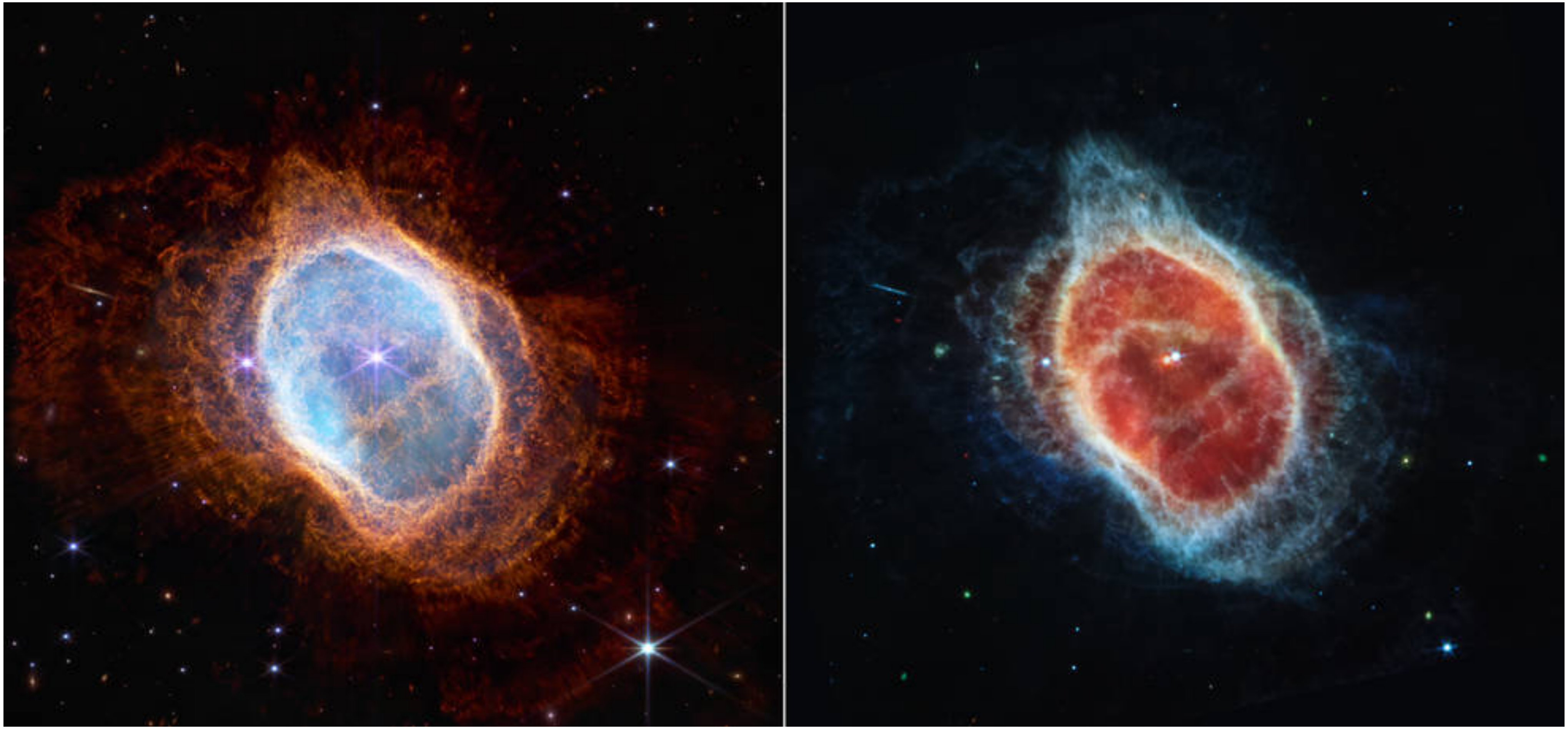
Recap of thermal physics concepts

Lecture 2, FYS2160, 2023

James Webb space telescope



Planetary nebula (clouds of gas and dust expelled by dying stars): Southern Ring Nebula

James Webb: Infrared images

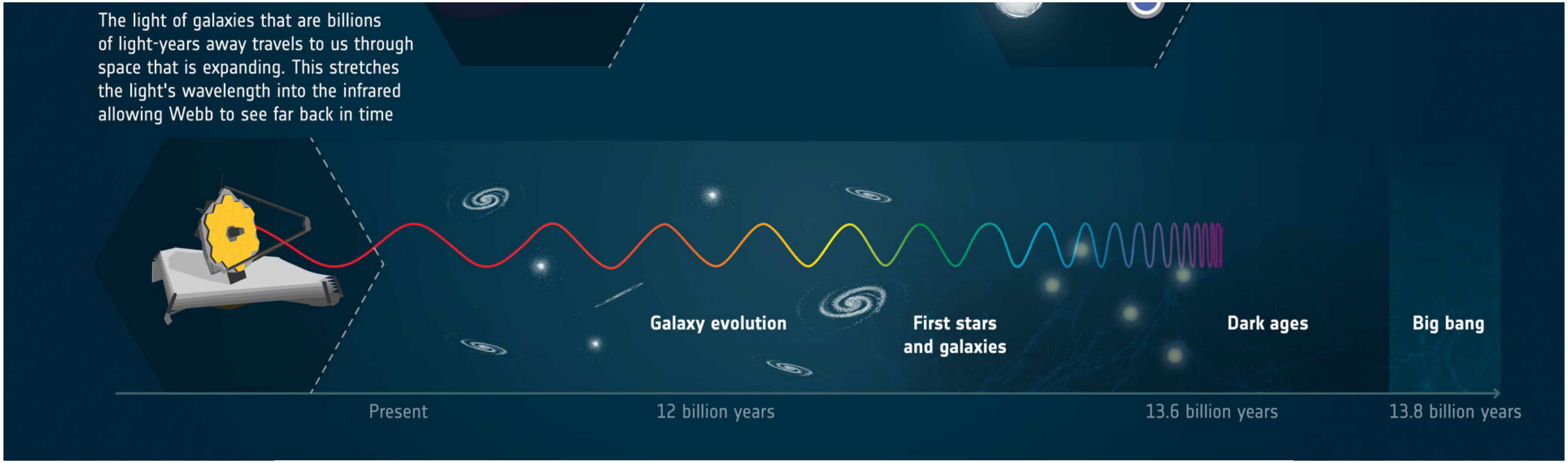
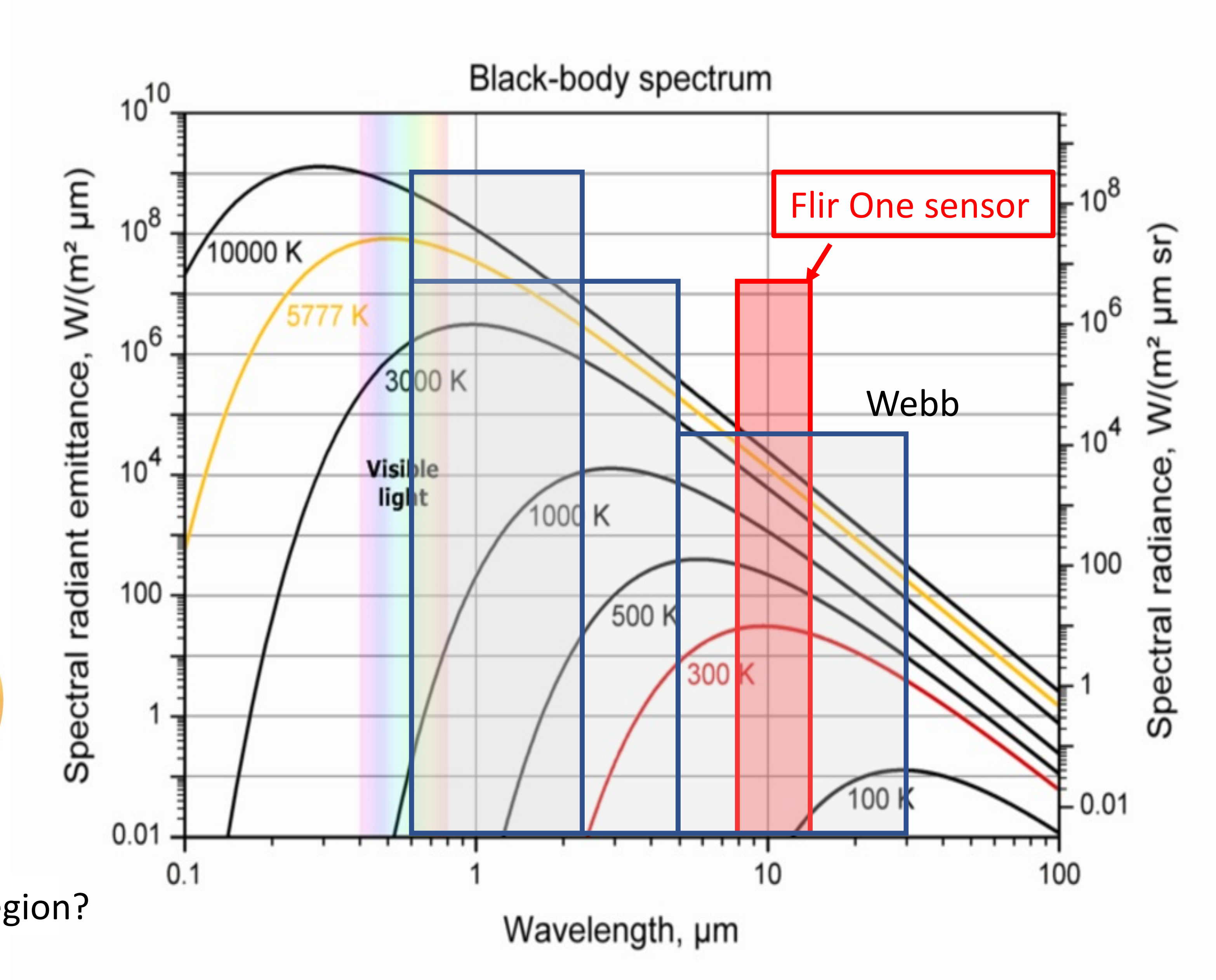


Table 1. JWST Instruments and their Detectors

Instrument	Mercury-cadmium-telluride H2RG		Arsenic doped silicon
	0.6 - 2.5 μm	0.6 - 5 μm	5 - 28 μm
NIRCam	8	2	
NIRSpec		2	
FGS/NIRISS		3	
MIRI			3

Black body radiation



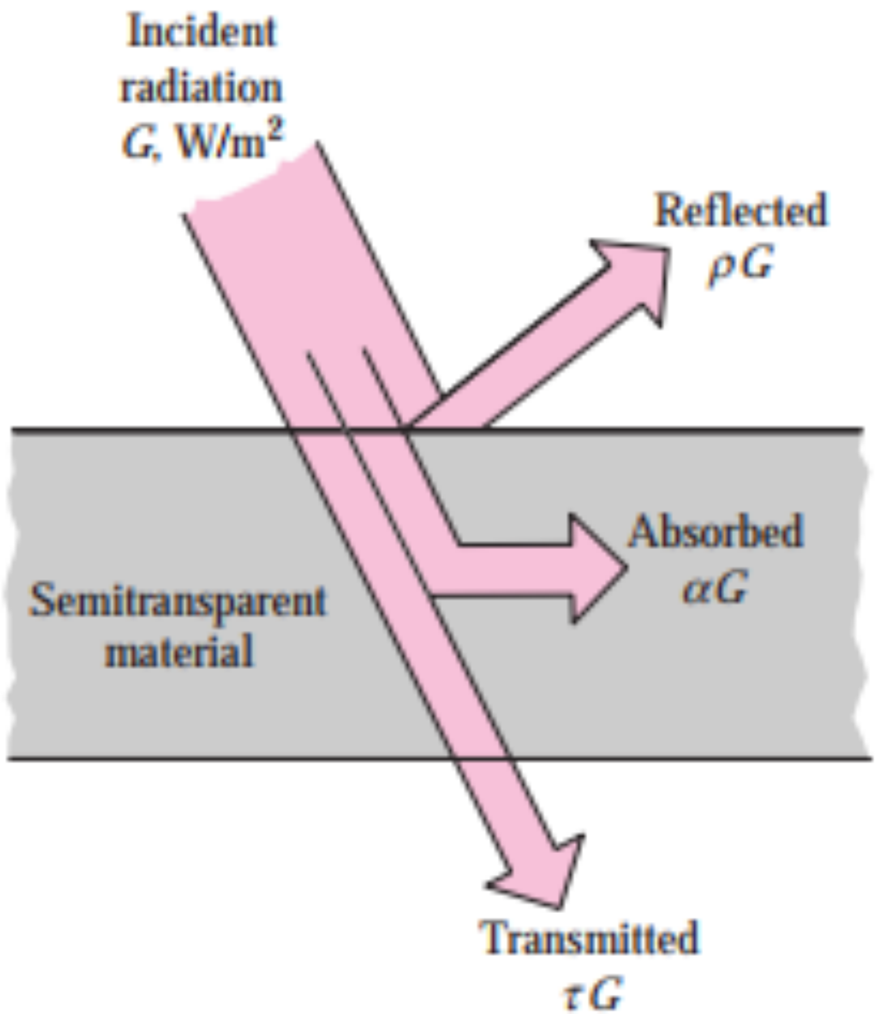
Wavelength region?

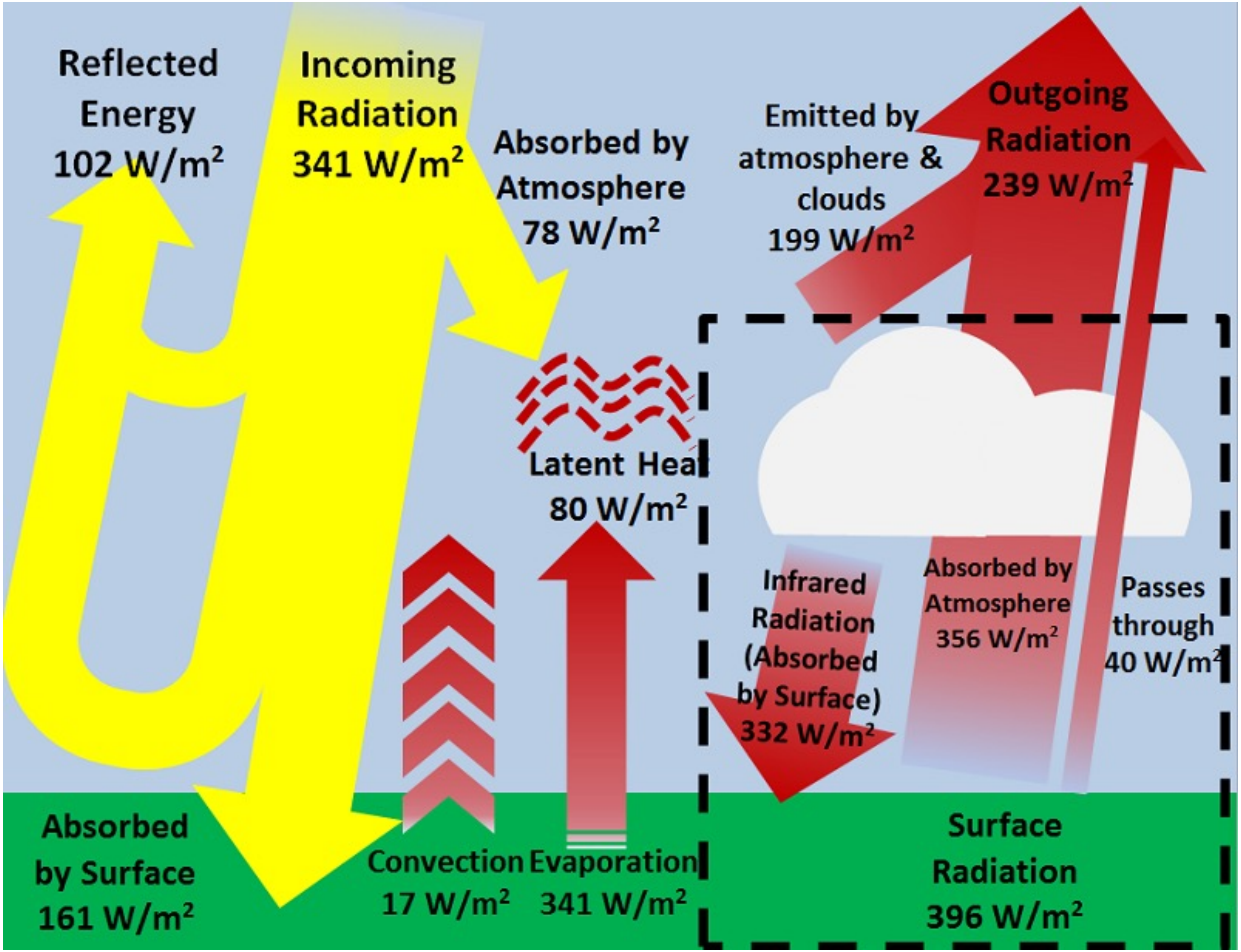
Radiation

- Real object: $J_Q = \epsilon\, J_{Q,B}$,
    - $\epsilon =$ emissivity
    - Black body: $\epsilon = 1$

- Real image:
    - $I = \epsilon f_{cal}\left(T_{obj}\right) + \rho f_{cal}(T_{back}$
    - Reflectivity: ρ

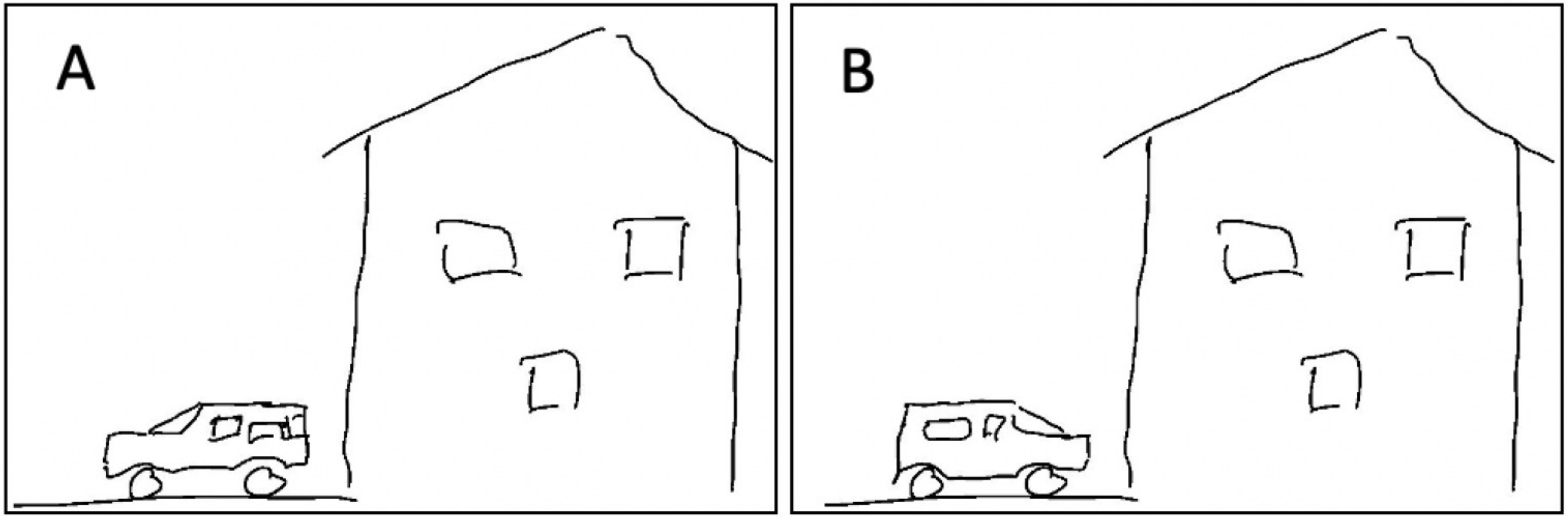
- $\epsilon = \alpha$, emissivity = absorptivity
- $\rho + \alpha + \tau = 1$





Reflected Energy 102 W/m²
Incoming Radiation 341 W/m²
Absorbed by Atmosphere 78 W/m²
Emitted by atmosphere & clouds 199 W/m²
Outgoing Radiation 239 W/m²
Latent Heat 80 W/m²
Infrared Radiation (Absorbed by Surface) 332 W/m²
Absorbed by Atmosphere 356 W/m²
Passes through 40 W/m²
Absorbed by Surface 161 W/m²
Convection 17 W/m²
Evaporation 341 W/m²
Surface Radiation 396 W/m²

Radiation balance ++



I park my car in front of my house and leave it overnight when there is a clear sky in winter. When the car has the front facing away from the house the windshield is icy in the morning, but not when the front is facing the house. Why does the windshield become icy? Why does it matter which way the car faces?

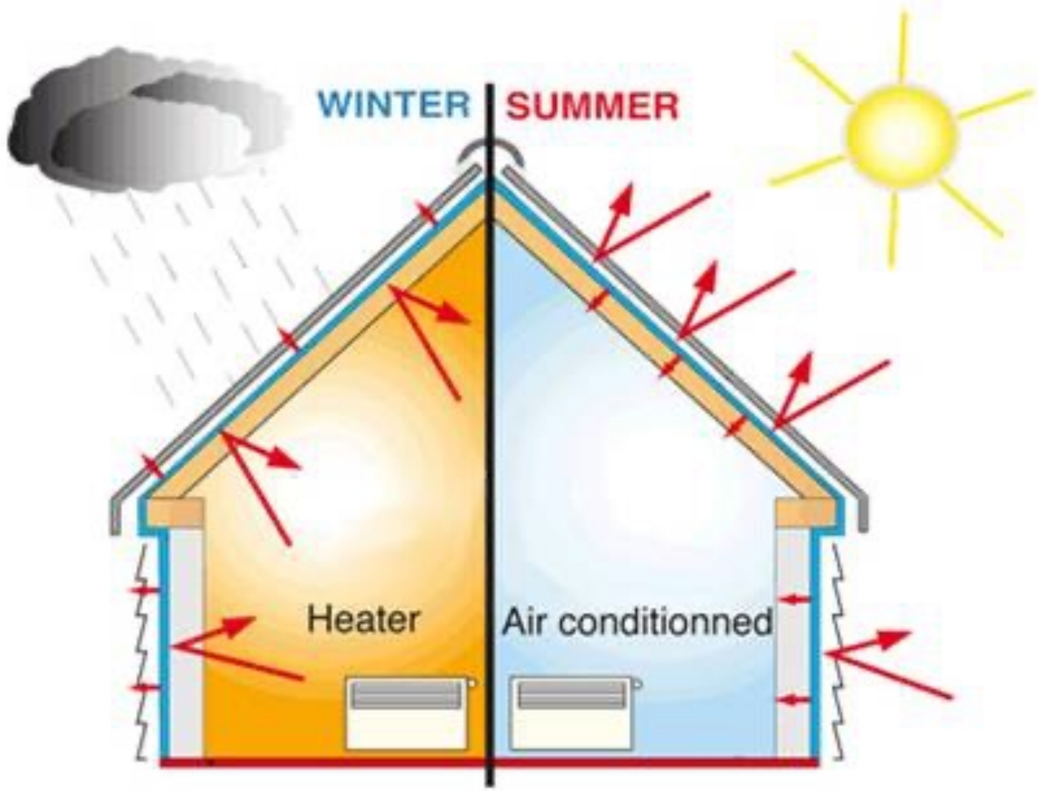
- Discuss and note all relevant relations and processes on the whiteboard
- Ask gpt.uio.no for answers and compare

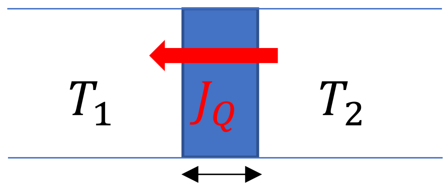
- The windshield gets icy when it is cold ($T<0$) and there is water vapour in the air at a higher chemical potential (vapour pressure) than on the windshield.
- The chemical potential in the air is regulated by the temperature of other surfaces around and by transport of (moist air) from the atmosphere
- The air circulates and the vapour pressure of the air is affected by the temperature of other surfaces in the vicinity. The distance to other surfaces like the house will (due to circulation) not affect the vapour pressure of the air by the windshield very much.
- Thus the difference between the two cases (facing towards or away from) must be due to the difference in the temperature of the windshield
- The temperature is affected by radiation, conduction and convection. Since the air has the same temperature and humidity in the two cases he conductive and convective heat loss should not be much different in the two cases, thus it is mainly an effect of radiation balance.
- There are two bodies radiating towards the car: the clear sky and the house.
- The clear sky has a background radiation of 4K and radiation from CO_2 and H_2O in the atmosphere (on average 255K according to Schroeder p 308, but much lower on a winter night).
- The outer surface of the house is slightly warmer than the air surrounding it (due to heat conduction through the walls).
- The cold, icy windshield of the car facing away from the house radiates less than the warmer, windshield facing the house, but still the difference in received radiation is more than large enough to offset this.

Radiation balance ++

- How many of the suggested relations and processes did you come up with?
- How did gpt.uio.no do?
- Did you understand all the suggested relations and processes?

Heating & thermal conduction





$$\Delta T = T_2 - T_1$$

On the whiteboard:
Write a formula for the heat flux through the wall

$$J_Q = \lambda \frac{\Delta T}{\Delta x}$$

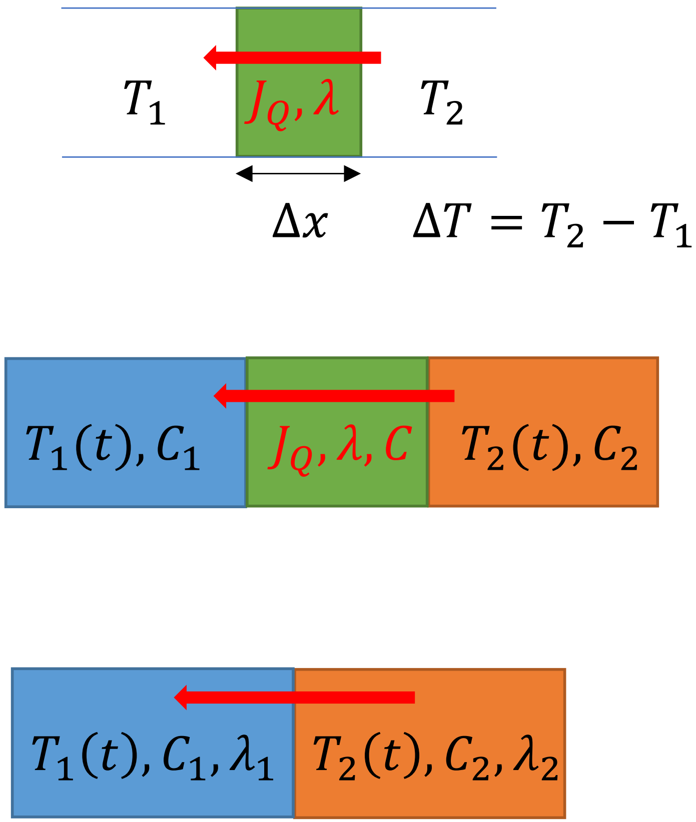
assumptions?

	c	λ
	[J K^{-1} kg^{-1}]	[W m^{-1}K^{-1}]
Air	1005	0.025
Water	4180	0.598
Silver	1005	429
Pine (furu)	1500	0.1213

Thermal conduction experiment

- Capstone
- Based on the temperature curves: which metal block is steel and which is lead?

Thermal conduction, boundary conditions



- $J_Q = -\lambda \nabla T$
- $\Delta Q = C\,\Delta T,$
- $\mathrm{c} = \frac{\mathrm{C}}{\mathrm{m}}, \quad \rho = \frac{m}{V}$
- Energy conservation (continuity equation)
$$\frac{\partial Q}{V \partial t} + \nabla J_Q = 0$$
- Thermal diffusion:
$$\frac{C}{V}\frac{\partial T}{\partial t} - \lambda \nabla^2 T = 0$$
$$\frac{\partial T}{\partial t} - \frac{\lambda}{c\rho} \nabla^2 T = 0$$

Mass diffusion

- Concentration of species 1 in a mixture: c_1

- Fick diffusion $$J_1 = -D\nabla c_1$$
  - D – diffusion coefficient, J_1 - flux of species 1

- Mass conservation

  (continuity equation) $$\frac{\partial c_1}{\partial t} + \nabla J_1 = 0$$

- Mass diffusion: $$\frac{\partial c_1}{\partial t} - D\nabla^2 c_1 = 0$$