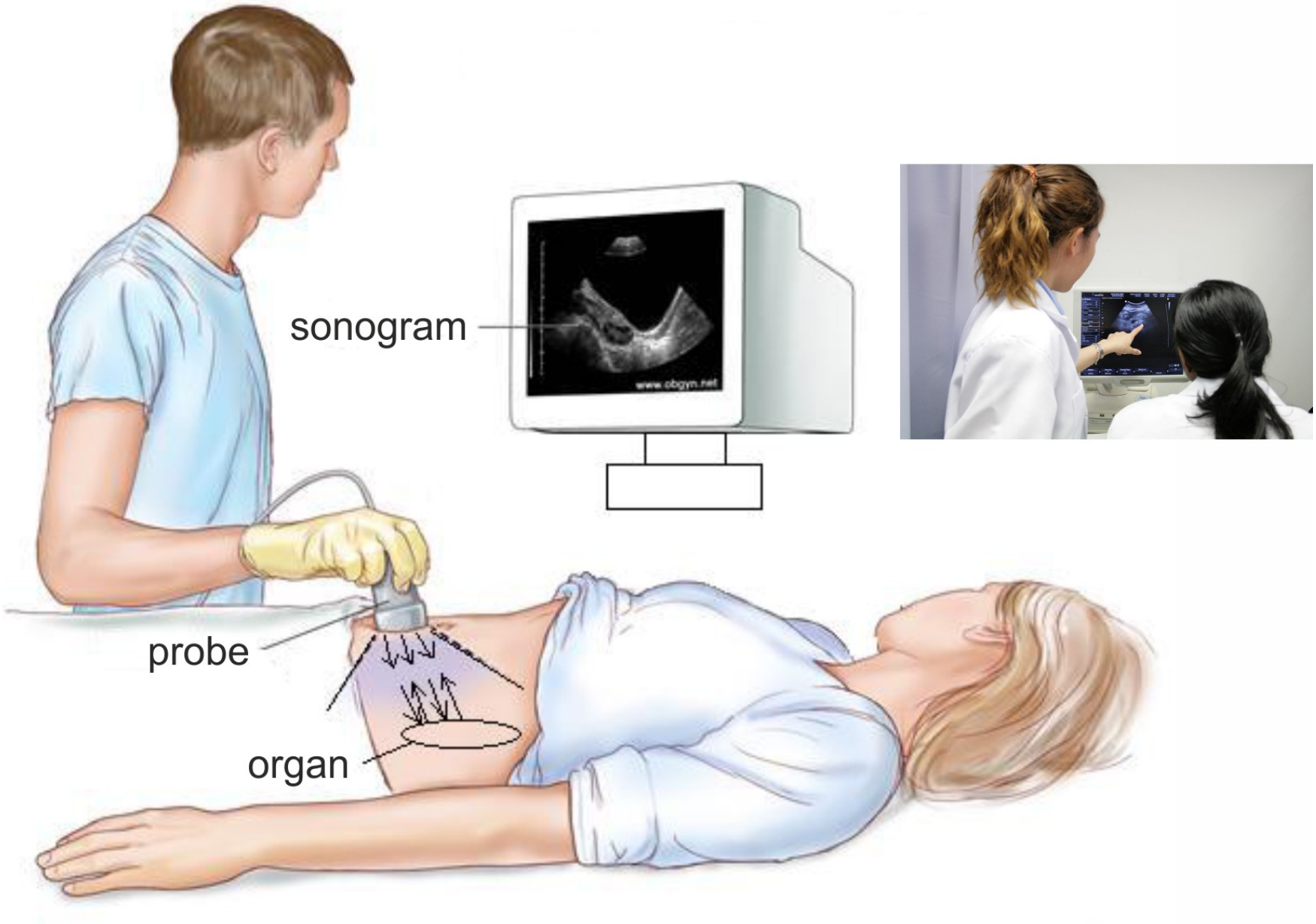
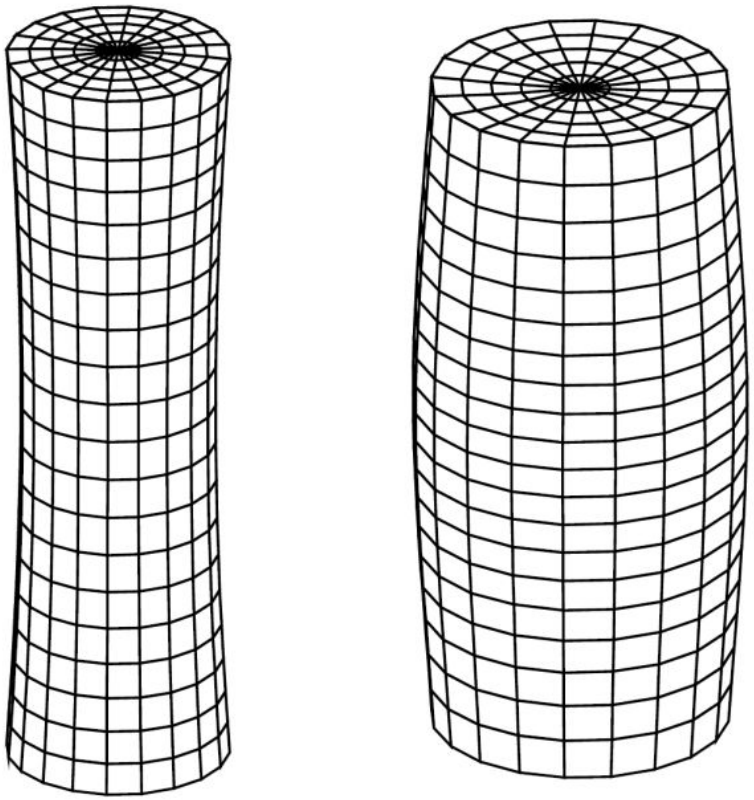


Image credits: Pavel student and Vision College (CC-BY-SA)

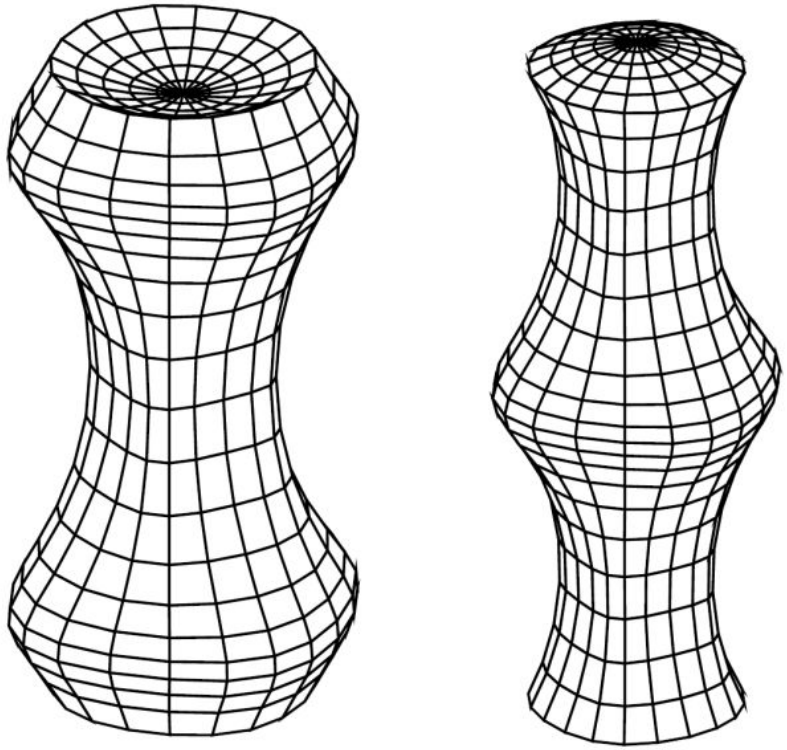
Acoustic resonance

Image credits: Brian0918 and Andy Dingley (CC-BY-SA)

Mechanical resonance in solids



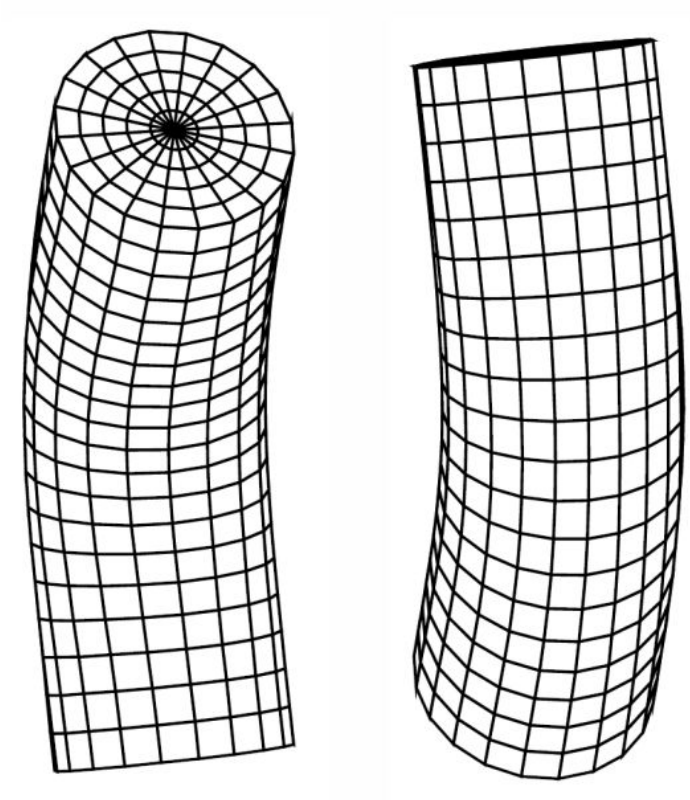
lowest extensional mode
36.85 kHz



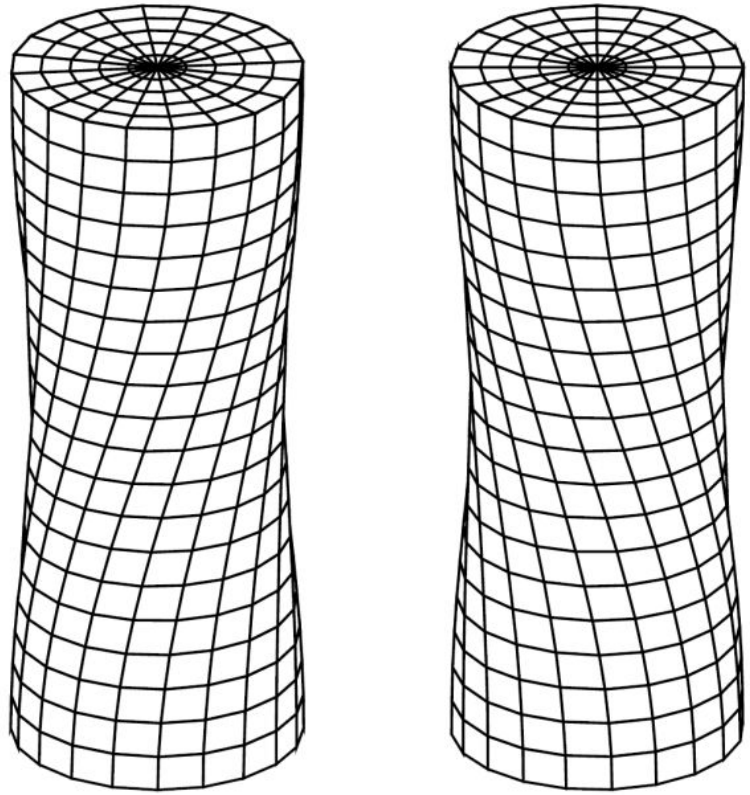
first extensional overtone
69.94 kHz

Geophys. J. Int. 156, 154 (2004)

Mechanical resonance in solids



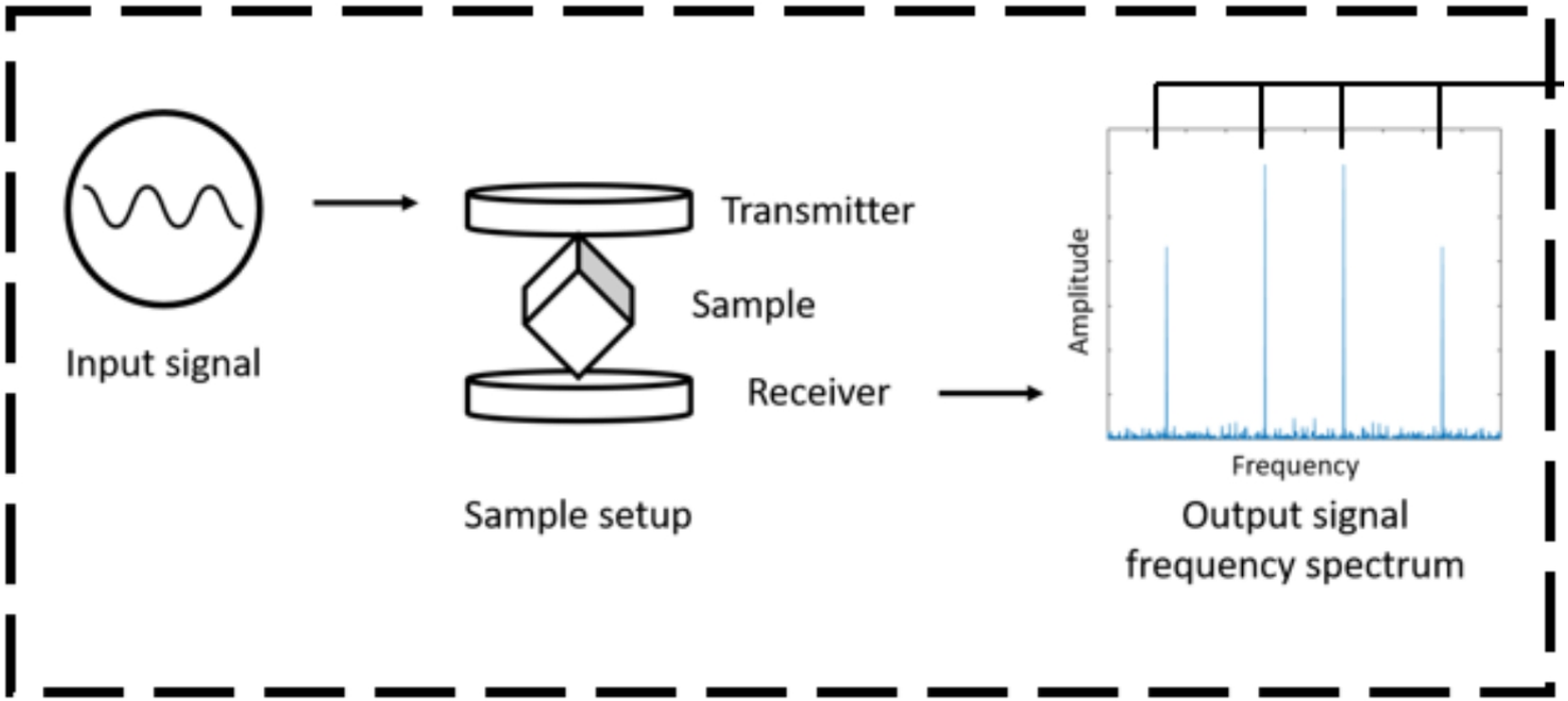
lowest flexural mode
20.49 kHz



lowest torsional mode
22.66 kHz

Geophys. J. Int. 156, 154 (2004)

Resonant ultrasound spectroscopy

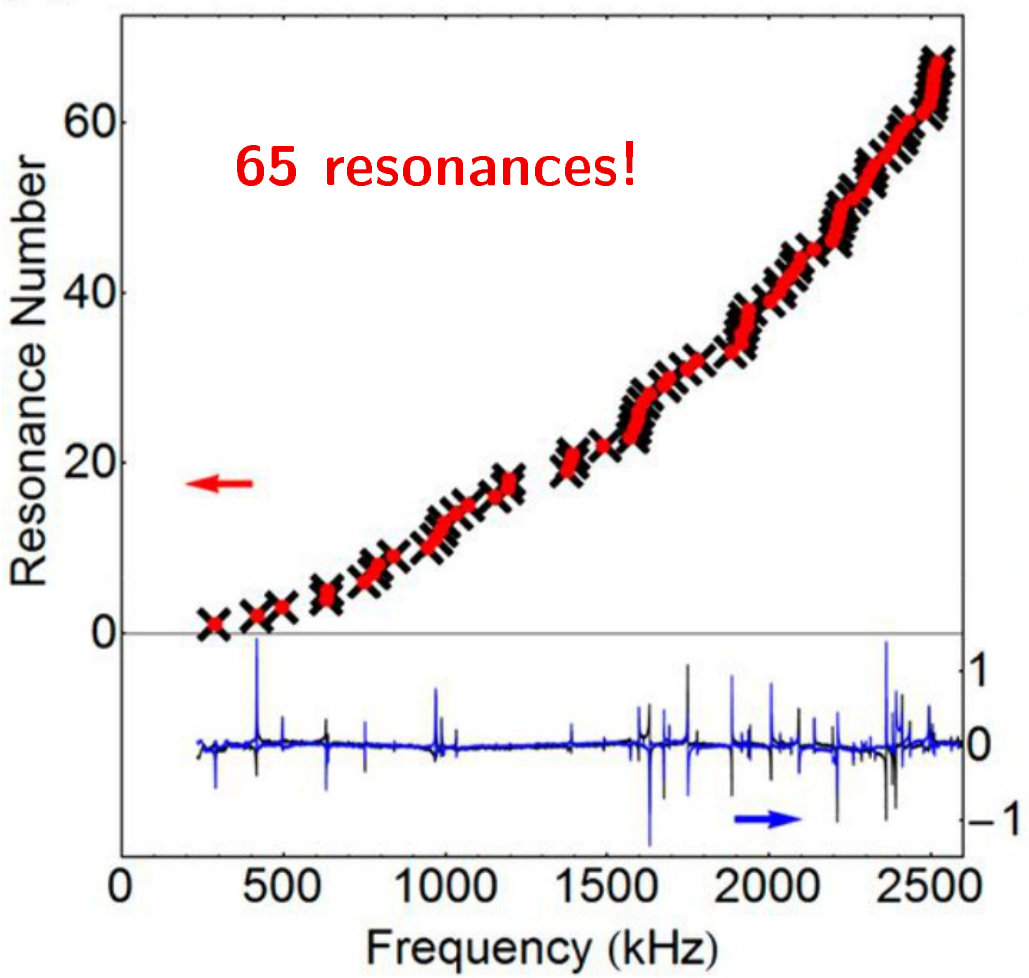


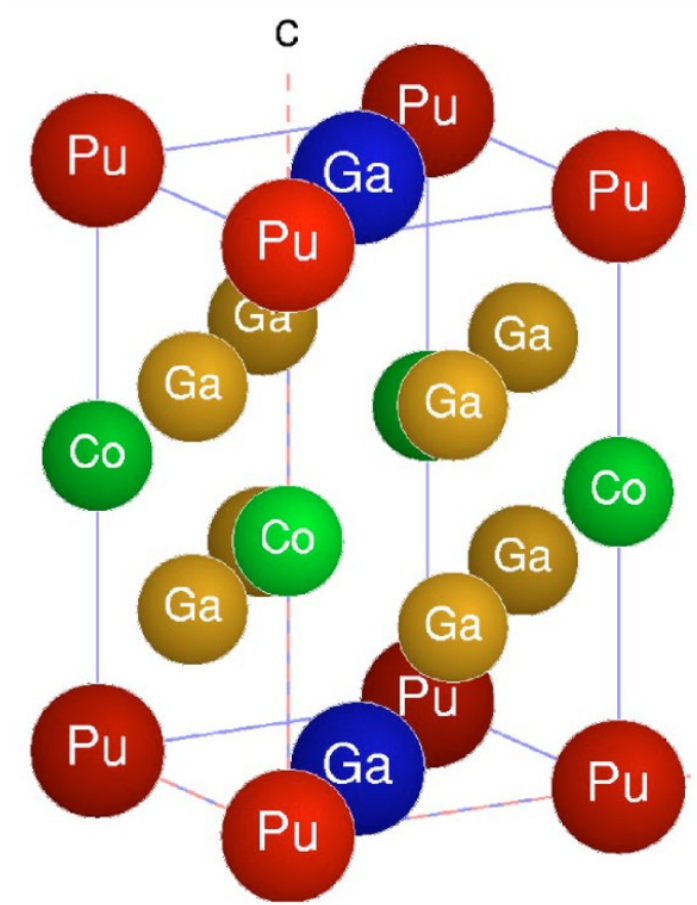
Resonance frequencies depend on:

- elastic constants (C_{ij})
- sample shape
- sample dimensions

Image credit: ZfP, TU München (CC-BY-NC)

Example: unconventional superconductivity





$PuCoGa_5$: tetragonal structure ($P4/mmm$), **6 elastic constants**

PNAS 112, 3285 (2015) and Phys. Rev. B 70, 104504 (2004)

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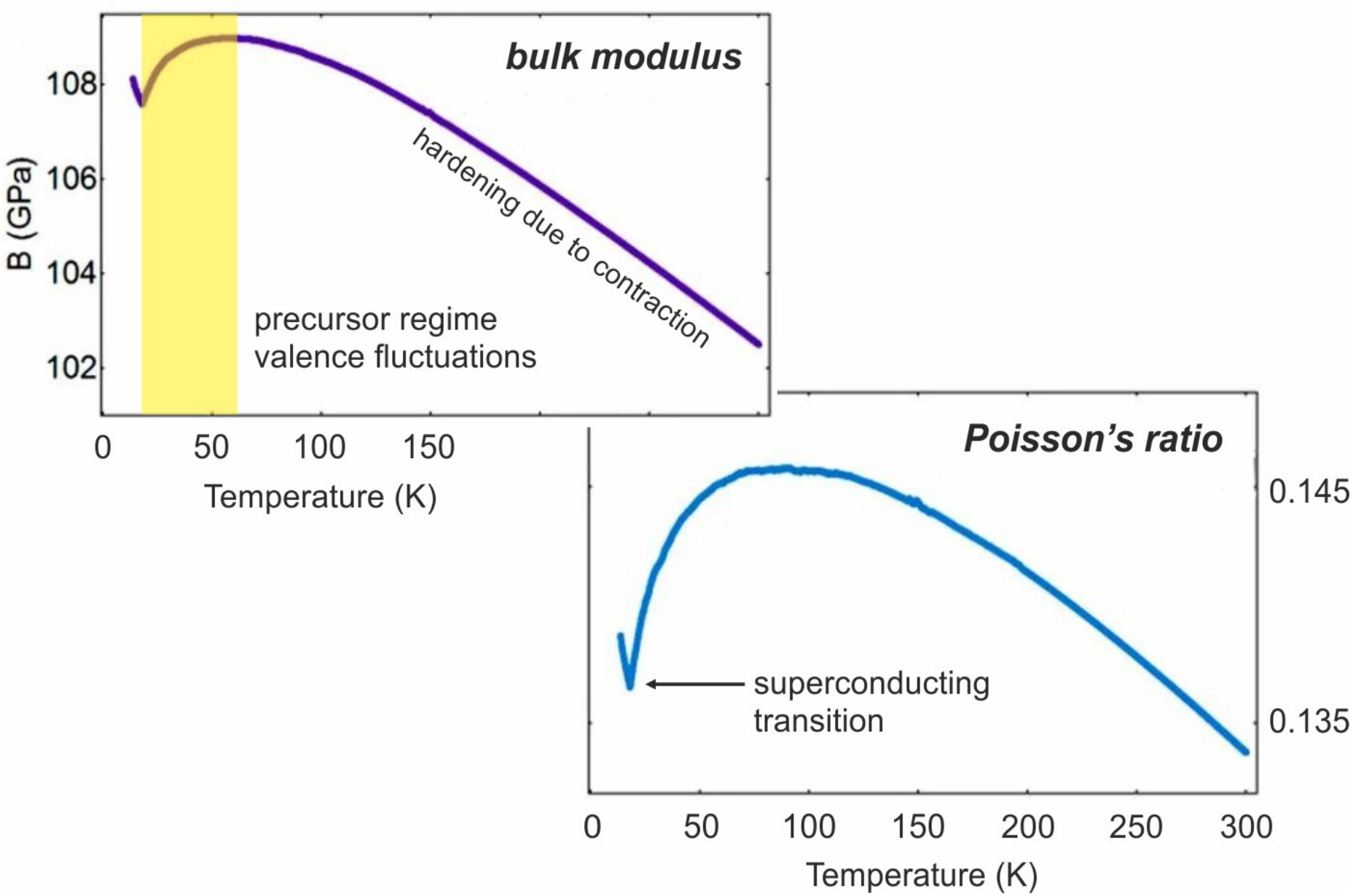

PNAS 112, 3285 (2015)

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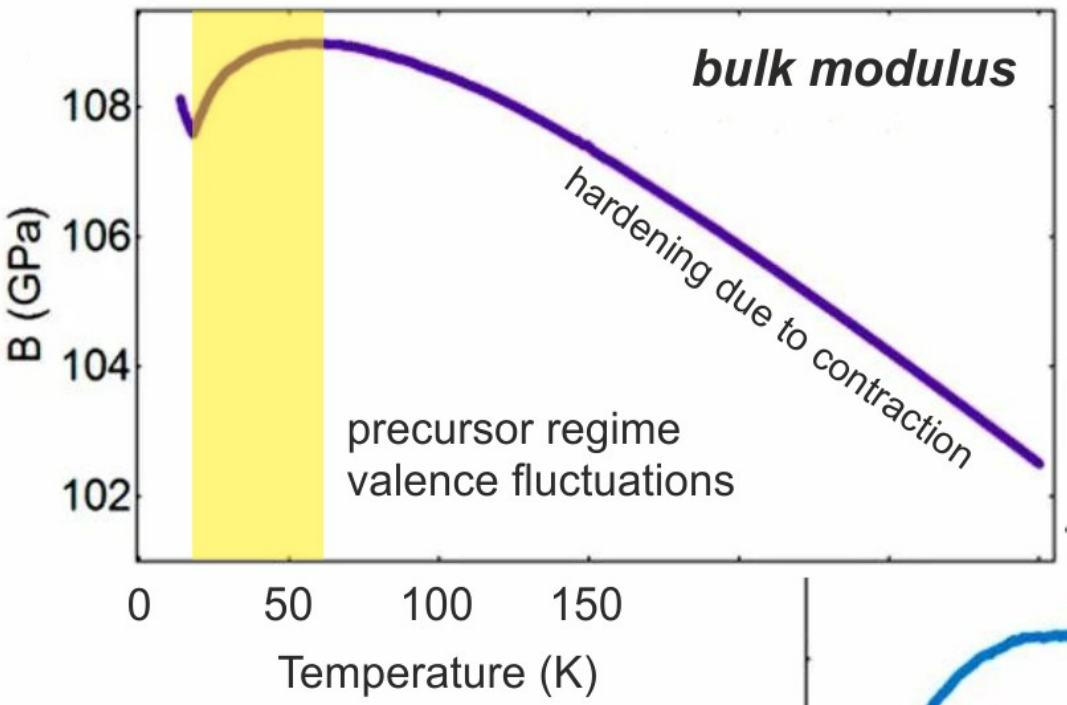
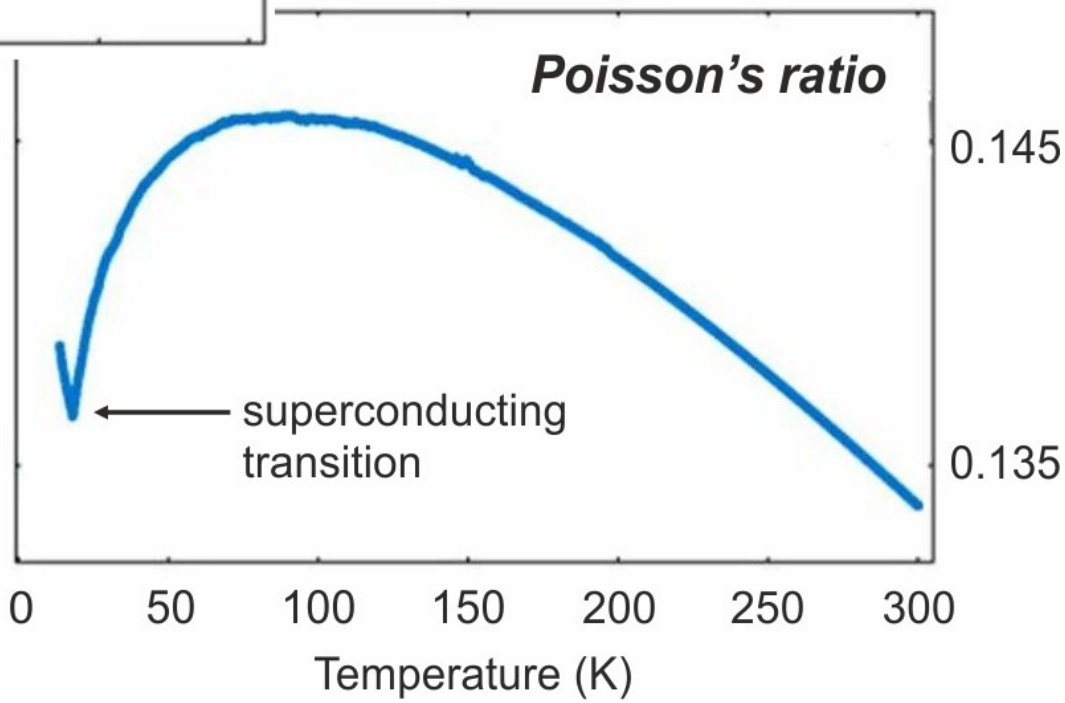


Probe of electronic effects via lattice response

Precise measurement of elastic constants



PNAS 112, 3285 (2015)

Diatomic chain

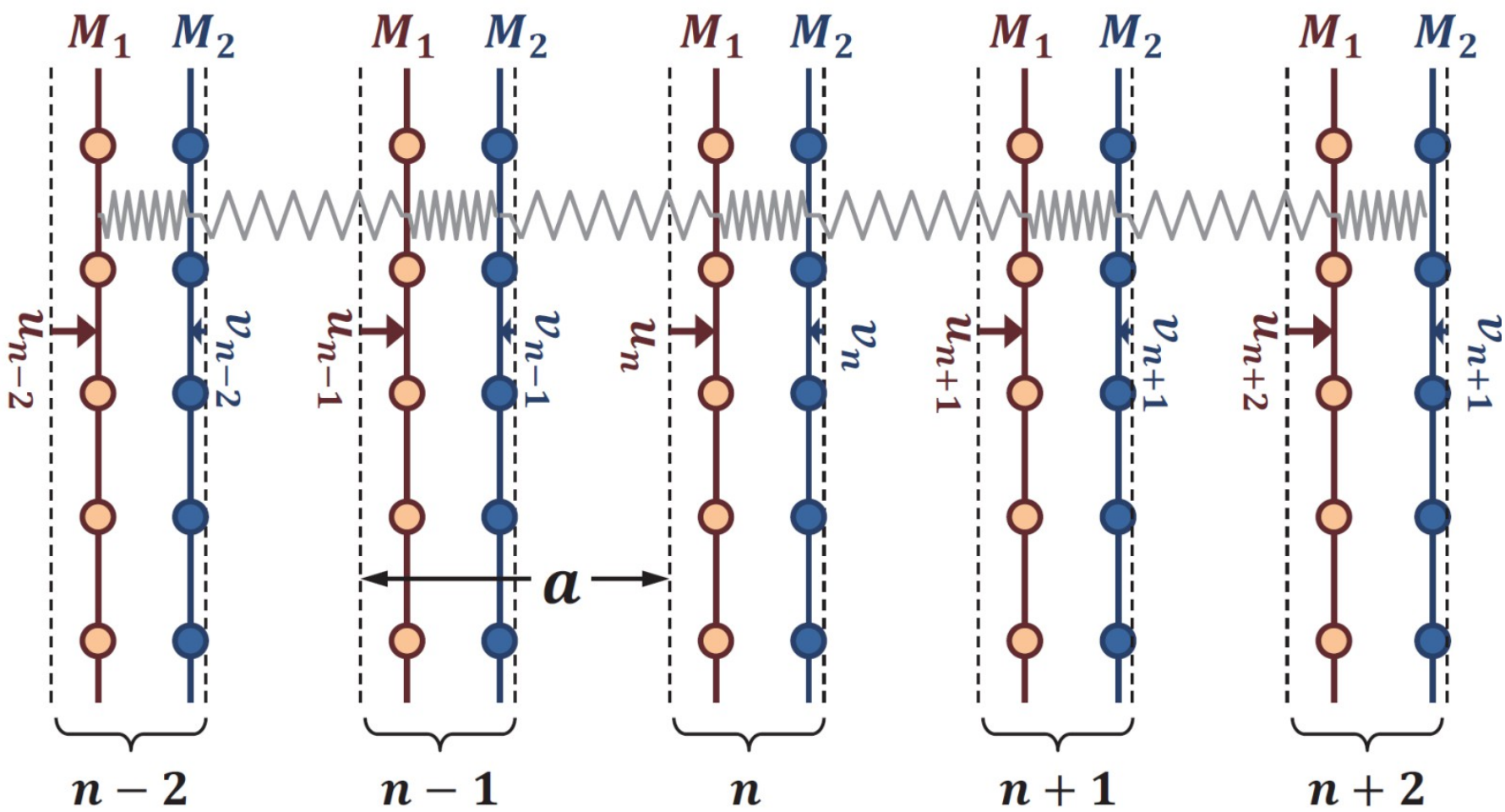


Image credit: Gross, Marx. Festkörperphysik