today:
  - what is a mosfet?
    - device level
    - iv characteristic
    - models
  - some simple problems

Device level mosfet:

```
+-----------------+    +-----------------+    +-----------------+
|                 |    |                 |    |                 |
|     n           |    |     p           |    |     n           |
|               (gate)    |   |               |
|     n           |    |     p           |    |     n           |
```

current wants to flow from the drain to the source, but it can't because there's a block of p-type in the way.

what do we do? charge up the gate!
Some electrons leak into the p-region.

- This makes a small amount of the p-region look like it's n-type.

We now have a conducting path and current flows.

In summary:
- Low gate voltage - the p-type blocks the current.
- Higher gate voltage - there's a conducting path.

The above is called a pnp transistor (named for the order of the Si regions). There's also a npp variety that conducts for low gate voltage and not for high gate voltage (opposite of npn).
we said when $V_G$ big, current can flow from drain to source, really, the i.v. characteristic is:

$\begin{array}{c}
\text{I_D (to the S)} \\
\text{Vs (relative to Vs)}
\end{array}$

this curve has a really nasty equation (in your book)

2 easy models:

what if we approximate the above by saying:

$V_G > 0 \Rightarrow \text{replace transistor with a short circuit}$

$V_G < 0 \Rightarrow \text{replace transistor with an open circuit}$

is this accurate? no

is it accurate enough for certain problems? maybe
slightly better model:

\[
G \quad \xrightarrow{V_G > 0} \quad R_{DS} \quad S
\]

(this model approximates the iv curve as a straight line)

is this accurate? kind of

"exact solutions":

- use the exact iv characteristic equations
- lots of messy math
- or could use a load-line technique to solve it graphically

how many models did I just discuss?

- 3

PnP

just like the above models, but everything with \( V_G \) is reversed

to show that it's PnP, we draw it as

\[
G \quad \downarrow \quad S \quad (S and D are swapped!)
\]
load line example:

Before I said $I_D$ is a function of $V_G$. Well, it's a function of $V_{DS}$ ($V_D - V_S$) too. The $iv$ characteristic above uses $V_{DS}$ instead of $V_G$. You may get either on a test, so BEWARE!

(Note: in this problem $V_{DS} = V_{out}$)

$I_{DS} = \frac{5 - V_{out}}{100}$
load line solution:

\[ I_{DS} = \frac{5 - V_{OUT}}{100} \]

where they intersect (at 1V, 40mA) is called the operating point.

So \( V_{OUT} = 1V \)

Does this seem sloppy and imprecise? It is!

Second sample problem:

\[ \text{This is called an inverter and is characterized by:} \]

<table>
<thead>
<tr>
<th>( V_{IN} )</th>
<th>( V_{OUT} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0V</td>
<td>5V</td>
</tr>
<tr>
<td>5V</td>
<td>0V</td>
</tr>
</tbody>
</table>
suppose we use the resistor model of the transistor with $R = 100 \, \Omega$

at $t=0$, we get this:

the cap will go from $5\, V \rightarrow 0\, V$ by discharging through $100\, \Omega$

- time constant $\tau = RC = 100 \cdot 10^{-6} = 100\, \mu s$
Note: when the output went to 5V, the output went to 0V. I said this circuit was an inverter. Is this behavior what we expect?