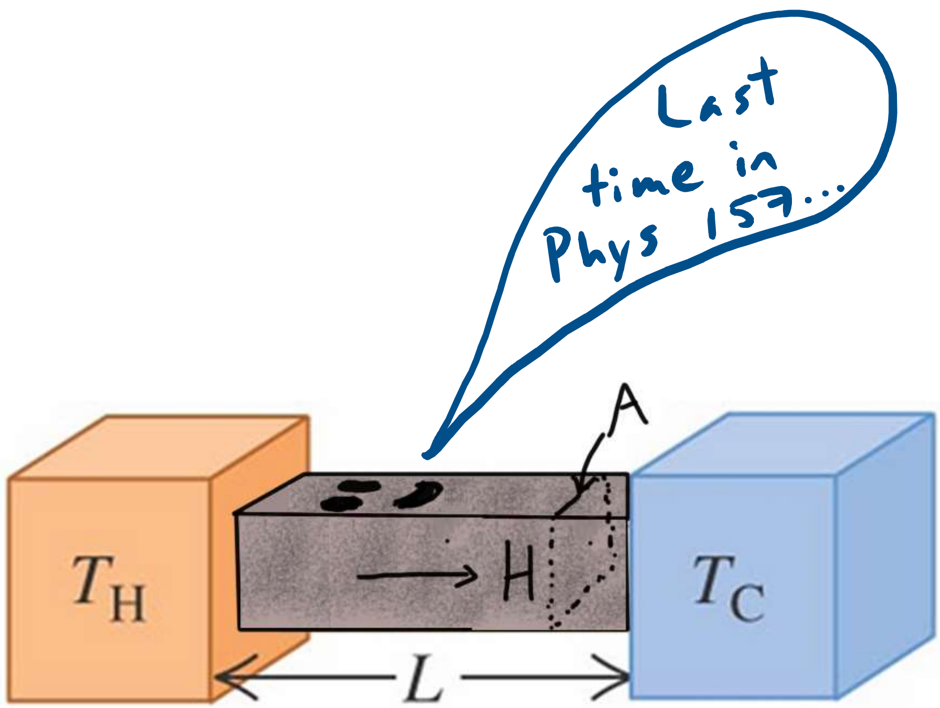
Learning goals:

- Explain how the thermal resistance (or R value) of an insulation layer is defined and how to find the thermal resistance of insulation with multiple layers in terms of the individual resistance
- To calculate heat current through an insulation layer given the temperature difference and thermal resistance
- Explain the physical mechanism of convection and how it differs from conduction
- Explain the microscopic origin of electromagnetic radiation
- Explain the connection between wavelength and the different types of electromagnetic radiation
- Given a spectrum graph calculate the relative power of a radiation source in different ranges of wavelengths, or the total power of the source



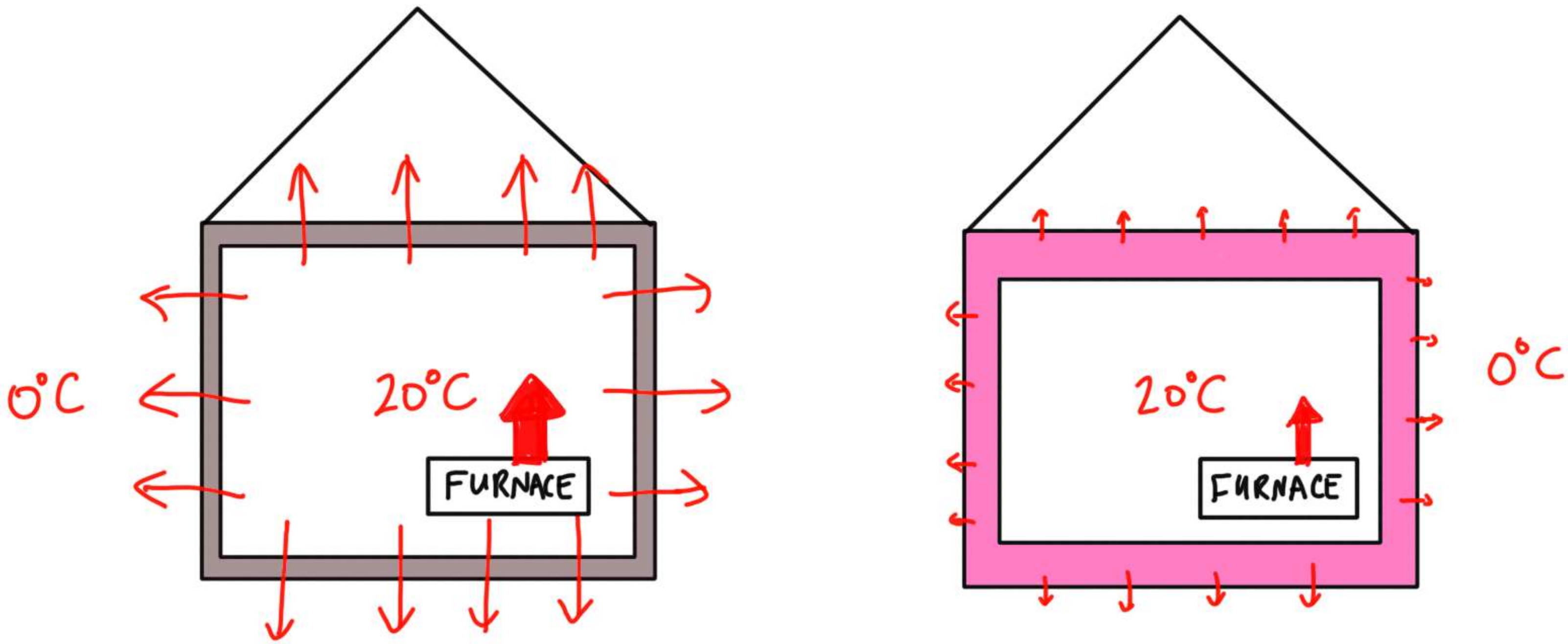
$$H = kA\frac{T_H - T_C}{L}$$

$\frac{T_H - T_C}{L}$ } temperature gradient

H: Heat current = Heat per time

k: Thermal conductivity

Application: insulation

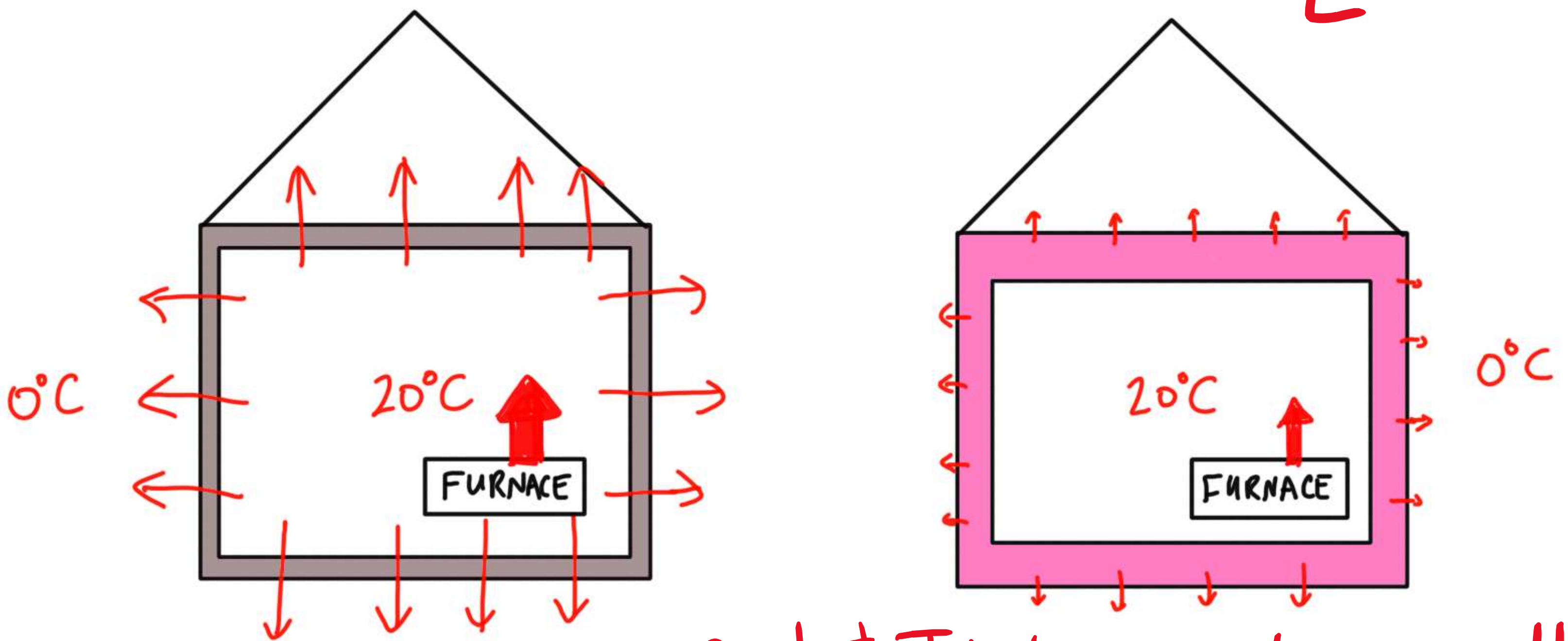


The second house has insulation that is twice as thick and made with a material that has half the thermal conductivity. To maintain the same inside temperature, the amount of fuel needed to be burned by the furnace in the second house is:

A) The same
B) 1/2 as much
C) 1/4 as much
D) 1/8 as much
E) 1/16 as much

Application: insulation

$$H = kA \cdot \frac{T_H - T_C}{L}$$



Constant T in house ⇒ $H_{furnace} = H_{through\ walls}$

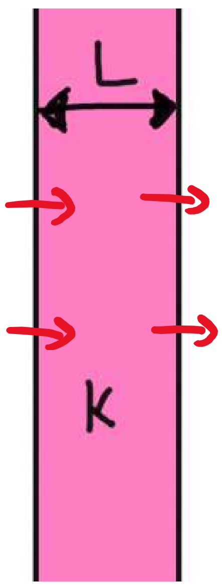
The second house has insulation that is twice as thick and made with a material that has half the thermal conductivity. To maintain the same inside temperature, the amount of fuel needed to be burned by the furnace in the second house is:

L is double
k is half

A) The same
B) 1/2 as much
C) 1/4 as much
D) 1/8 as much
E) 1/16 as much

∴ H is $\frac{1}{4}$

THERMAL RESISTANCE: measures effectiveness of insulation layer



$$R = \frac{L}{k}$$

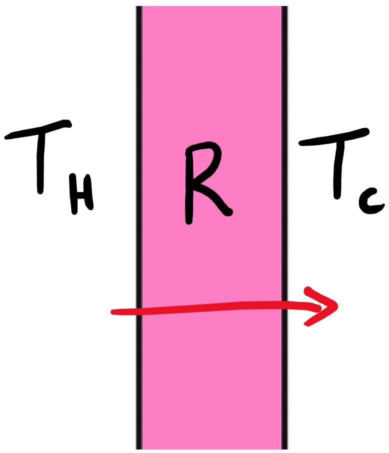
L ← thickness

k ← thermal conductivity

"R-value" is this quantity in units of

$$ft^2 \cdot F^\circ \cdot \frac{\text{hours}}{\text{Btu}}$$

Larger is better

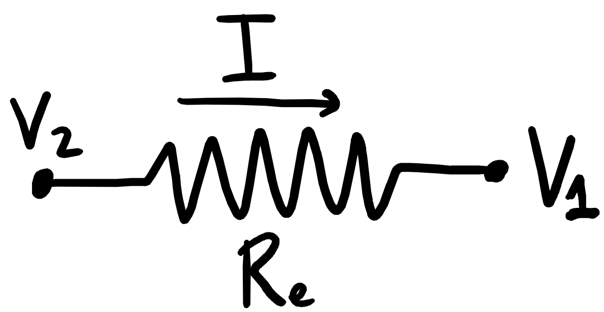


$$\frac{H}{A} = \frac{T_H - T_c}{R}$$

heat current per area (H/A)

thermal resistance (R): $\frac{L}{k}$

Analogy with electrical resistance + Ohm's Law:

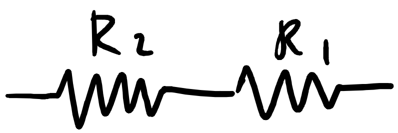


$$I = \frac{V_2 - V_1}{R_e}$$

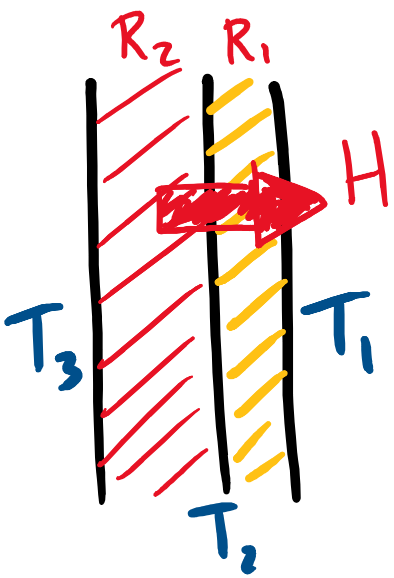
current (I)

electrical resistance (R_e)

R values add for multiple layers



$$R = R_1 + R_2$$



$$R = R_1 + R_2$$

How to show this:

$$T_3 - T_2 = \frac{H}{A} \cdot R_2$$

$$T_2 - T_1 = \frac{H}{A} \cdot R_1$$

Add these:

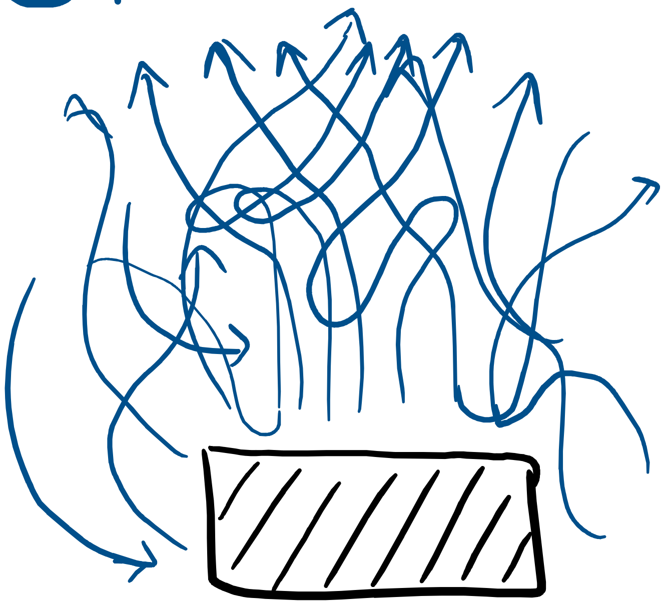
$$T_3 - T_1 = \frac{H}{A}(R_1 + R_2)$$

net temp. difference

heat current

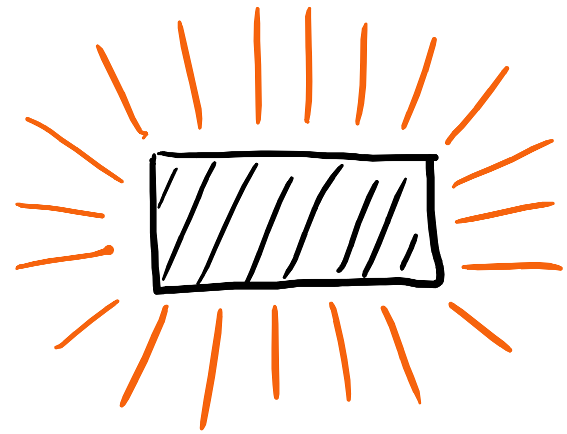
net resistance

Other mechanisms for heat transfer:



CONVECTION: heat transfer via macroscopic motion of fluids

- very complicated fluid dynamics to understand

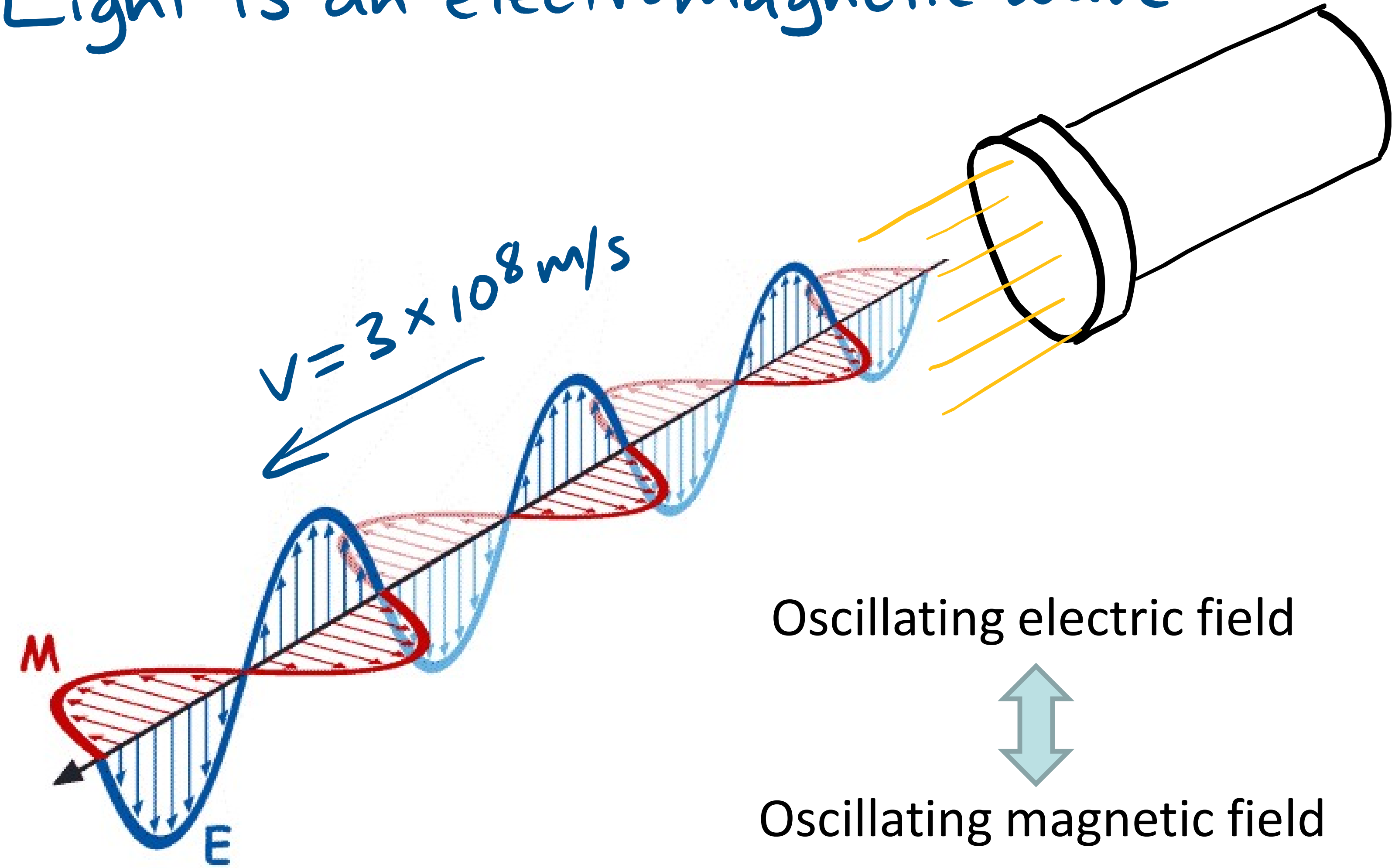


RADIATION: all objects give off electromagnetic radiation (light, IR, etc...)

- this carries energy away from the object

Electromagnetic Radiation:

Light is an electromagnetic wave:



Oscillating electric field

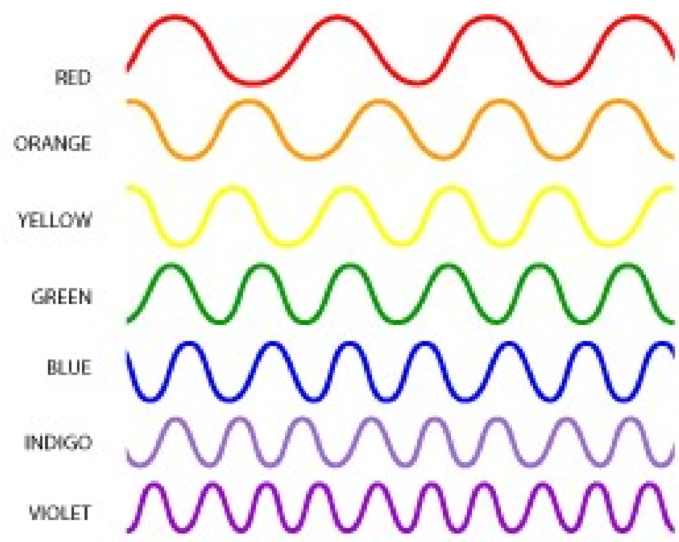
⇕

Oscillating magnetic field

James Clerk Maxwell 1864

Properties of Light

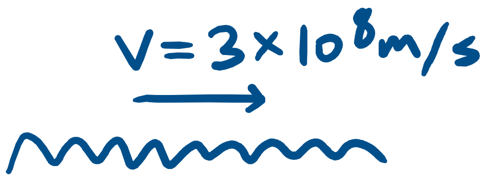
Colour: determined by wavelength

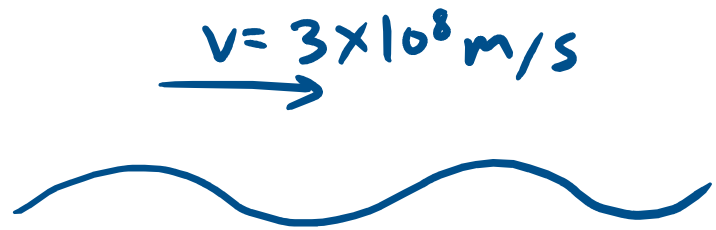


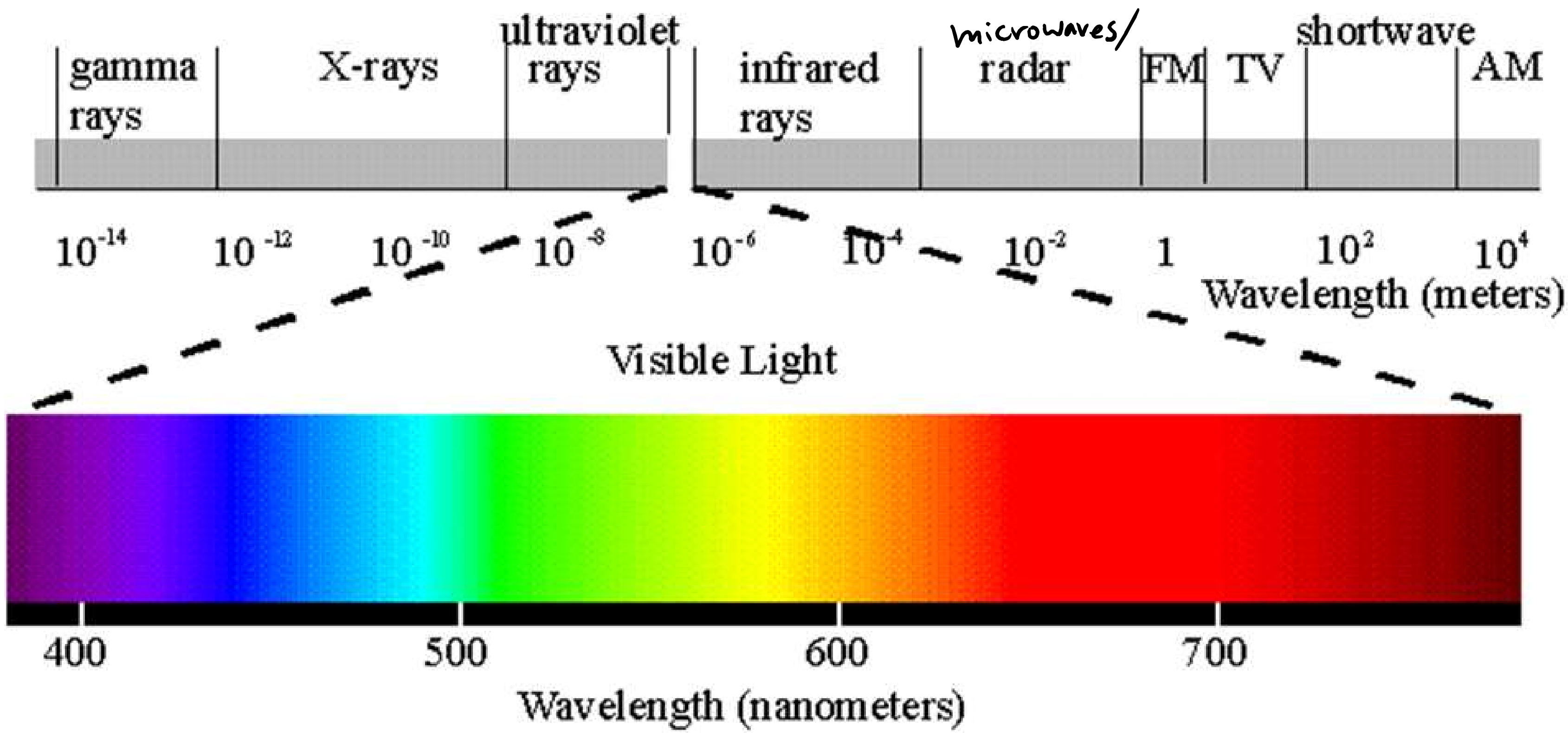
Intensity/brightness: determined by amplitude

↳ light carries energy!

Can have electromagnetic waves at all wavelengths:

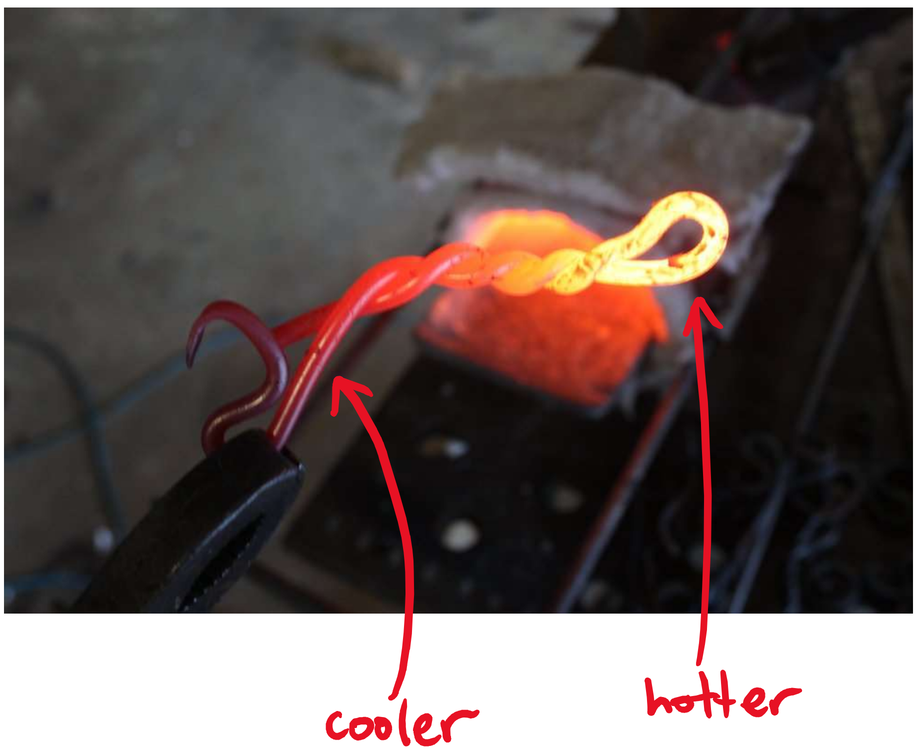


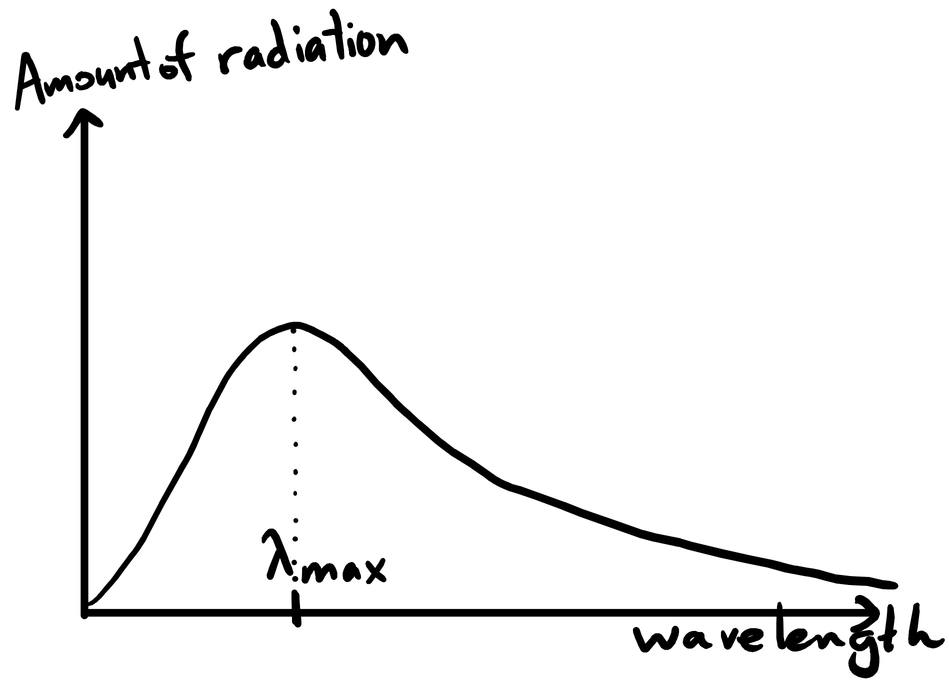


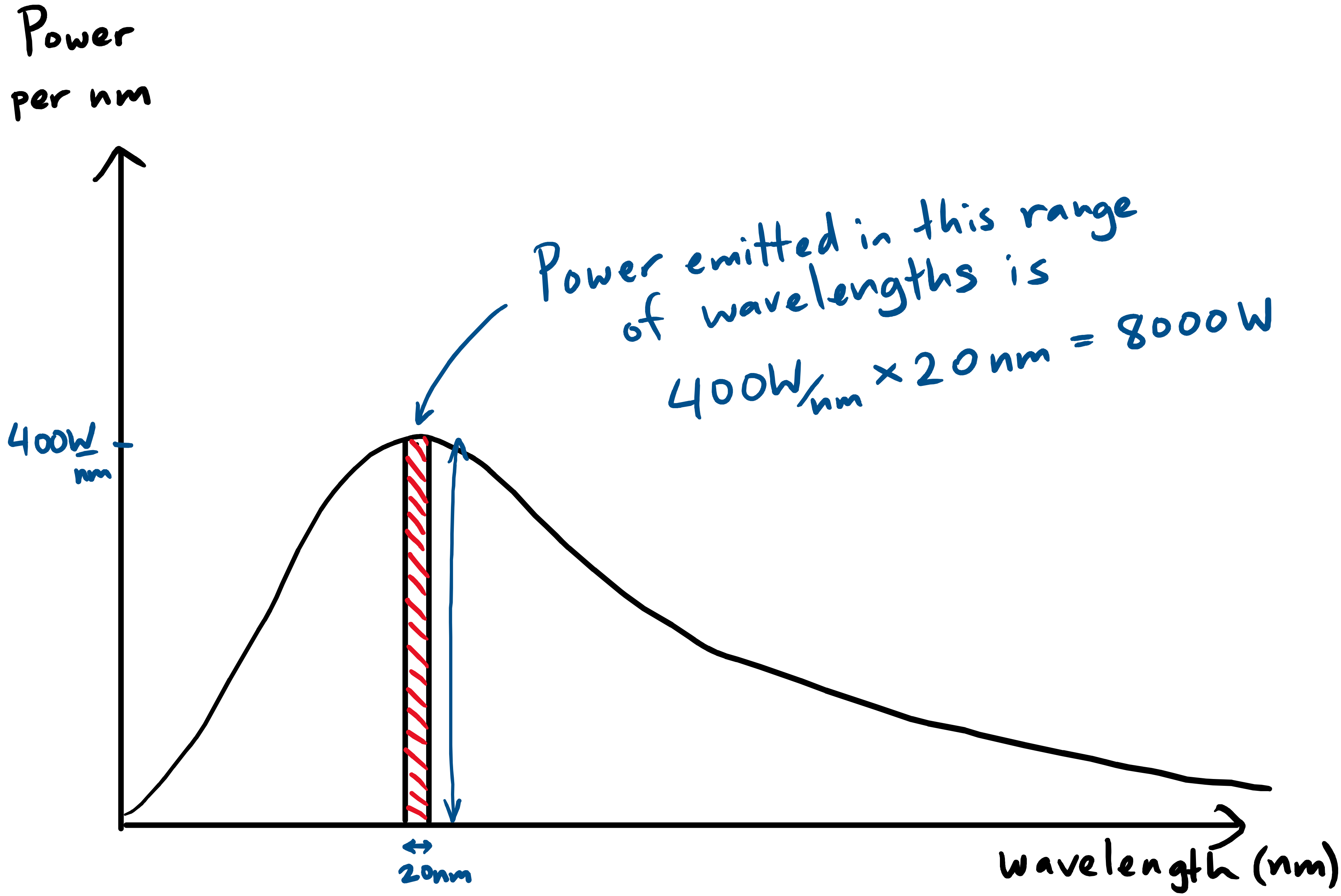


Thermal radiation from an object:

- typically in IR/visible
- can measure energy current at various wavelengths = spectrum



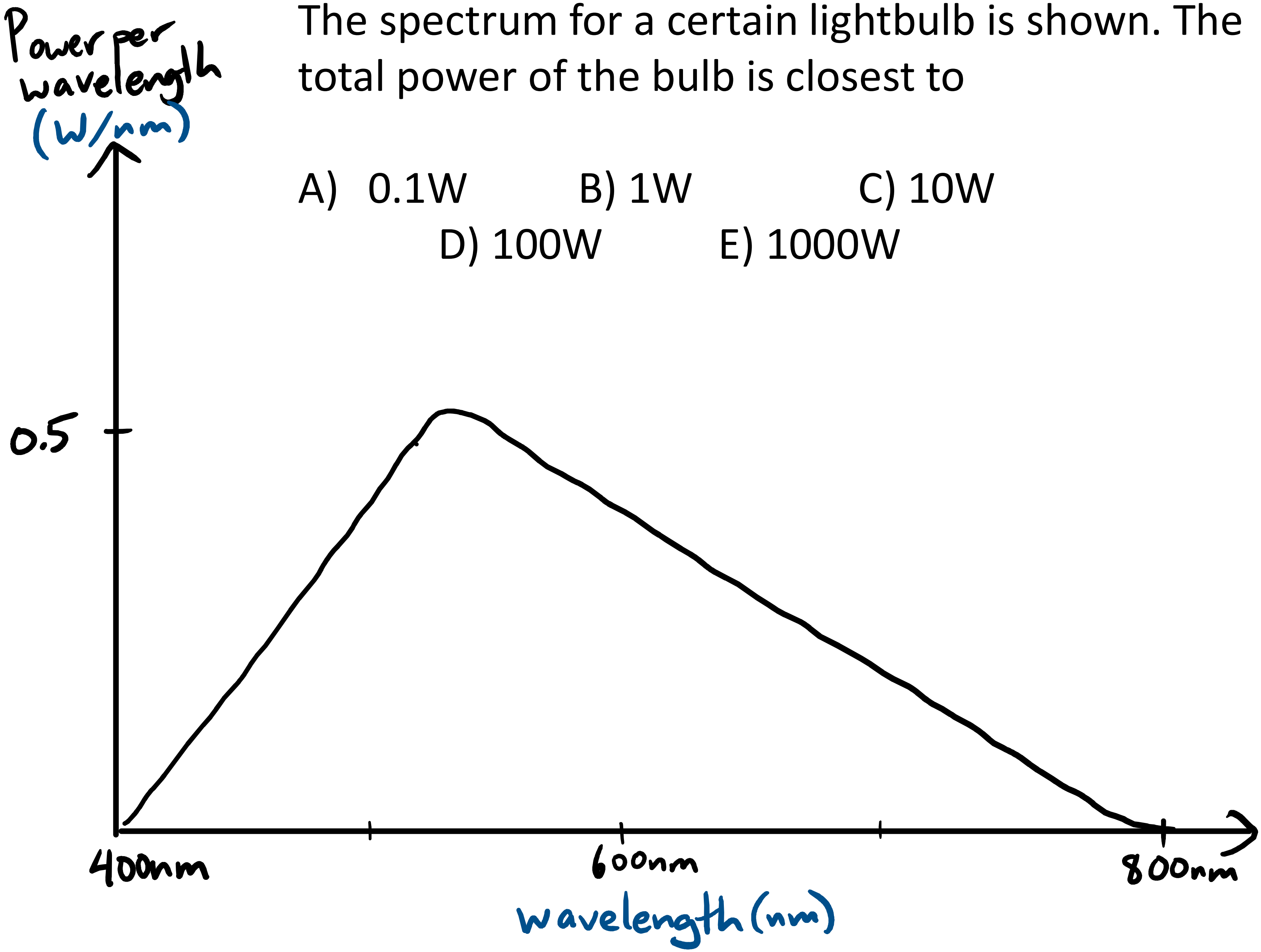




Power per nm
400W/nm
Power emitted in this range of wavelengths is
400W/nm × 20nm = 8000W
20nm
wavelength (nm)

The spectrum for a certain lightbulb is shown. The total power of the bulb is closest to

A) 0.1W B) 1W C) 10W D) 100W E) 1000W



The spectrum for a certain lightbulb is shown. The total power of the bulb is closest to

A) 0.1W B) 1W C) 10W
D) 100W E) 1000W