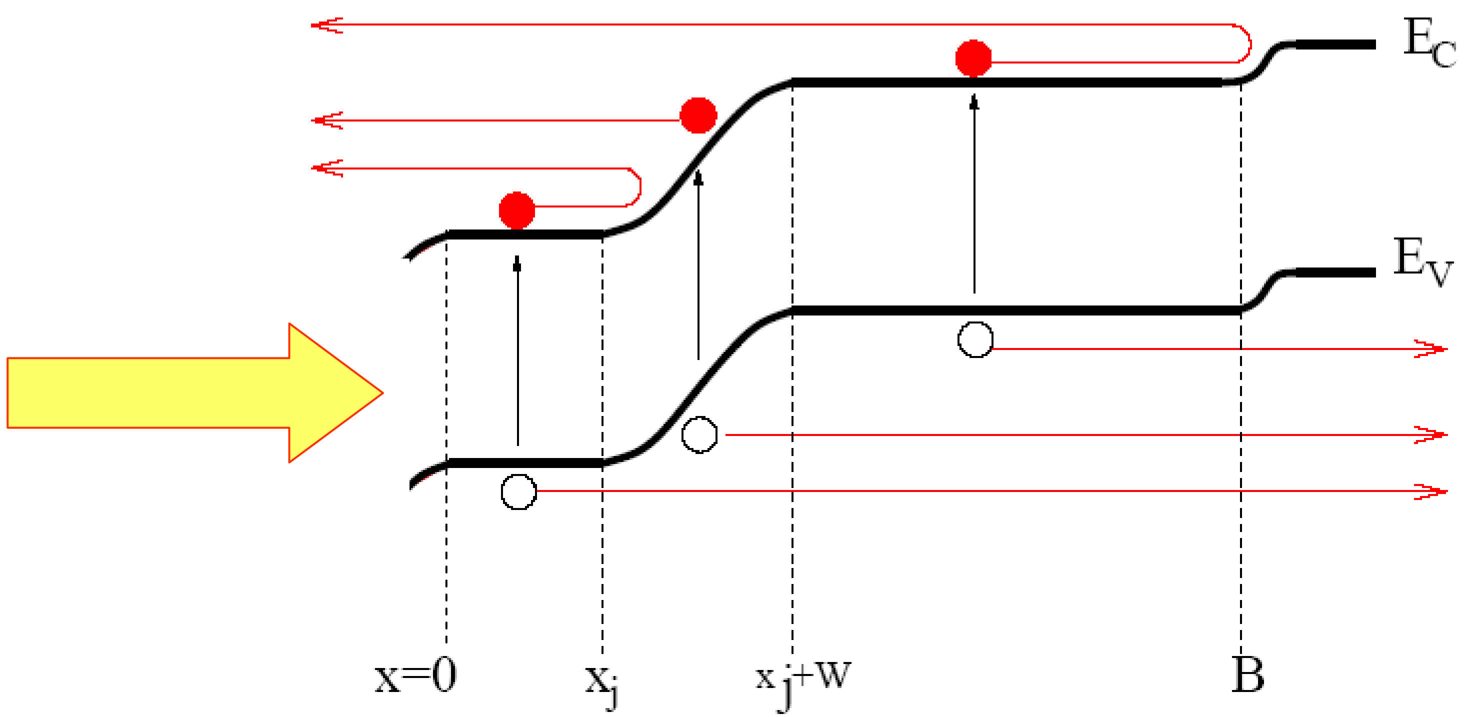
Photo-IV

LECTURE 10

- photocurrent components
- surface recombination velocity
- world-record Si cell
- photovoltage
- fill-factor
- maximum power point

Sec. 7.4

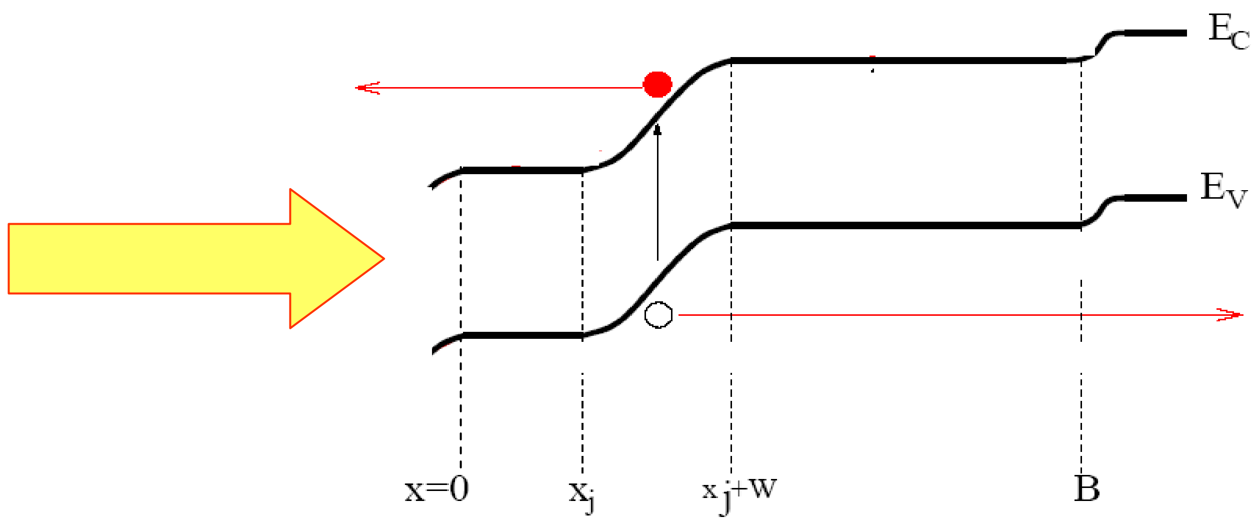
Photocurrent



- Divide cell into 3 regions: emitter, space-charge, base.
- Note new *x*-axis origin.
- Note the surface fields at x=0 and x=B
- What is the purpose of these surface regions, and how are they made?

Sec. 7.4.4

SCR photocurrent



From our toolbox:

$$
\begin{aligned}
-\nabla^2\psi &= \frac{q}{\epsilon}[p - n + N_D - N_A] \\
J_e &= qn\mu_e\nabla\psi + qD_e\nabla n \\
J_h &= qp\mu_h\nabla\psi - qD_h\nabla p \\
\frac{\partial n}{\partial t} &= \frac{1}{q}\nabla\cdot J_e - \frac{n-n_0}{\tau_e} + G_{op} \\
\frac{\partial p}{\partial t} &= \frac{1}{q}\nabla\cdot J_h - \frac{p-p_0}{\tau_h} + G_{op}
\end{aligned}
$$

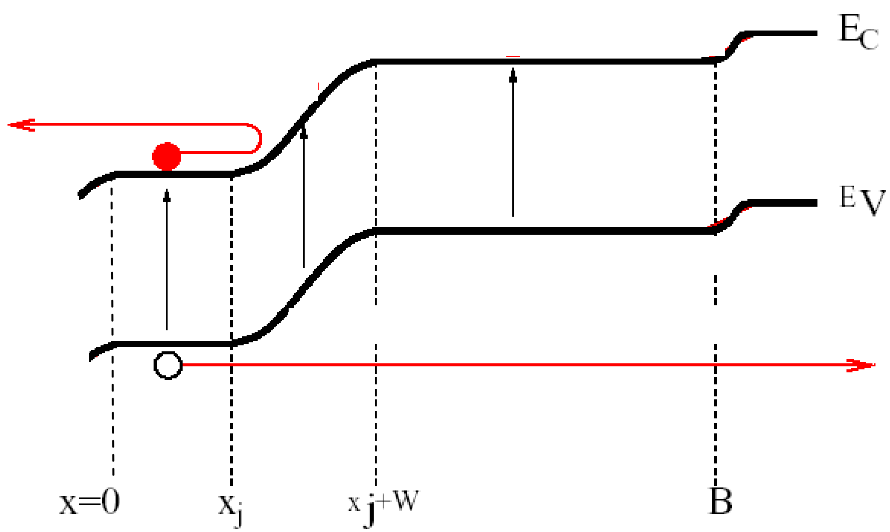
What are the BC's for J_e ?

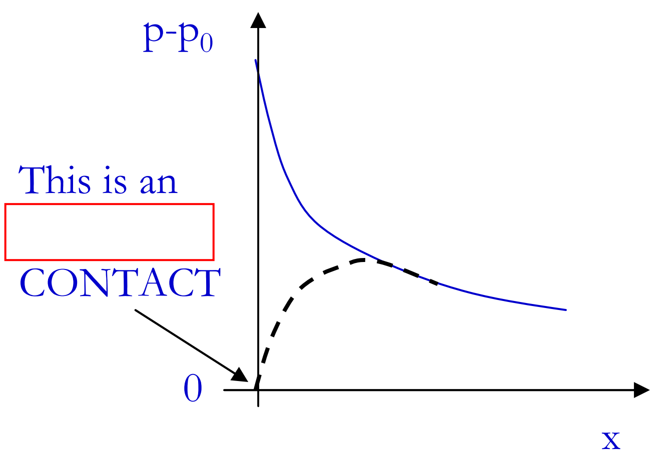
The result is:

$$J_e^D(\lambda, x_j) = q\,\boxed{}\,[1 - e^{-\alpha W}]$$

Sec. 7.4.1

Surface recombination velocity





What do the blue and dashed lines represent?

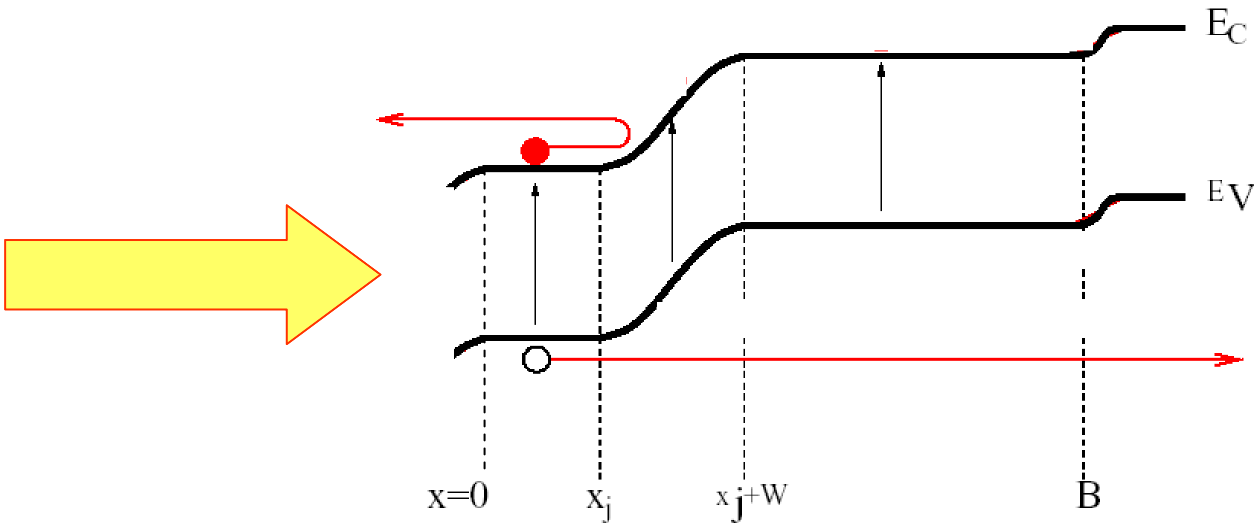
" Rate of recombination of holes at the surface is the same as if a flux of holes ($p(0)-p_0$) were drifting towards the surface with ____________ S".

∴ Our BC at x=0 is

$$D_h \frac{dp}{dx}\Big|_{x=0} = \qquad$$

Sec. 7.4.2

Emitter photocurrent



From our toolbox:

$$-\nabla^2\psi = \frac{q}{\epsilon}[p - n + N_D - N_A]$$

$$J_e = -qn\mu_e\nabla\psi + qD_e\nabla n$$

$$J_h = -qp\mu_h\nabla\psi - qD_h\nabla p$$

$$\frac{\partial n}{\partial t} = \frac{1}{q}\nabla\cdot J_e - \frac{n-n_0}{\tau_e} + G_{op}$$

$$\frac{\partial p}{\partial t} = -\frac{1}{q}\nabla\cdot J_h - \frac{p-p_0}{\tau_h} + G_{op}$$

What is the BC for $p(x_j)$?

What is the BC for p(0) ?

Sec. 7.4.2

Emitter photocurrent

1. Solve the usual 2nd – order ODE in the usual way with the correct boundary conditions.

2. Get p(x).

3. Get current from dp/dx at $x=x_j$

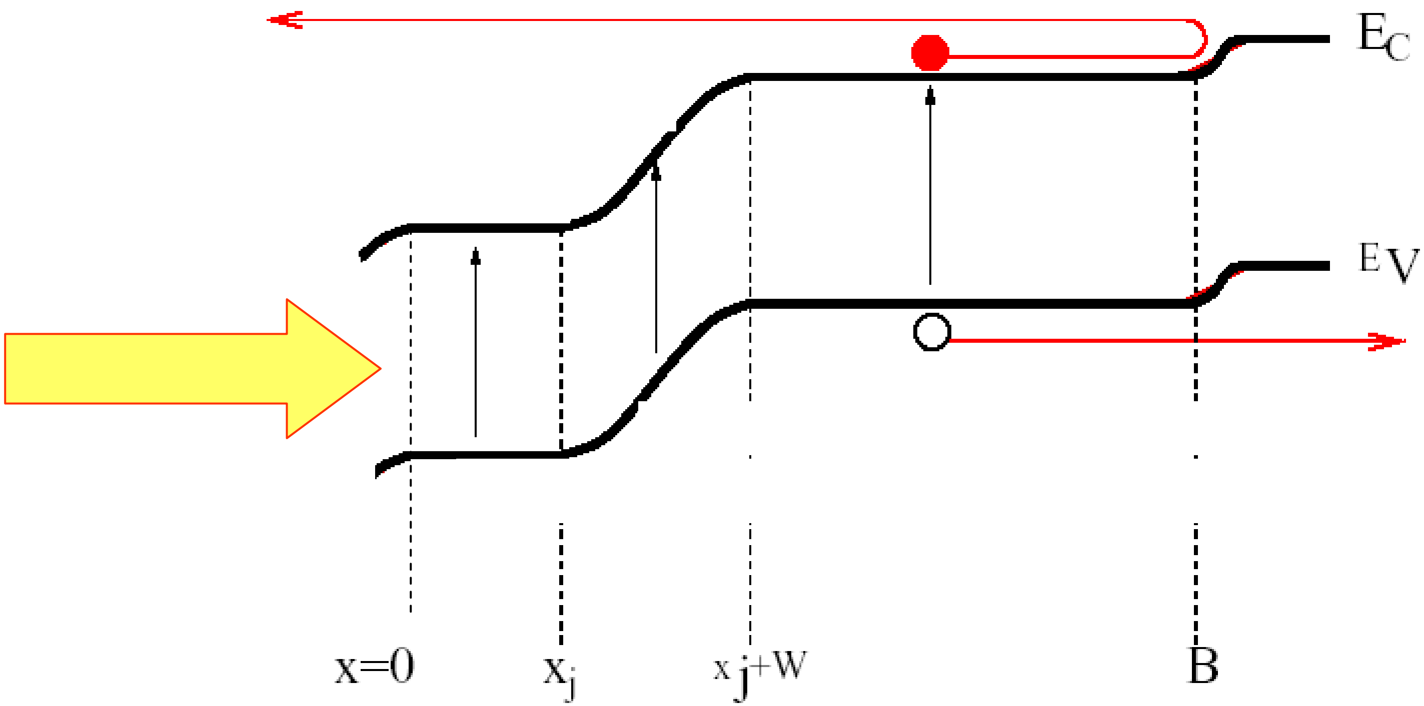
$$J_h^E(\lambda, x_j) = \frac{q\Phi_0 \alpha L_h}{\alpha^2 L_h^2 - 1}\left[-\alpha L_h e^{-\alpha x_j} + \frac{H_h + \alpha L_h - e^{-\alpha x_j}(H_h \cosh Q_h + \sinh Q_h)}{H_h \sinh Q_h + \cosh Q_h}\right]$$

$$Q_h = x_j / L_h,\ H_h = S_F L_h / D_h$$

What would be a good value for S_F ?

Sec. 7.4.3

Base photocurrent



What is the BC at x=B ? $= S_B\left[n(B) - n_0\right]$

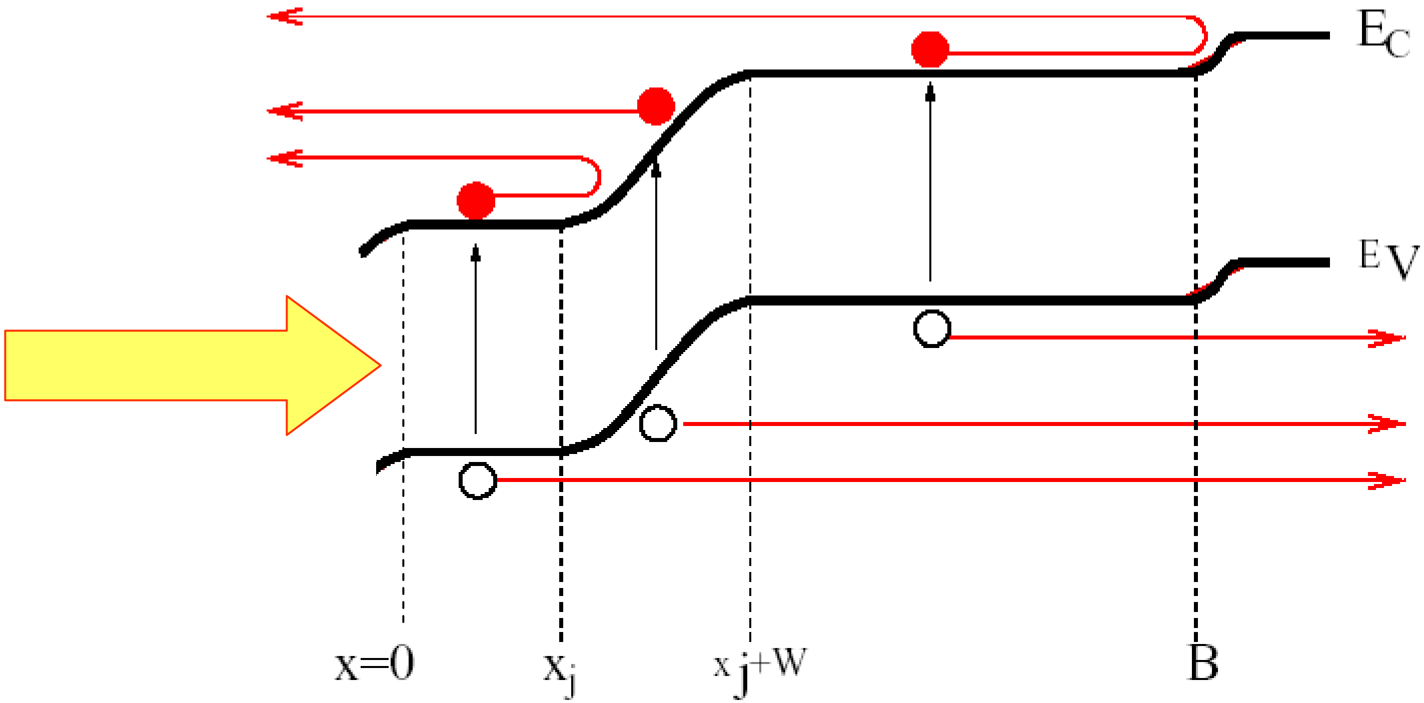
The end result is:

$$J_e^B(\lambda, x_j + W) = \frac{q\Phi_0 \alpha L_e e^{-\alpha(x_j+W)}}{\alpha^2 L_e^2 - 1}\left[\alpha L_e - \frac{H_e(\cosh Q_e - e^{-\alpha B'}) + \sinh Q_e + \alpha L_e e^{-\alpha B'}}{H_e \sinh Q_e + \cosh Q_e}\right]$$

where $B' = B - (x_j + W),\ Q_e = B'/L_e,\ H_e = S_B L_e/D_e$

Sec. 7.4.5

The total photocurrent



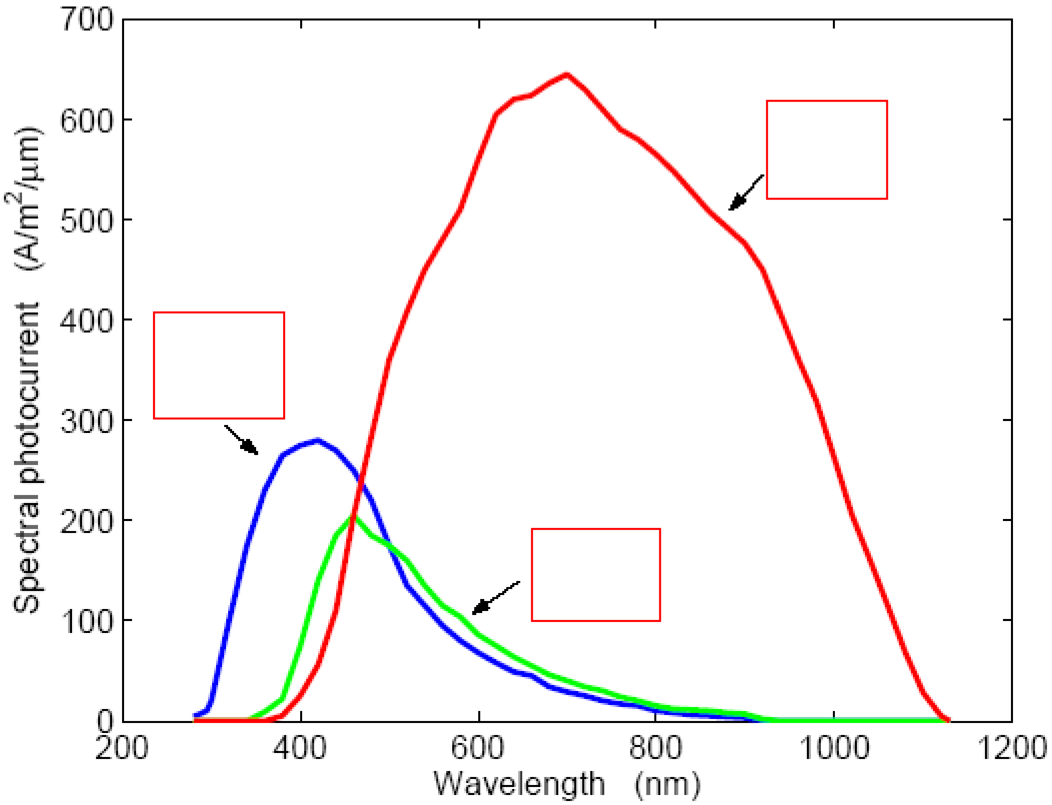
Is it OK to add-up our 3 regional photocurrents?

$$J_{photo}(\lambda) = J_h^E(\chi, x_j) + J_e^D(\chi, x_j) + J_e^B(\chi, x_j + W)$$

Sec. 7.4.5

A numerical example

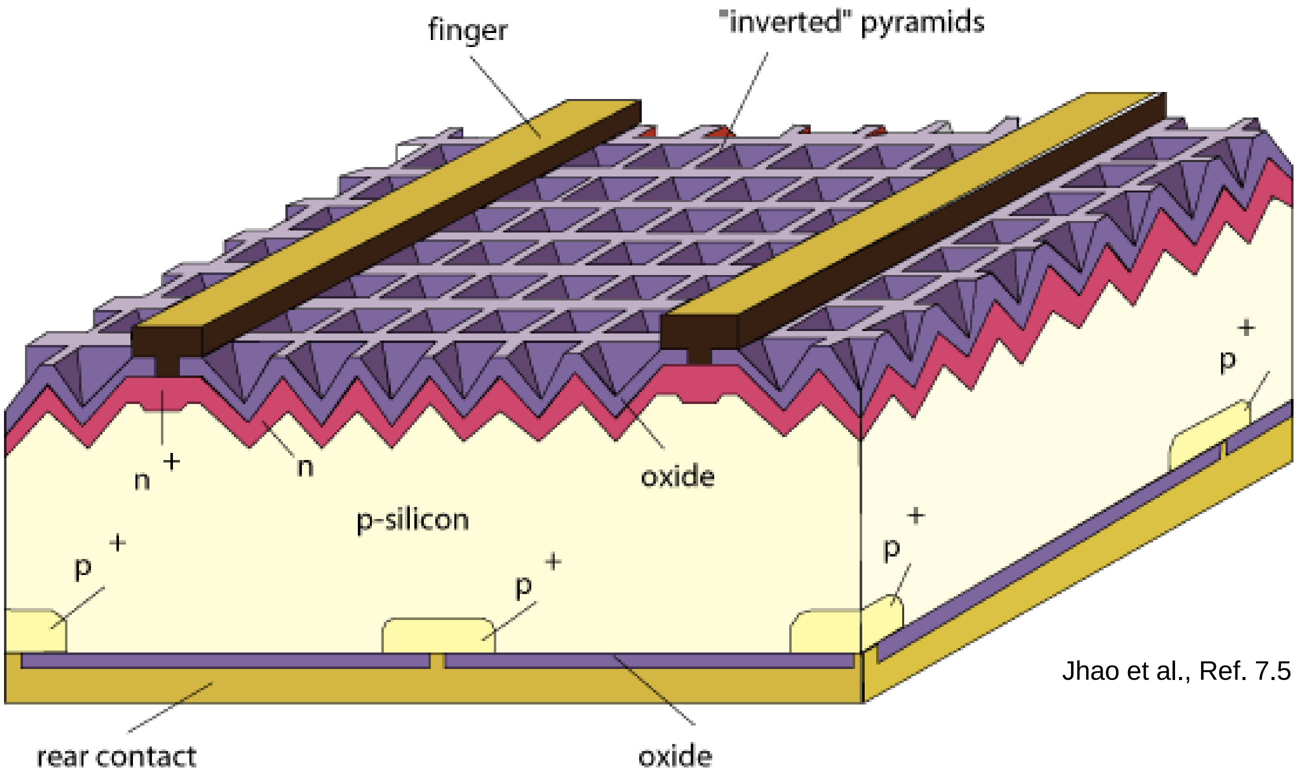
Identify each curve with a region of the solar cell.



Note: the labels here are true spectral photocurrent densities

Sec. 7.4.5

The world record holder

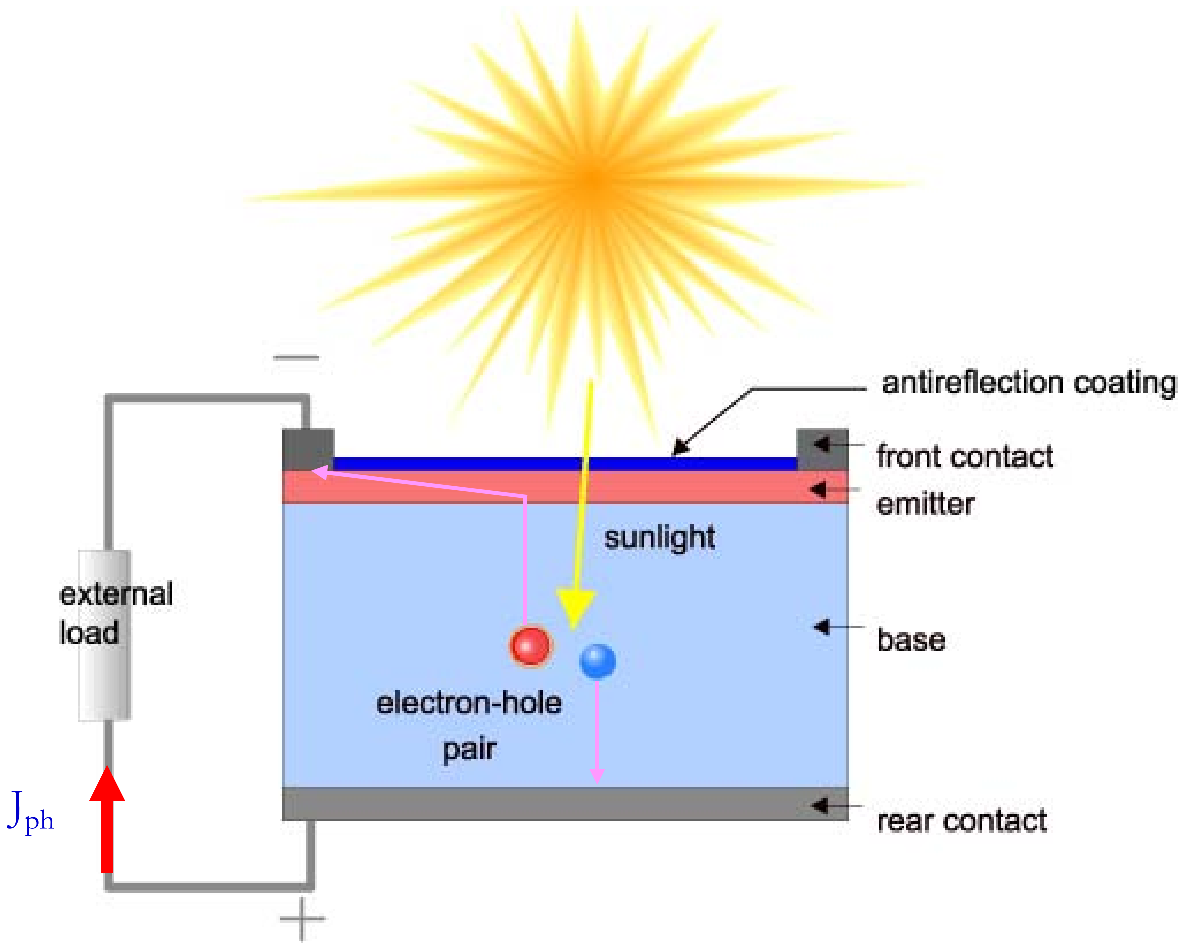


Jhao et al., Ref. 7.5

- Why is the front surface textured?
- Why is there a thin oxide over most of the front and the back?

Sec. 7.5

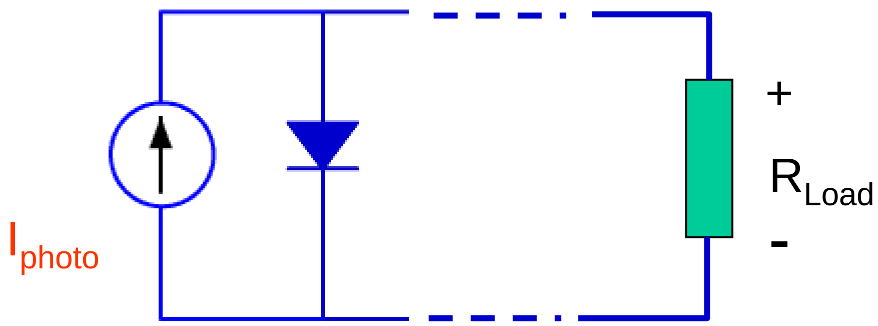
Generating a voltage



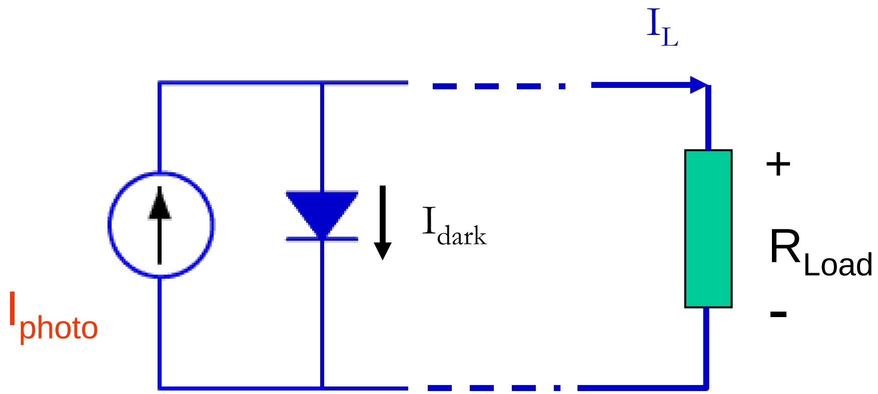
How does the voltage that is generated across the resistor bias the diode ?

Sec. 7.5

Photovoltage



- Connect load
- Voltage across the load forward biases the diode
- Dark current opposes I_{photo}



$I_L < I_{photo}$

Sec. 7.5

Superposition

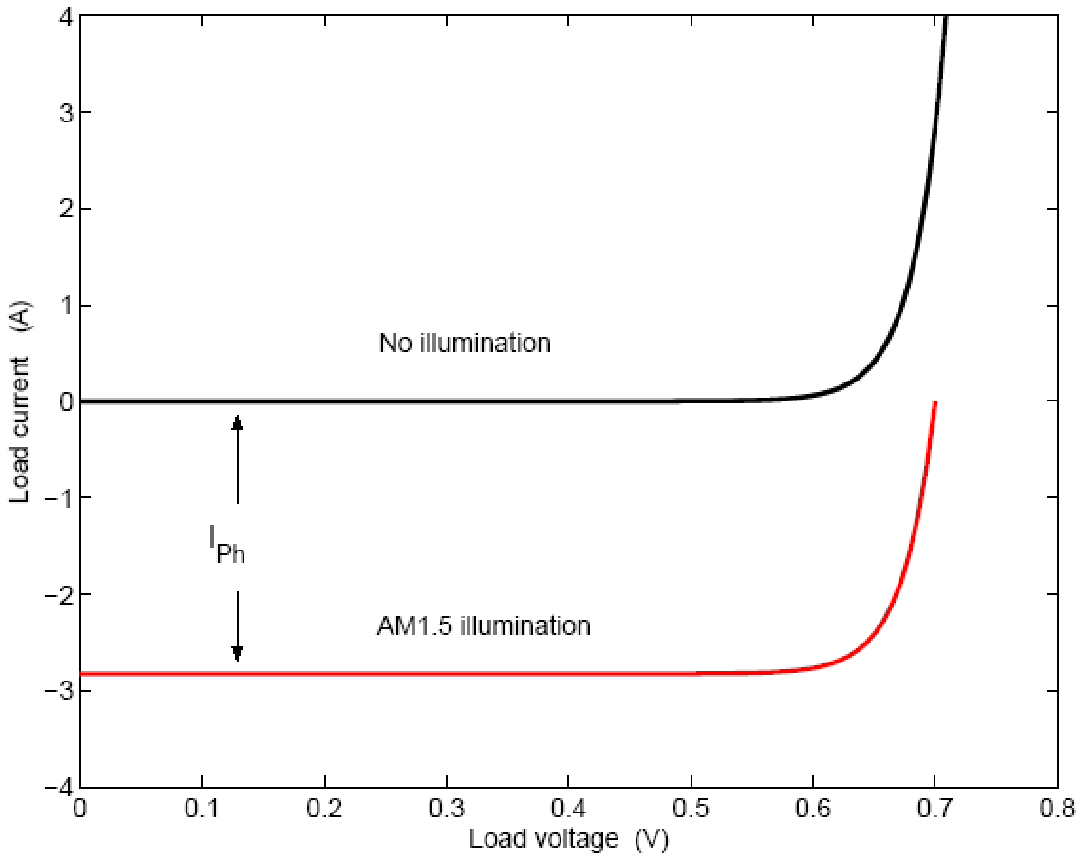


Figure 7.9: Solar cell I-V characteristic, illustrating the superposition of the photocurrent and the usual, exponential diode current. The polarity of the load current has been chosen to emphasize that the solar cell generates power ($IV < 0$). The load absorbs power, of course, ($IV > 0$).

Identify V_{oc}, and derive an expression for it.

Sec. 7.5.1

PV Power

$$
\begin{aligned}
P_{mp} &= J_{mp} V_{mp} \\
&\equiv FF\, J_{sc} V_{oc}
\end{aligned}
$$

Illustration of Fill Factor