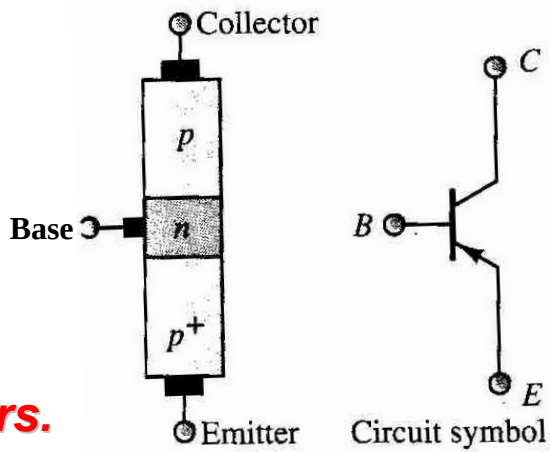
Introduction to Transistors

Bipolar Junction Transistors (BJTs)

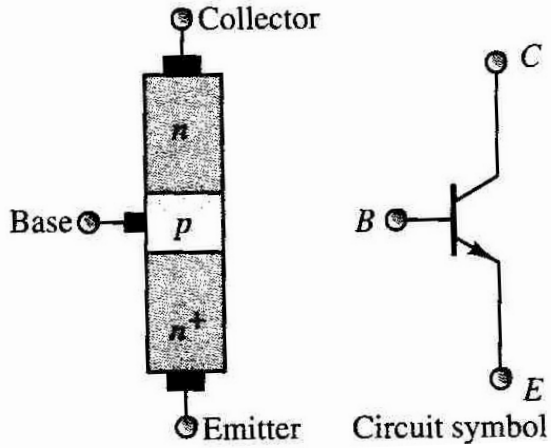
- Transistor = Trans- resistor
- 3-terminal device
- BJTs are made from 3 types of silicon.
- Sort of like back-to-back diodes.

- **BJTs are *current amplifiers.* *Base-Emitter current controls Collector-Emitter current.***

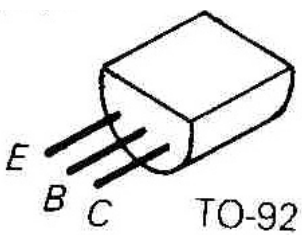
[figure from Rizzoni (1993)]

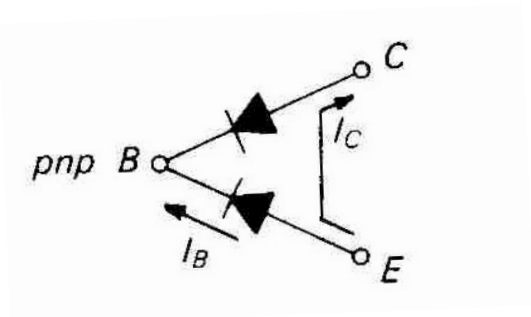


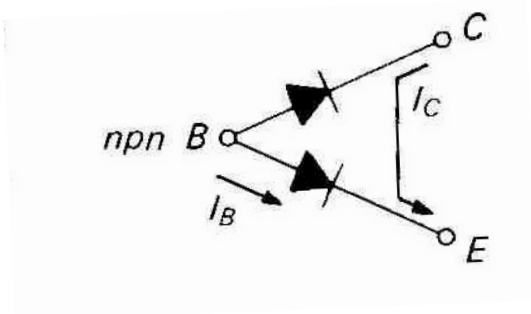
PNP



NPN



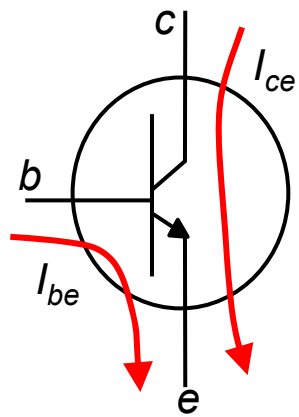




[images from Horowitz and Hill (1999)]

Basic Transistor Model (I)

- Conventional notation
  - Collector-emitter current (I_{ce})
  - Base-emitter current (I_{be})
- In a *npn* transistor
  - Base current flows to the emitter when $V_b > V_e$
  - Collector current flows to the emitter when $V_c > V_e$

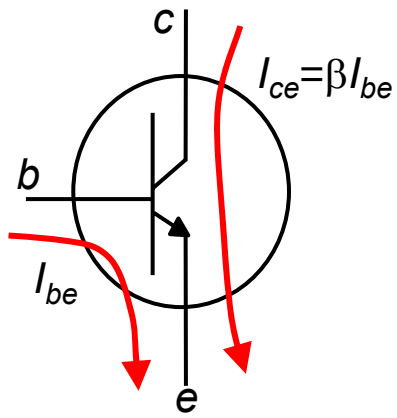


npn transistor

Basic Transistor Model (II)

"transistor rules" for an npn transistor to conduct current:

1. $V_{be} > 0$
   - Since this is a diode, normally $V_{be} \approx 0.6V$
2. $V_{bc} < 0$
   - Since this is a back-biased diode, base current will normally flow to the emitter.
   - If $V_{bc} > 0$ then transistor goes into saturation.
3. Gain
   - $I_{ce} = \beta I_{be}$
   - "β" or h_{fe} is the gain - typical 100 ~ 200
   - **A BJT is a current amplifier**

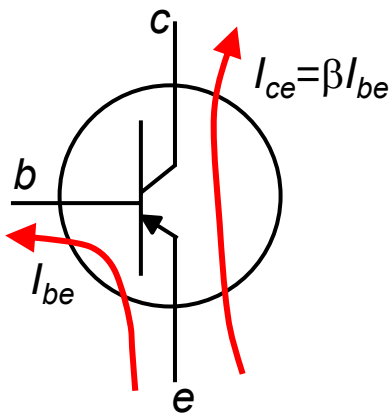


npn transistor

Basic Transistor Model (III)

The **"transistor rules"** are reversed for ***pnp*** transistors*:*

→ The arrow on the emitter indicates the way current is supposed to flow.



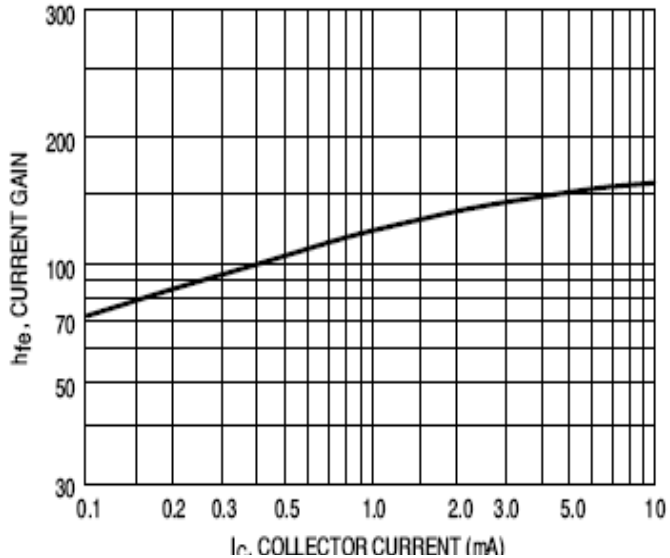
pnp transistor

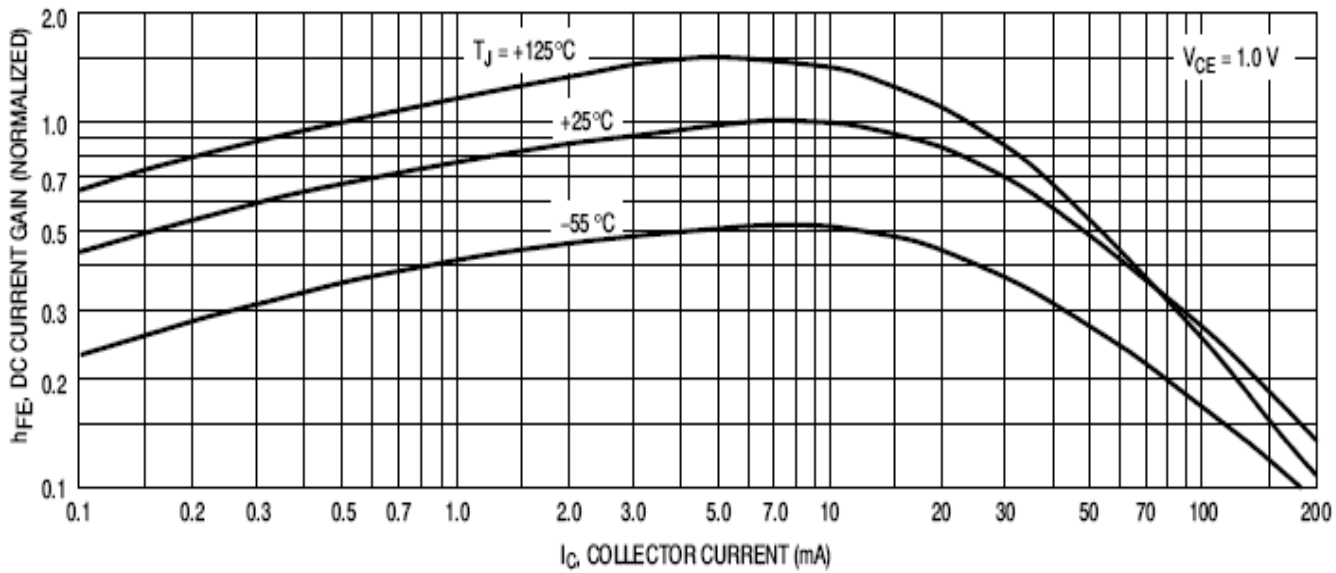
Design Note: Circuit performance should not to depend on β too much !!!

- ***β* is NOT a constant.**
- β depends on current, temperature, etc …
- β varies greatly from device to device

Don't Rely on β (h_{fe})

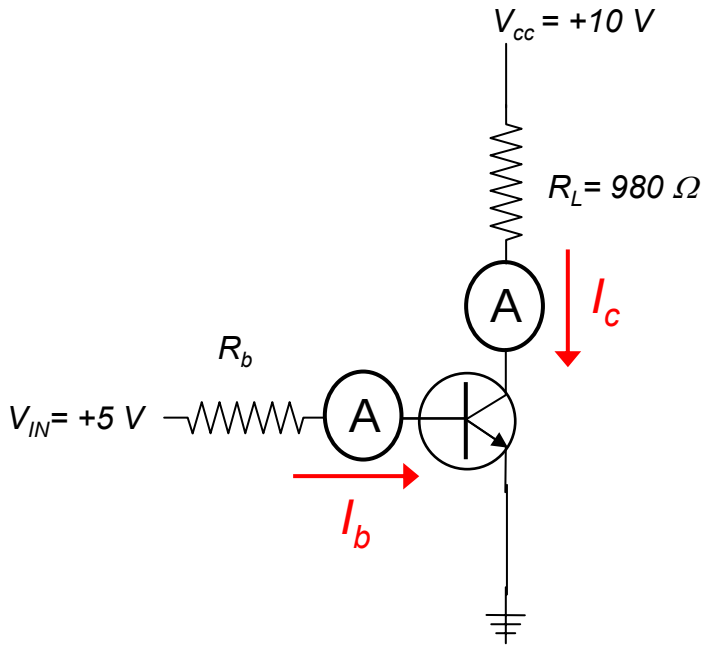
From the 2N3904 NPN BJT spec sheet





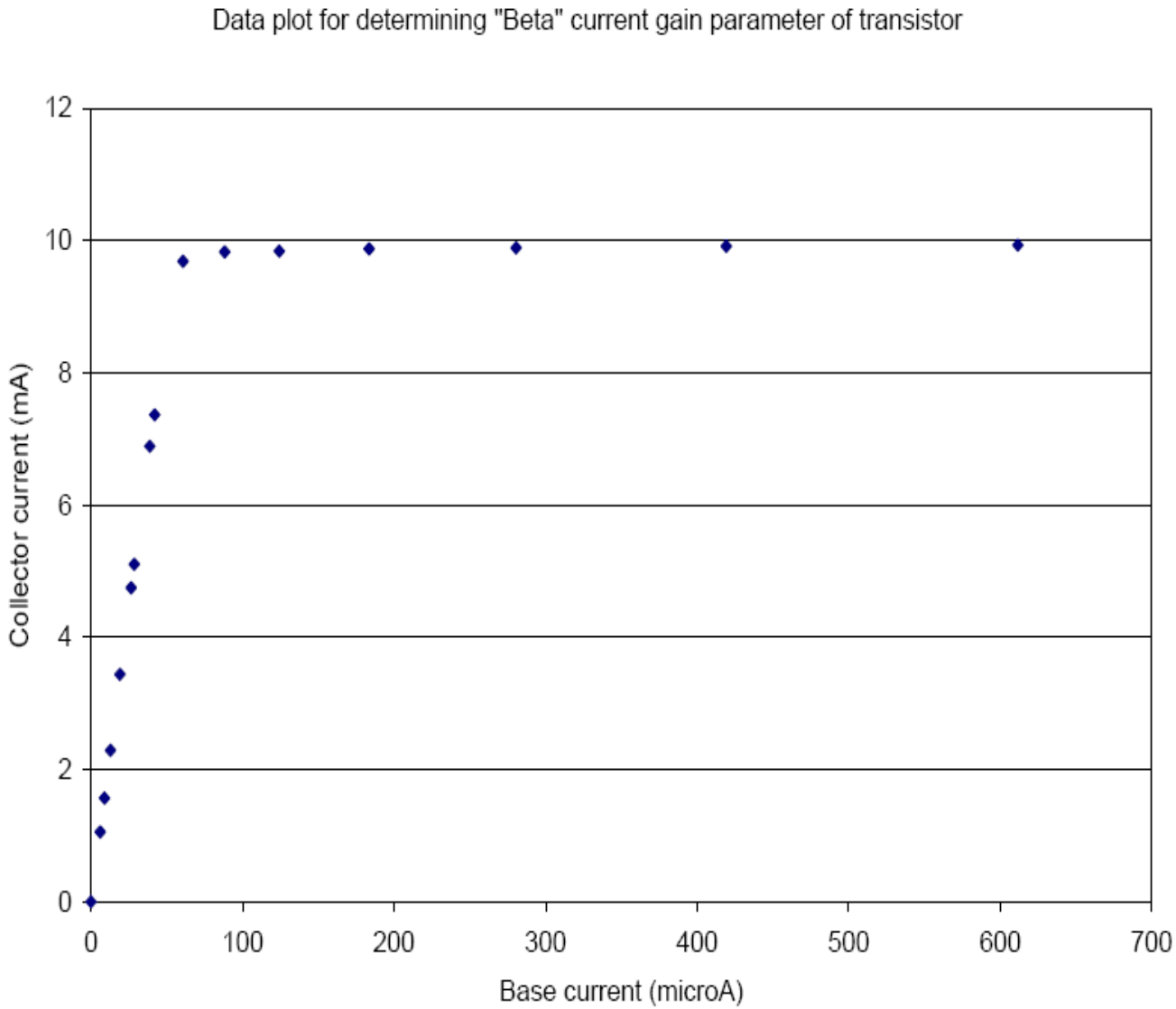
Lab Exercise 6-1

Set-up for Lab Exercise 6-1

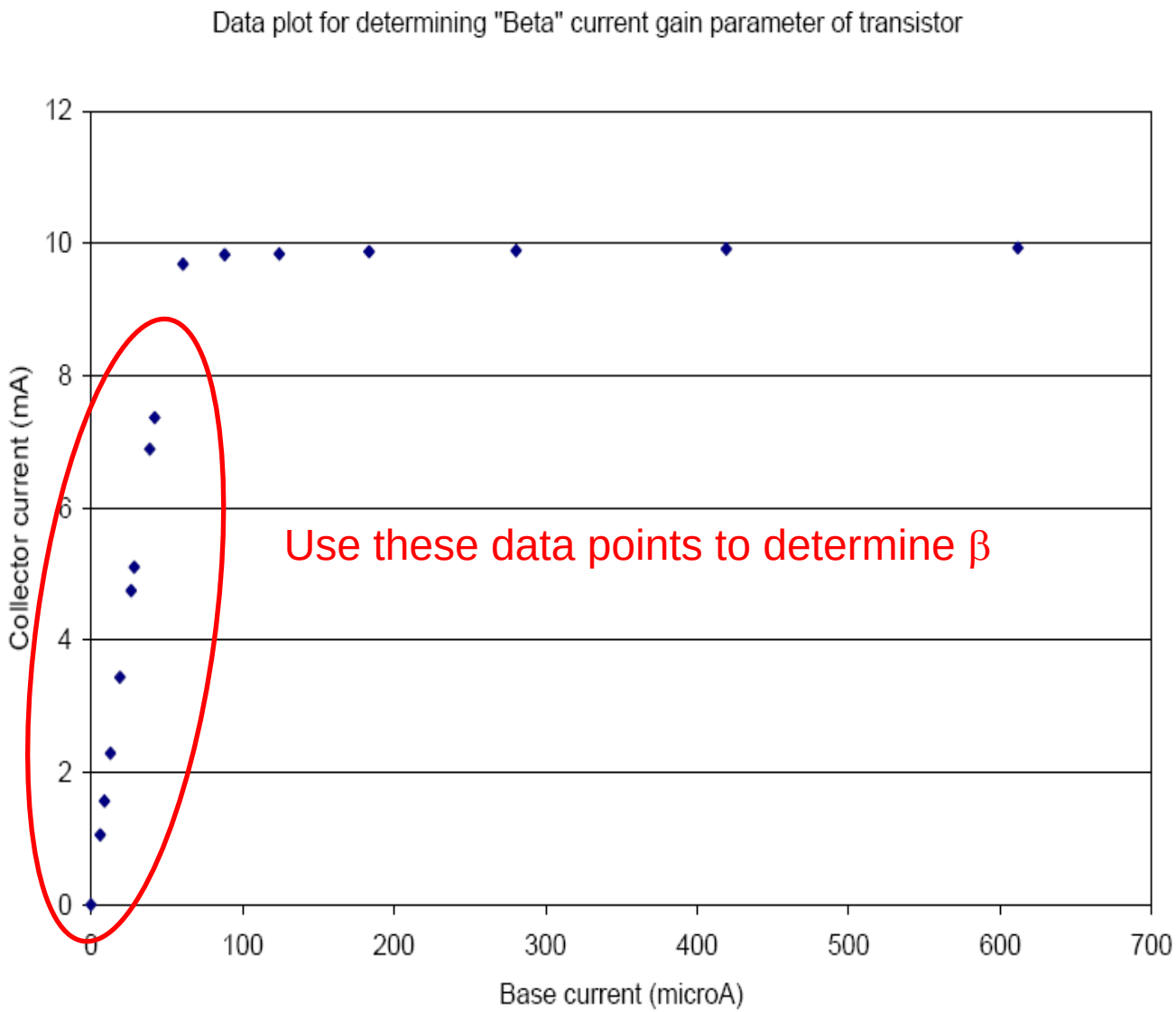


Procedure: vary R_b, measure I_b and I_c

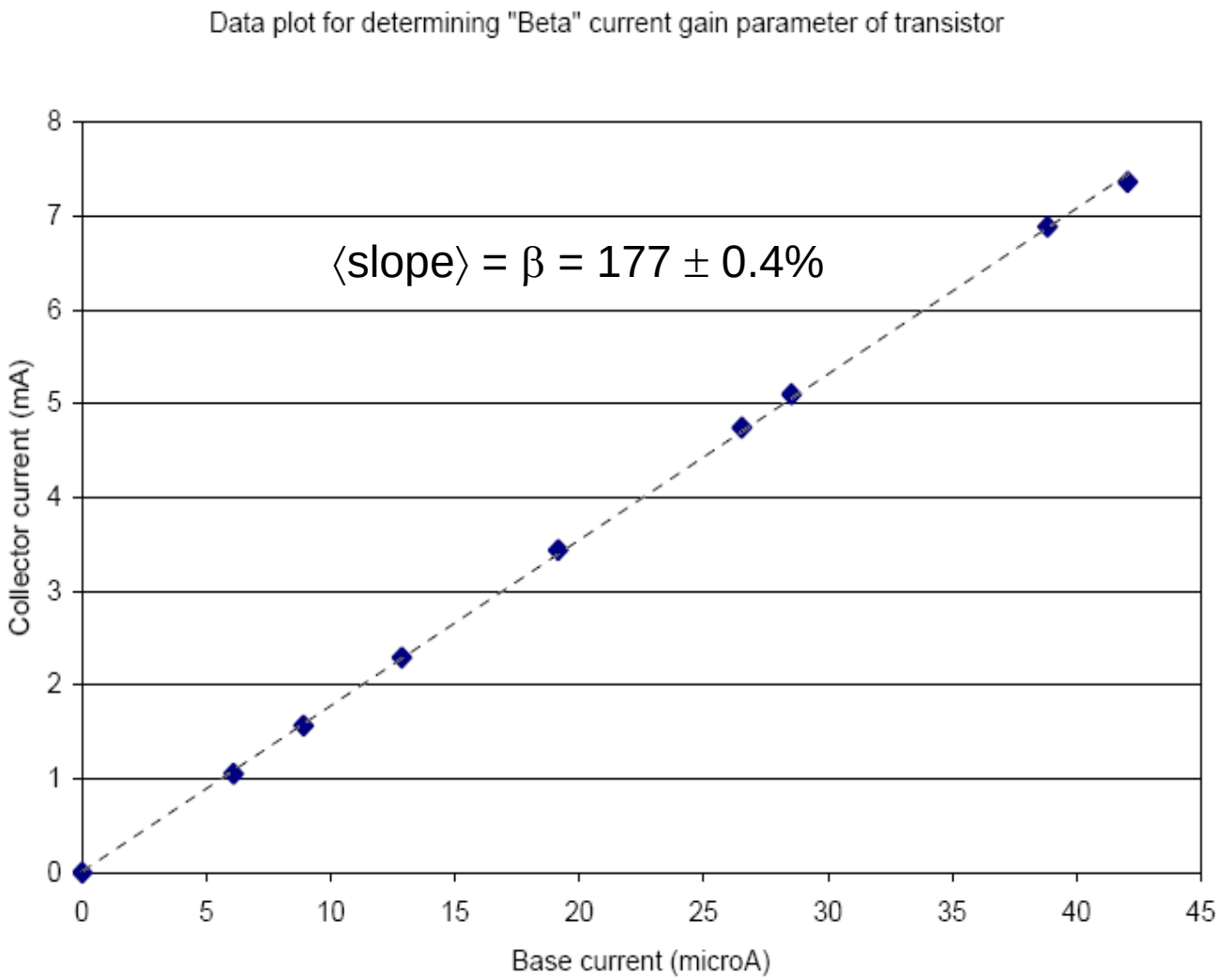
Lab Exercise 6-1



Lab Exercise 6-1



Lab Exercise 6-1



Lab Exercise 6-2

2. (same set-up as lab exercise 1) With the component values you calculated for design exercise 6-1 ~~(appropriately updated for your measured value of β)~~, verify that the circuit is indeed a constant current source by trying different collector/load resistors and measuring the collector current. Verify that the constant current source goes into saturation when you expect it to.

Design a current source based on the set-up of Lab Exercise 6-1.

Assume $\beta = 150$, and determine R_b so that $I_c = 10$ mA.

→ You should be able to determine β roughly by measuring both I_b and I_c. Make sure to measure the voltage across R_L as a cross-check.

→ Does your constant current source go into saturation when you expect it to (based on your estimate of β)?