# EE 521 Measurement and Instrumentation

**Fall 2007 - Dr. Anders M. Jorgensen**

## Measurements on a Light Bulb - solution

1. Let's say 400-700 nm.

2. $$I(\lambda, T) = \frac{2hc^2}{\lambda^5} \frac{1}{e^{\frac{hc}{\lambda kT}} - 1}$$

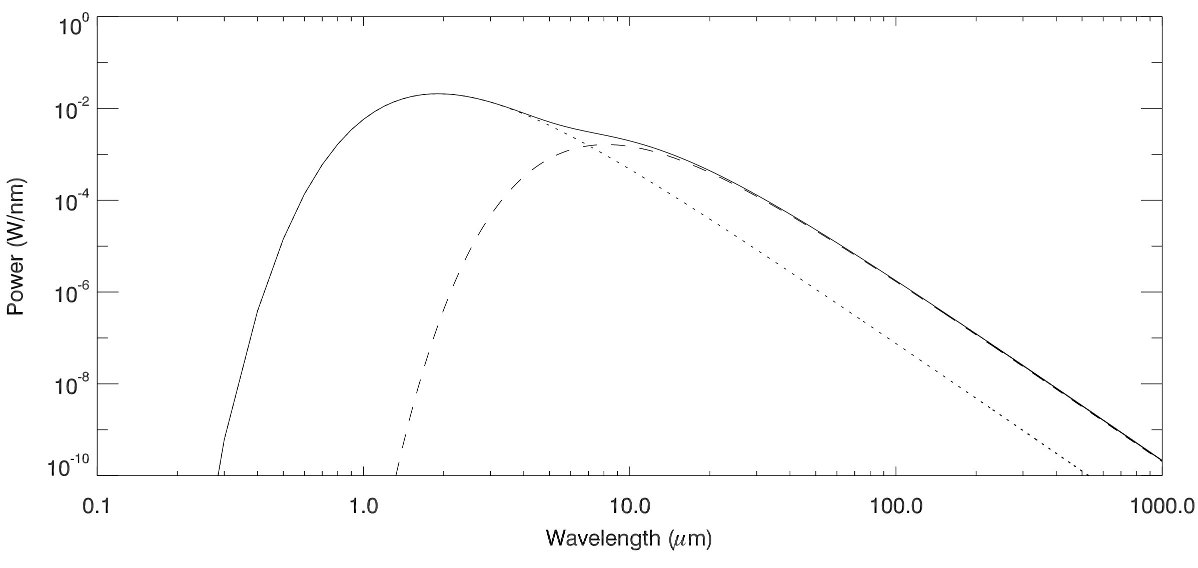
3. We integrate over surface area of the emitting surface, and over solid angle.

$$P = \int_\Omega \int_A I(\lambda, T) d\Omega dA$$

   If we assume $\Delta\Omega = 2\pi$ and uniform temperature across the surface area, then

$$P = 2\pi A I(\lambda, T)$$

4. I will assume that the temperatur of the filament is $T_{\text{filament}} = 1500\,\text{K}$, and its area is $A_{\text{filament}} = 1\,\text{cm}^2$, and that the temperature of the bulb is $T_{\text{bulb}} = 350\,\text{K}$, and it's area is $A_{\text{bulb}} = 4\pi R^2$ with $R = 3\,\text{cm}$ such that $A_{\text{bulb}} = 113\,\text{cm}^2$.




5. Integrate the function over the visible spectrum, and integrate it over all wavelengths. Integral in the visible spectrum becomes

$$P_{\text{vis}} = 0.075\,\text{W}$$

   Integral over all spectrum becomes

$$P_{\text{tot}} = 80.92\,\text{W}$$

Fraction of energy in the visible spectrum is

$$\frac{P_{\text{vis}}}{P_{\text{tot}}} = \frac{0.075}{80.92} = 0.0009 = 0.09\%$$

(Given what I think I know about light bulbs, I think I may have underestimated the temperature of the filament and overestimated its area)

6. Measure $V$ and $I$ on the power line connecting to the bulb and multiply them.

7. Use the photodiode setup in Northrop Figure 6.20,

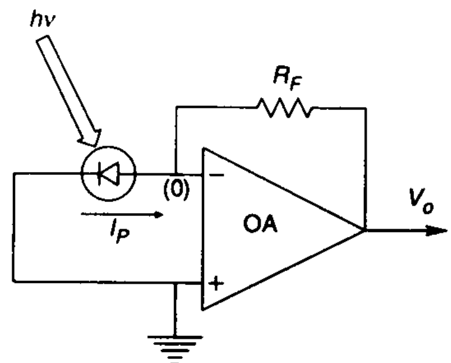



**FIGURE 6.20**
**Op-amp transresistor circuit in which a photodiode is operated in the short circuit mode. Response speed is low due to large zero bias junction capacitance.**

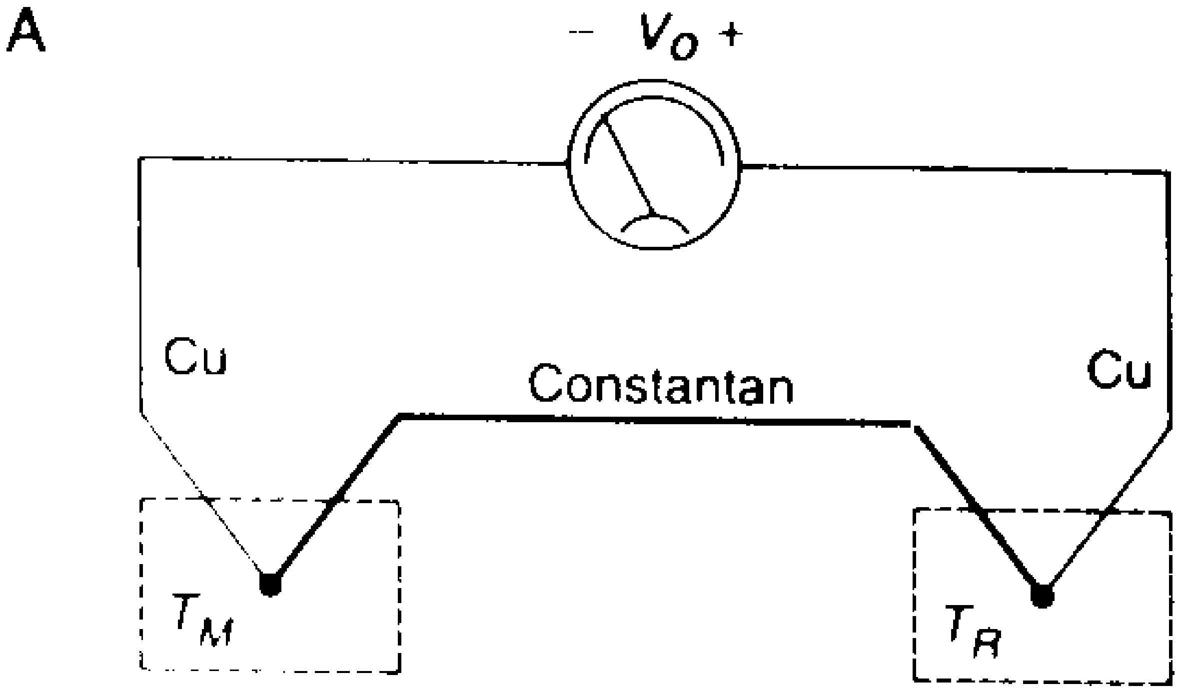
The photodiode produces a certain number of amperes per watt, $K$, of incident power. If the area of the detector is $A_{\text{det}}$, and the distance from the bulb is $d$, and the power output from the bulb is $P$, then the current produces by the diode is

$$I = KP\frac{A_{\text{det}}}{4\pi d^2}$$

The output voltage is

$$V_o = RI$$

8. We could use the setup in Northrop figure 6.18a amplified by an inverting amplifier.




Assume $K = 40\,\mu\text{V}/K$, and that we will be looking at temperature differences up to 200 K, and we want to operate up to 15 V. The gain of the amplifier is

$$G = \frac{R_F}{R}$$

The output range of the thermocouples is $\Delta V = 200 \times 40 \times 10^{-6}\,\text{V}$. The gain of the amplifier is then

$$G = \frac{15}{200 \times 40 \times 10^{-6}} = 1875$$

We could achieve this gain by choosing $R_F = 100\,\text{k}\Omega$, and $R = 53\,\Omega$.

9. We might use the sun, although we have to be careful since sunlight is approximately black body radiation with a temperature of 5500 K.