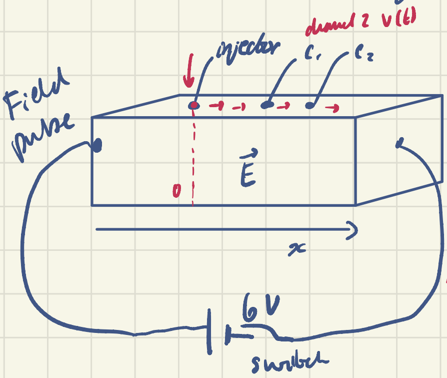
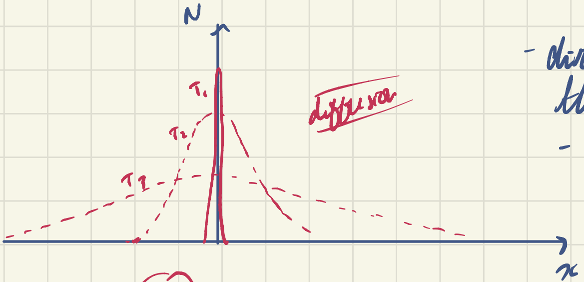
# overview of experiment

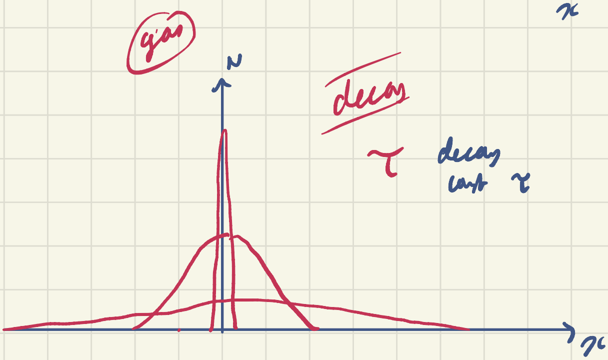



holes = +ive charges

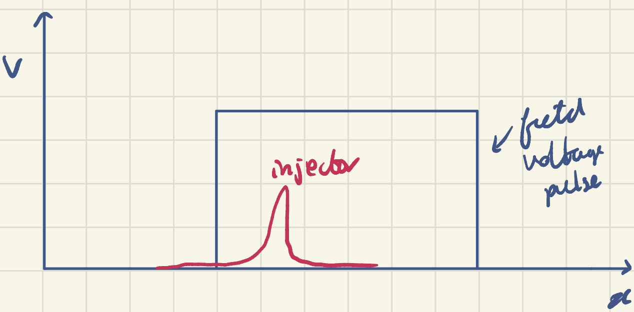
e- = -ive charges




- dirac-δ function of e- where you inject them
- e- behave like gas => diffuse



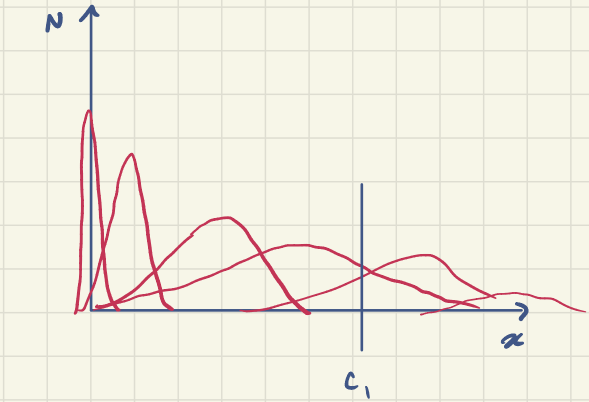

- e- lose at the surface - annihilate with a hole
- vice versa - holes annihilate with e-s
- total pop. decays over time.




when switch is closed -> $\vec{E}$ field created across the semiconductor
$\vec{E}$ field sweeps e- down the crystal
will be able to see a signal at the different contacts.

If left for a while, flowing current will heat up semiconductor
↓
bad + can change conductivity

moving → mobility $\mu$





time-representation of the charges at a specific location

· why does electric field cause drift velocity and not drift acceleration → why doesn't it reach a terminal velocity?

$\frac{dV}{dt}$ = Big for overall voltage

$\Rightarrow$ causes lots of noise / EM radiation which is picked up by $C_1$

- Diffusion
- Decay
- Mobility
- Shape is not quite Gaussian
  ↳ 1D analysis.

# theorician

- responsible for linking underlying physics & physical phenomena to the raw measured quantity
- work closely w/ comp. and analyst.

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# Notes from HS video

- Single crystal rod of Germanium
- Contacts @ both ends - 2 wires touching either end

Minority carriers in semiconductor

↳ - drift
- diffusion
- recombination

③ experiment : - Source, transmitting medium, detector

↓

n type germanium rod

↳ what do we use?

resistivity

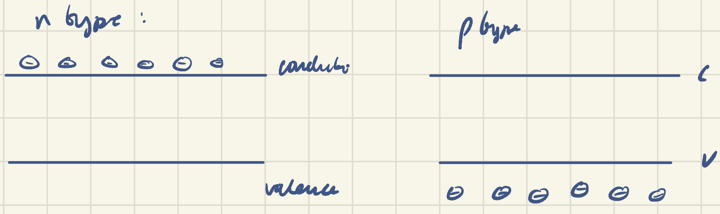
majority :

minority :

carry current in uniform $\vec{E}$

- originally used a flash of light → we use an injection voltage make hole e- pairs

- We use n type → inject holes, causes holes in conduction band, makes e- drop down to valence band → create local region of p-type



- undisturbed field
holes drift towards a detecting electrical contact

measure:
- transit time $t$
- distance $w$

determine:
drift velocity $\frac{w}{t} = v_d = \mu(T)\vec{E}$

mobility

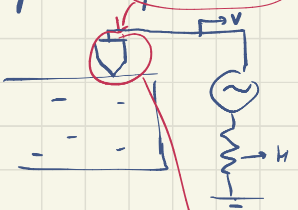
previous: Hall effect to non directly measure $v_d$ of majority charge carriers
HS: focus on motion of pulse of minority holes.

1st show:
disturbance does move along rod

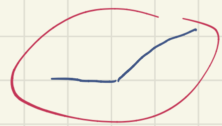
Quantities involved to measure $\mu$:
V, length, time

light focused on germanium bar by optical setup
low resistance contacts
↳ wires make small area contacts

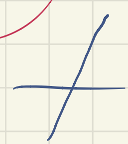
right hand point contact used as detector of minority holes




rectifying voltage-current characteristic



V/I characteristic: for -ve V, current is negligible
reverse polarity
+ve V: relatively large I: easy flow / forward direction



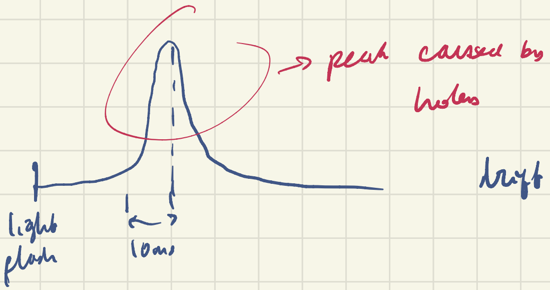
to use as a detector:
- provide reverse bias, use a resistor to show I changes, connect to vertical scope
- if a pulse of minority holes passes underneath (effective +ve charge) they are attracted to the -ve charge contact
    ↳ from -ve applied voltage
- some holes collected, => current momentarily flows causing upwards V on oscilloscope

- use battery to reverse bias RH point
- resistor is chosen for best signal to noise ratio
- 0 of distance scale set at injection / light pulse

holes

measure time for disturbance caused by light pulse to move, under influence of $\vec{E}$ field, down to the detector

↳ they used output of photocell to trigger oscilloscope sweep (NOT for us)




drift time = 30ms

- Remove field
- remove light pulse
- reverse the field direction

} NO PULSE

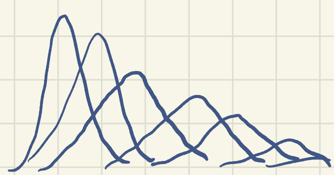
Only when $\vec{E}$ field is directed from source to detector do we see pulse / delayed

From $v_d = \mu(T)E$:

- $v_d$ should ↓ when E ↓

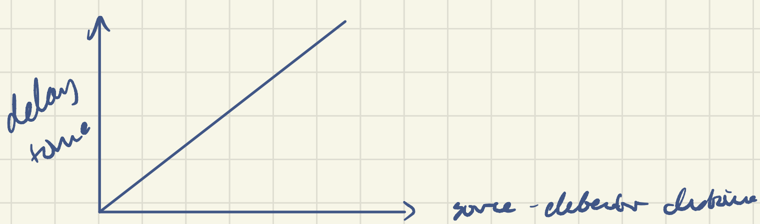
↳ experimental: drift time does increase : as expected when E is decreased.

now measure E in bar by connecting voltmeter
use voltage and distance to find E



delay time $\propto$ (directly) distance from source to detector

↳ ∴ $v_d$ is constant



## experiment ①

shows that minority hole pulse moves like a positive charge with constant drift velocity

## experiment ②

### shape of pulse

as delay time increases, pulse spreads out 

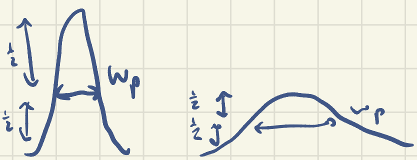
initially:

holes bunched together in narrow pulse

↳ very large concentration gradient

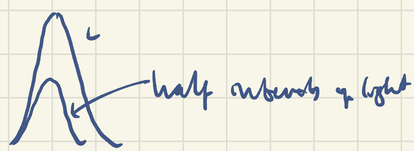
↳ diffusion causes them to rapidly spread out

width at half max. amplitude




$$v_d T_p = w_p$$

$w_p$ depends only on transit time and hole diffusion const.



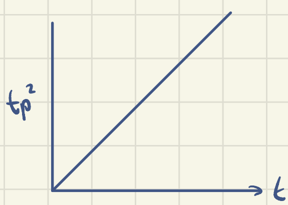

$$w_p^2 \propto Dt$$

must 1st show that hole conc. at detector is proportional to scope deflection $\delta V$

↳ this property is a result of reversed biased detector rectifier

↳ pn junctions ?..

for various $t$, measure $t_p$



the diffusion const. and mobility $\mu$ have values governed by random thermal motion
the importance of thermal motion is expressed by the Einstein relation

$$\frac{D}{\mu} = \frac{kT}{q}$$

$kT$ → random thermal energy
$q$ → electron charge

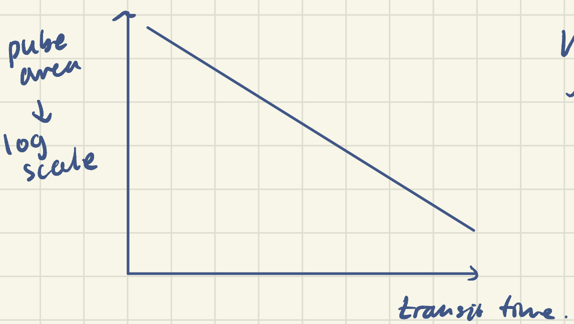
Thermal voltage

$\sim \frac{1}{40}$ V near room temp

## Experiment ③ - Recombination

number of holes not constant
↳ as they drift, holes recombine with e-
total no. of holes represented by area under curve

exponential decay, lifetime $\tau$




no of carriers decreases by $\frac{1}{e}$ in time $\tau$

Similar exps. can be done with p-type germanium → minority e-

if we had used intrinsic material: equal conc. of e- and holes
pulse of e- - hole pairs would not move in $\vec{E}$ field. just spread out by diffusion

in HS minority = v. small minority

when conc. of e- / holes become at all comparable, you must consider the effect of disturbance of $\vec{E}$ field