ECE 205 “Electrical and Electronics Circuits”

Fall 2023 – FINAL REVIEW

MWF – 12:00pm

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2062 ECE Building

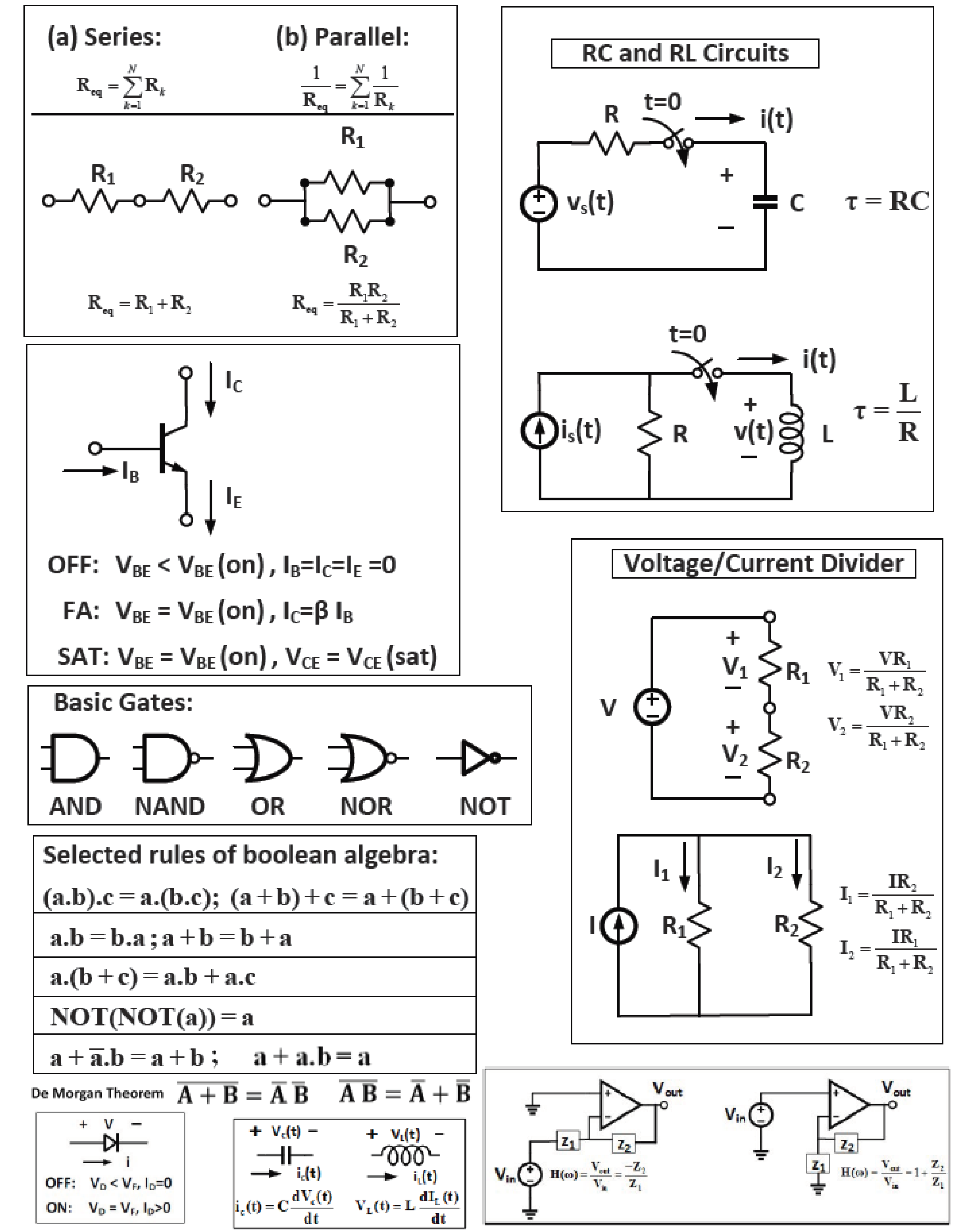
Final Exam

Exam is comprehensive. Duration: 1h 50m.

Expect 10 problems. Topics:

- **Circuit analysis (loop and/or node voltage) (1)**
- **Equivalent circuit (Thevenin and/or Norton) (1)**
- **Circuit analysis using phasors (1)**
- **Transient analysis of RC and/or RL circuit (1)**
- **Circuits with diodes and BJTs (2)**
- **Digital logic (1)**
- **RC Filters (1)**
- **Operational Amplifier with resistors (1)**
- **Operational Amplifier with impedance (1)**

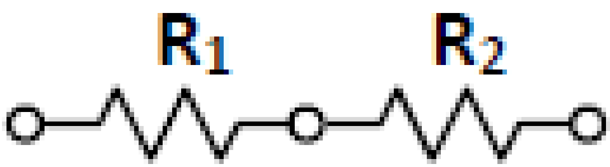
- Help Sheet


(a) Series:
$R_{eq}=\sum_{k=1}^{N}R_k$
(b) Parallel:
$\frac{1}{R_{eq}}=\sum_{k=1}^{N}\frac{1}{R_k}$
R1 R2
$R_{eq}=R_1+R_2$
$R_{eq}=\frac{R_1R_2}{R_1+R_2}$
IC IB IE
OFF: $V_{BE} < V_{BE}(on)$, $I_B=I_C=I_E=0$
FA: $V_{BE} = V_{BE}(on)$, $I_C=\beta I_B$
SAT: $V_{BE} = V_{BE}(on)$, $V_{CE} = V_{CE}(sat)$
Basic Gates:
AND NAND OR NOR NOT
Selected rules of boolean algebra:
(a.b).c = a.(b.c); (a + b) + c = a + (b + c)
a.b = b.a ; a + b = b + a
a.(b + c) = a.b + a.c
NOT(NOT(a)) = a
$a+\bar{a}.b=a+b$; $a+a.b=a$
De Morgan Theorem $\overline{A+B}=\bar{A}\,\bar{B}$ $\overline{AB}=\bar{A}+\bar{B}$
+ V − i
OFF: $V_D < V_F$, $I_D=0$
ON: $V_D = V_F$, $I_D>0$
+ $V_c(t)$ − $i_c(t)$
+ $V_L(t)$ − $i_L(t)$
$i_c(t)=C\frac{dV_c(t)}{dt}$
$V_L(t)=L\frac{dI_L(t)}{dt}$
RC and RL Circuits
R t=0 i(t)
$v_s(t)$ + C −
$\tau = RC$
t=0 i(t)
$i_s(t)$ R + v(t) − L
$\tau=\frac{L}{R}$
Voltage/Current Divider
V + V1 − R1 + V2 − R2
$V_1=\frac{VR_1}{R_1+R_2}$
$V_2=\frac{VR_2}{R_1+R_2}$
I I1 I2 R1 R2
$I_1=\frac{IR_2}{R_1+R_2}$
$I_2=\frac{IR_1}{R_1+R_2}$
Vout Z1 Z2 Vin
$H(\omega)=\frac{V_{out}}{V_{in}}=\frac{-Z_2}{Z_1}$
Vout Vin Z2 Z1
$H(\omega)=\frac{V_{out}}{V_{in}}=1+\frac{Z_2}{Z_1}$

- Help sheet

(a) Series:

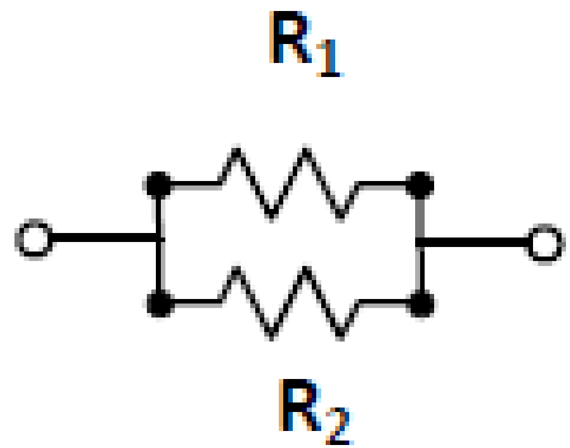
$$R_{eq} = \sum_{k=1}^{N} R_k$$



$$R_{eq} = R_1 + R_2$$

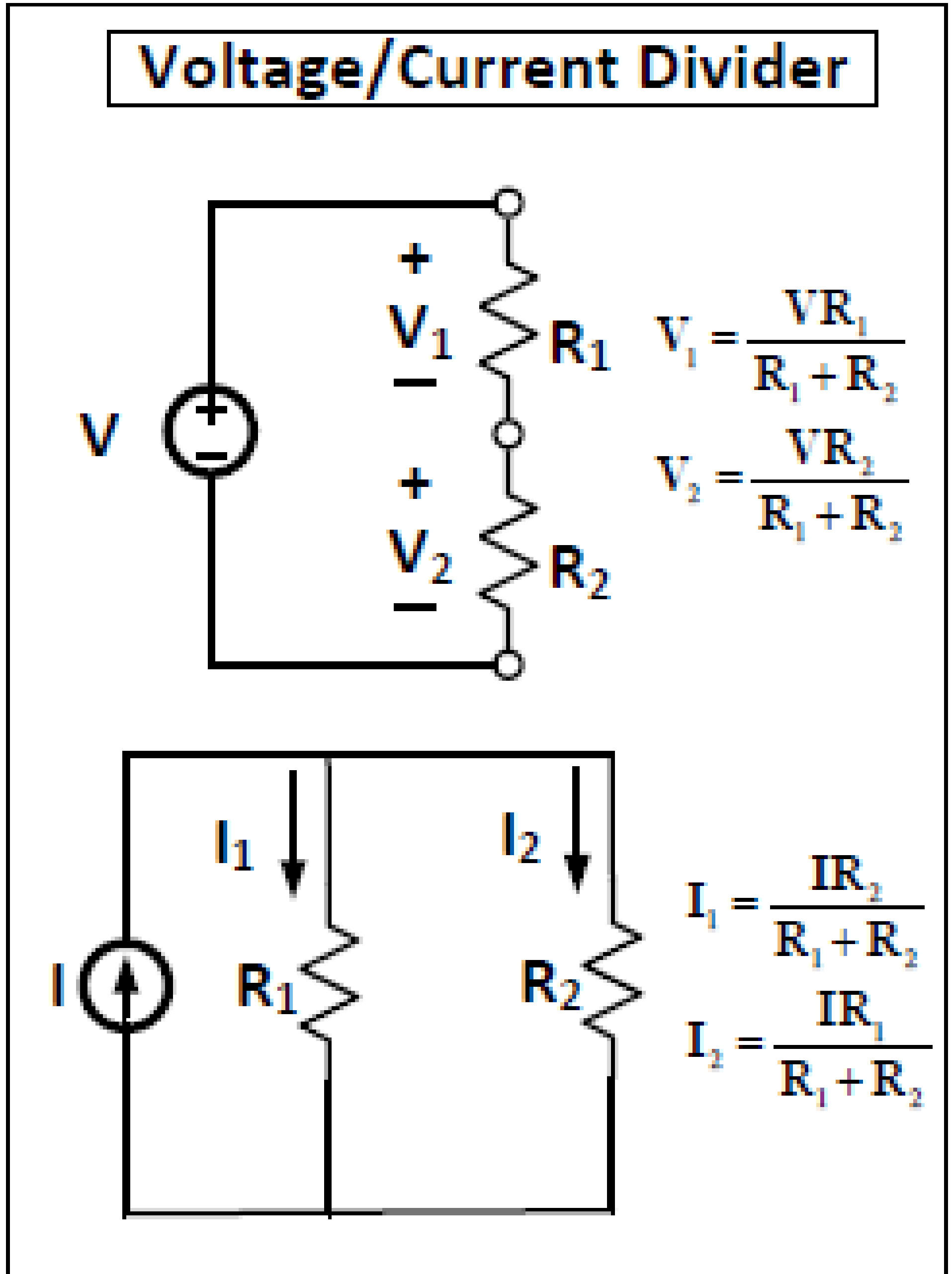
(b) Parallel:

$$\frac{1}{R_{eq}} = \sum_{k=1}^{N} \frac{1}{R_k}$$



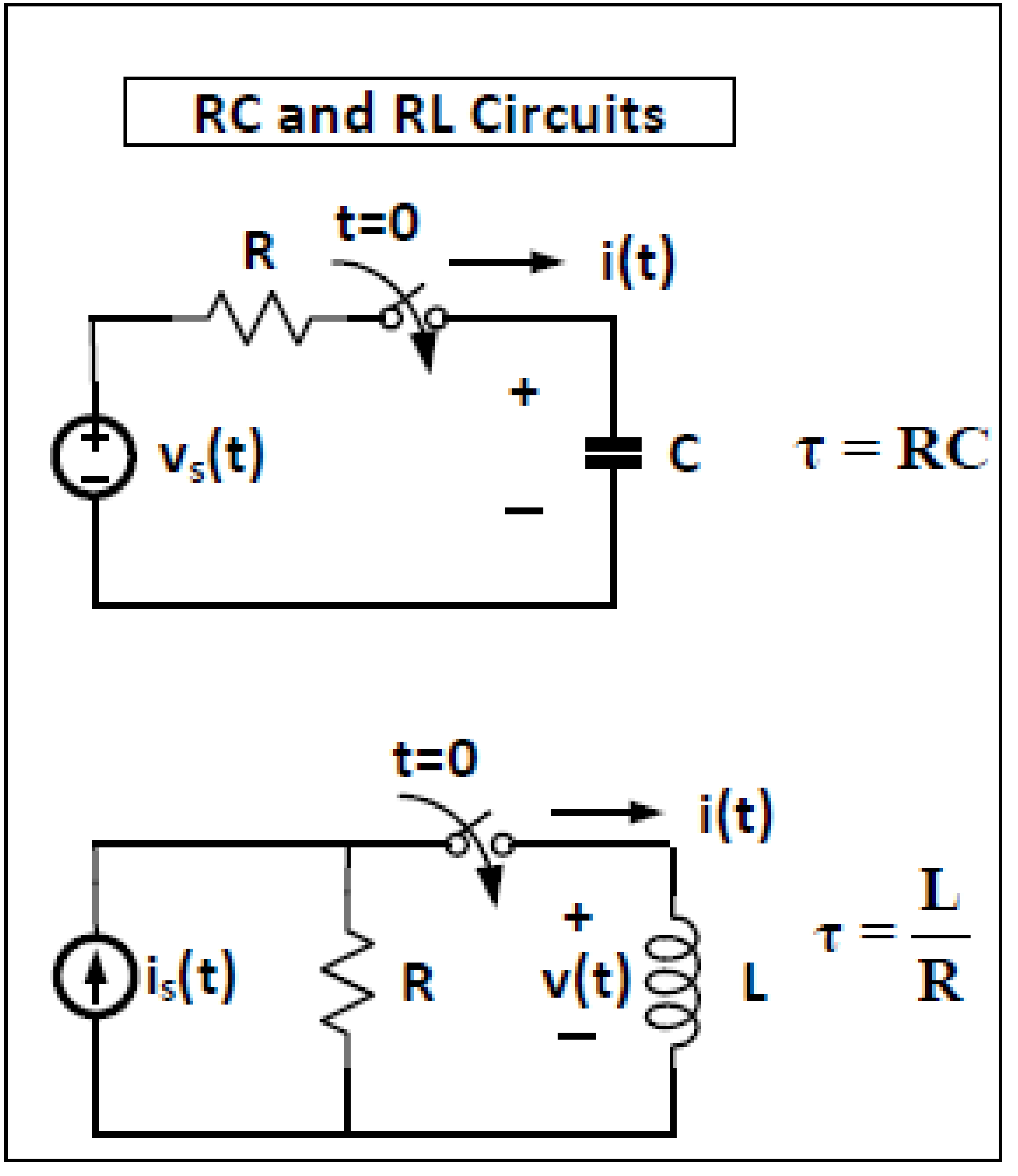
$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

- Help sheet



Voltage/Current Divider
V
+
V_1
−
R_1
+
V_2
−
R_2
$V_1 = \frac{VR_1}{R_1 + R_2}$
$V_2 = \frac{VR_2}{R_1 + R_2}$
I
I_1
I_2
R_1
R_2
$I_1 = \frac{IR_2}{R_1 + R_2}$
$I_2 = \frac{IR_1}{R_1 + R_2}$

- Help sheet



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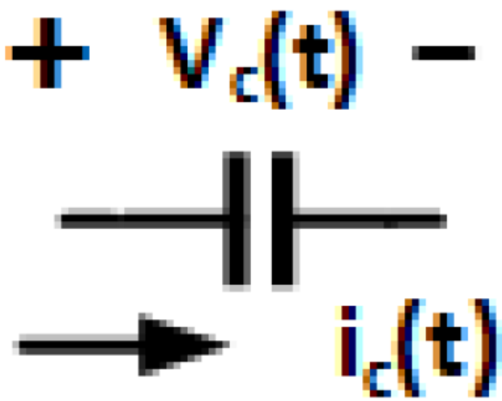
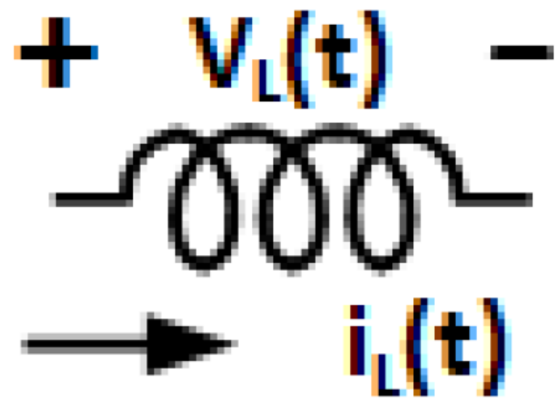
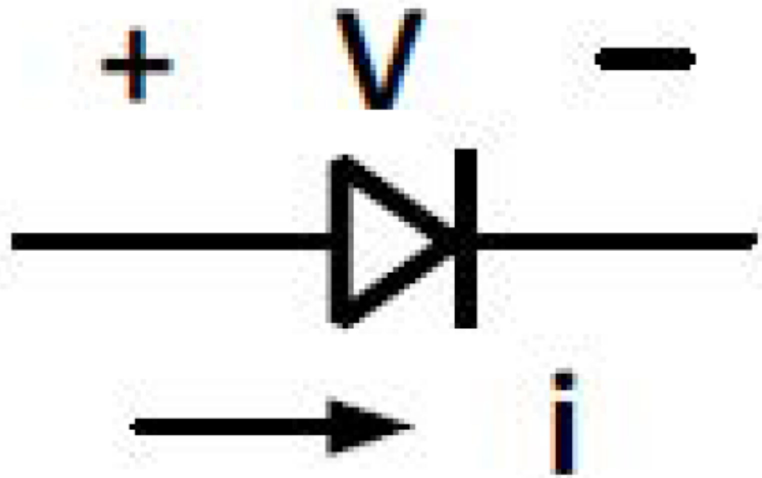




$$i_c(t) = C\frac{dV_c(t)}{dt}$$

$$V_L(t) = L\frac{dI_L(t)}{dt}$$

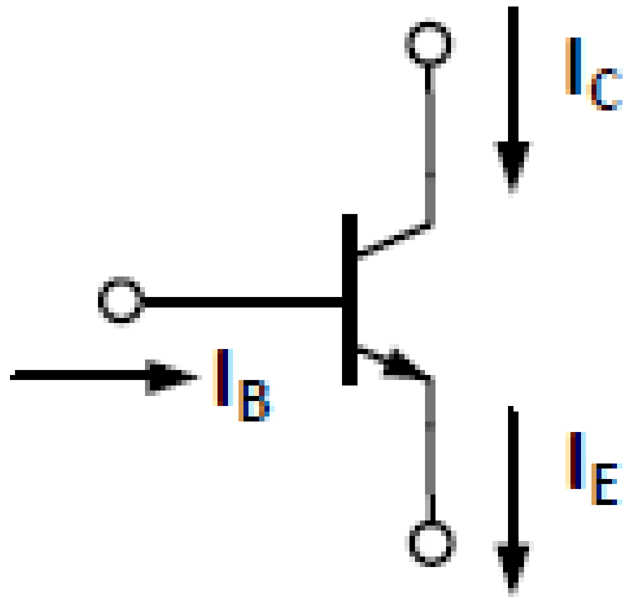
- Formula sheet



OFF: $V_D < V_F, I_D=0$

ON: $V_D = V_F, I_D>0$

- Help sheet

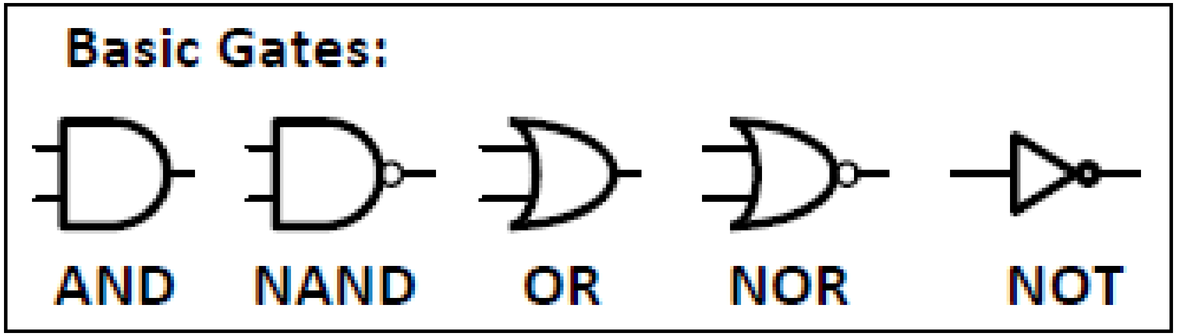


OFF: $V_{BE} < V_{BE}(on)$, $I_B = I_C = I_E = 0$

FA: $V_{BE} = V_{BE}(on)$, $I_C = \beta\, I_B$

SAT: $V_{BE} = V_{BE}(on)$, $V_{CE} = V_{CE}(sat)$

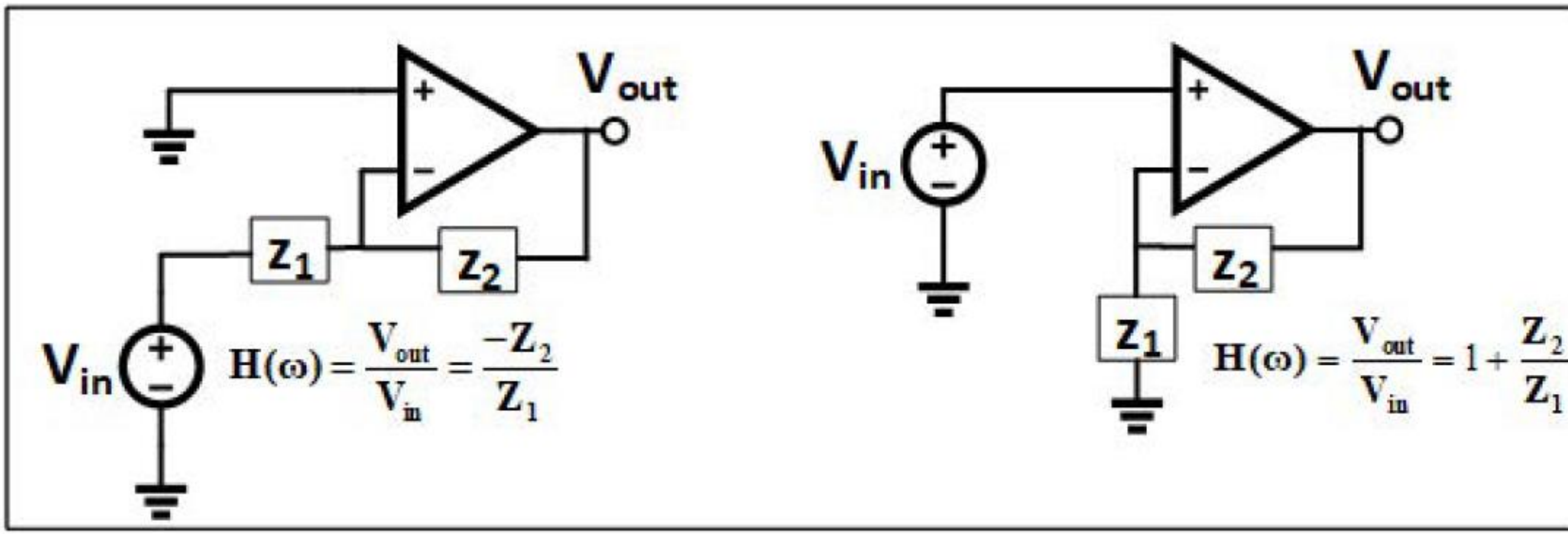
- Help sheet



Selected rules of boolean algebra:
$(a.b).c = a.(b.c); \ (a+b)+c = a+(b+c)$
$a.b = b.a \, ; a+b = b+a$
$a.(b+c) = a.b + a.c$
$\mathrm{NOT}(\mathrm{NOT}(a)) = a$
$a + \overline{a}.b = a + b \, ; \quad a + a.b = a$

De Morgan Theorem $\overline{A+B} = \overline{A}\,\overline{B} \quad \overline{A\,B} = \overline{A} + \overline{B}$

- Help sheet



V out
V in
Z1
Z2
$H(\omega) = \frac{V_{out}}{V_{in}} = \frac{-Z_2}{Z_1}$
V out
V in
Z2
Z1
$H(\omega) = \frac{V_{out}}{V_{in}} = 1 + \frac{Z_2}{Z_1}$

You have plenty of time for the test. Verify your answers by plugging results back into the equations before pushing the "Grade" button.

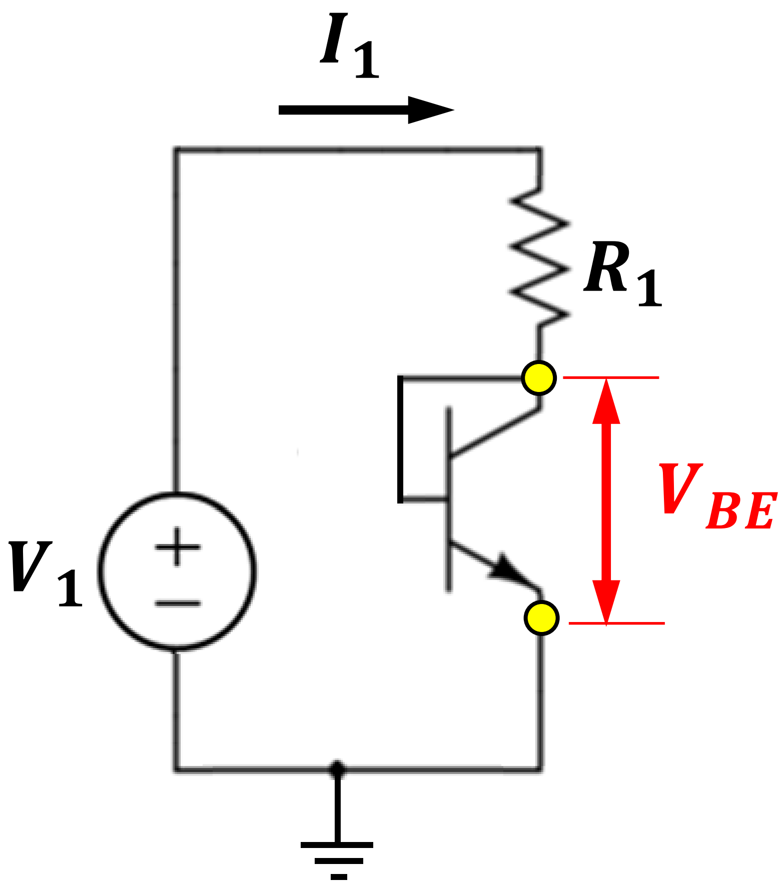
Make sure you read the questions carefully (at least three times). Many of the mistakes you make are due to the fact that you solve a different problem than asked.

As last technical comments, let's revisit a few examples

BJT wired as a diode

$$-V_1 + R_1 I_1 + V_{BE} = 0$$

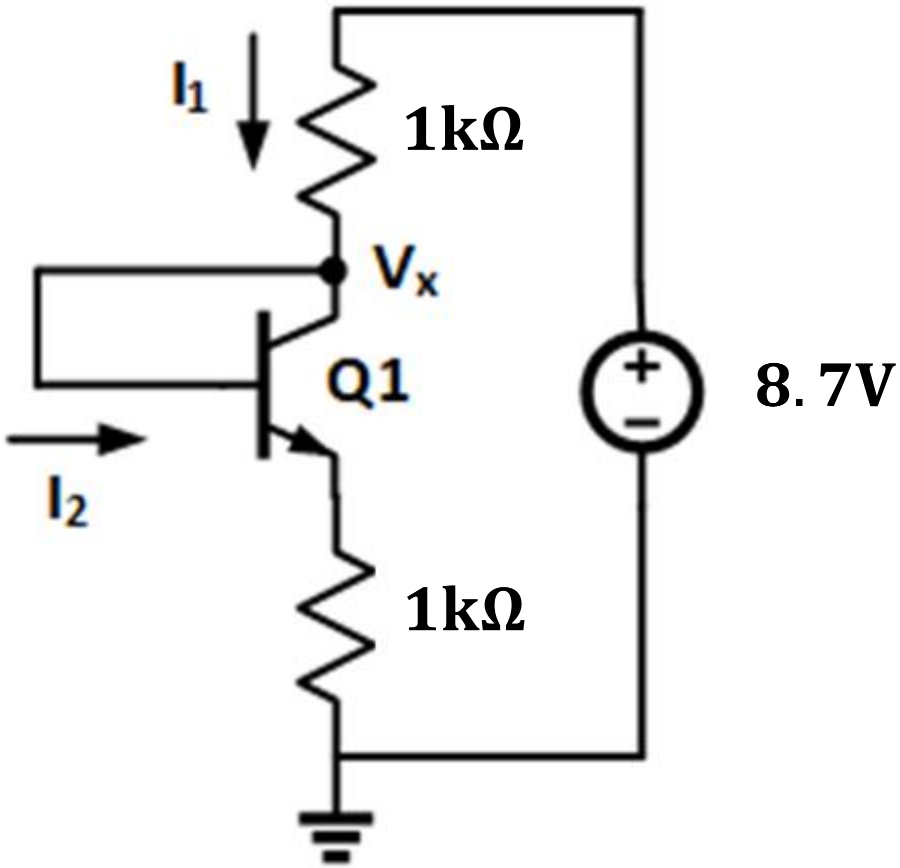
$$I_1 = \frac{V_1 - V_{BE}}{R_1}$$



As long as $V_1 > V_{BE}(\text{on})$, the BJT is in Forward-Active mode.

BJT's wired as in the diagram, are often adopted in integrated circuits, to obtain ultra-low leakage diodes and for design of circuits which are temperature compensating.

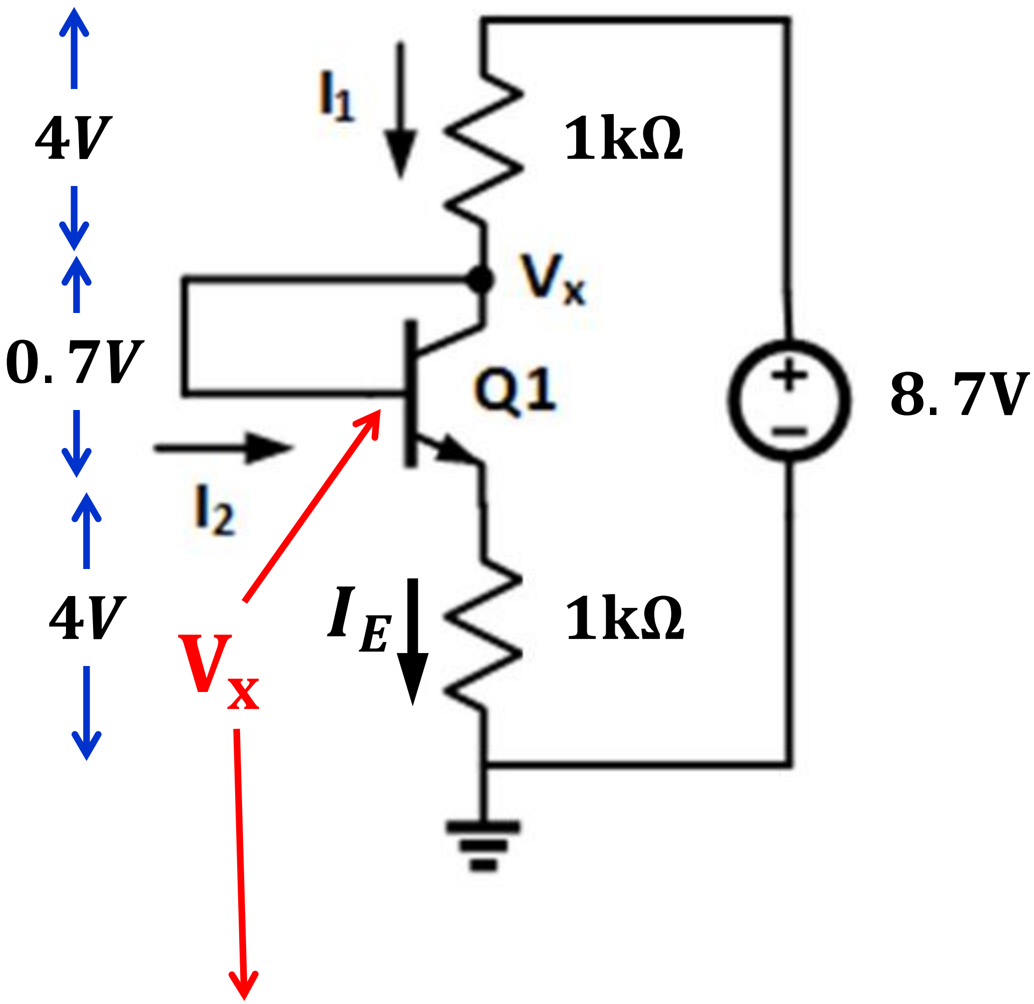
$$\beta = 100$$
$$V_{BE}(on) = 0.7\text{V}$$
$$V_{CE}(sat) = 0.2\text{V}$$



$\beta = 100$

$V_{BE}(on) = 0.7V$

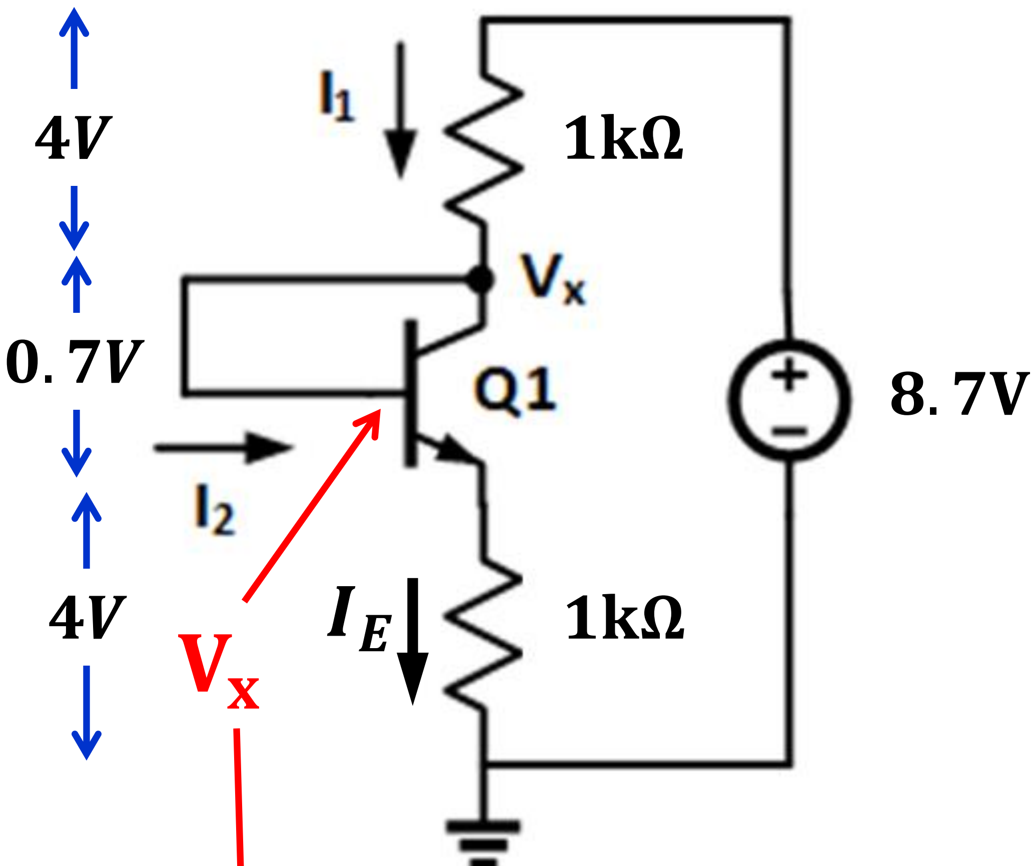
$V_{CE}(sat) = 0.2V$



Assume: BJT ON

$$V_{BE} = V_{CE} = 0.7V$$

$$V_x = V_{CE} + 4V = 4.7V$$



$\beta = 100$

$V_{BE}(on) = 0.7\text{V}$

$V_{CE}(sat) = 0.2\text{V}$

Assume: BJT ON

$$I_1 = I_C + I_2 = I_C + I_B$$

$$I_1 = I_E$$

$$I_1 = 1k\Omega \times 4\text{V} = 4\text{mA}$$

$$I_E = 1k\Omega \times 4\text{V} = 4\text{mA}$$

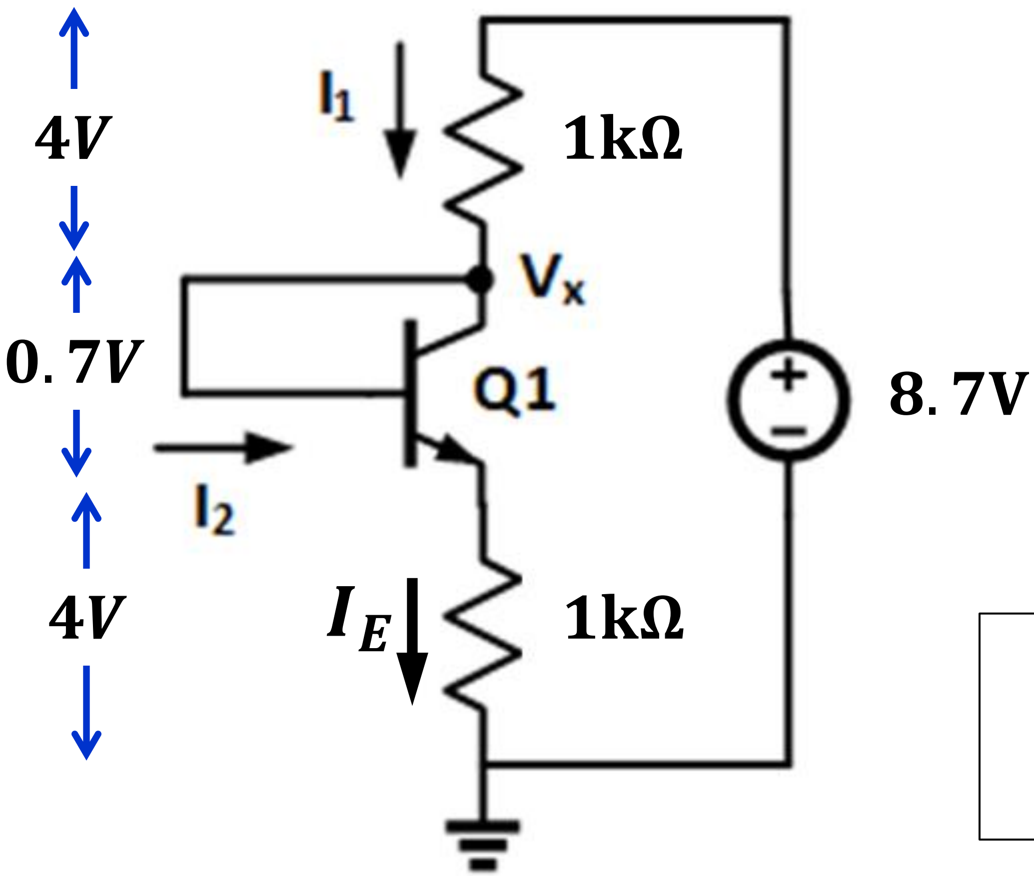
$$V_{BE} = V_{CE} = 0.7V$$

$$\text{V}_\text{x} = V_{CE} + 4V = 4.7V$$

$\beta = 100$

$V_{BE}(on) = 0.7\text{V}$

$V_{CE}(sat) = 0.2\text{V}$



$$I_1 = I_E = 4\text{mA}$$

$$V_{CE} = 0.7V$$

What are I_B and I_C?

$$V_{CE} > V_{CE}(\text{sat})$$

Forward-Active Mode

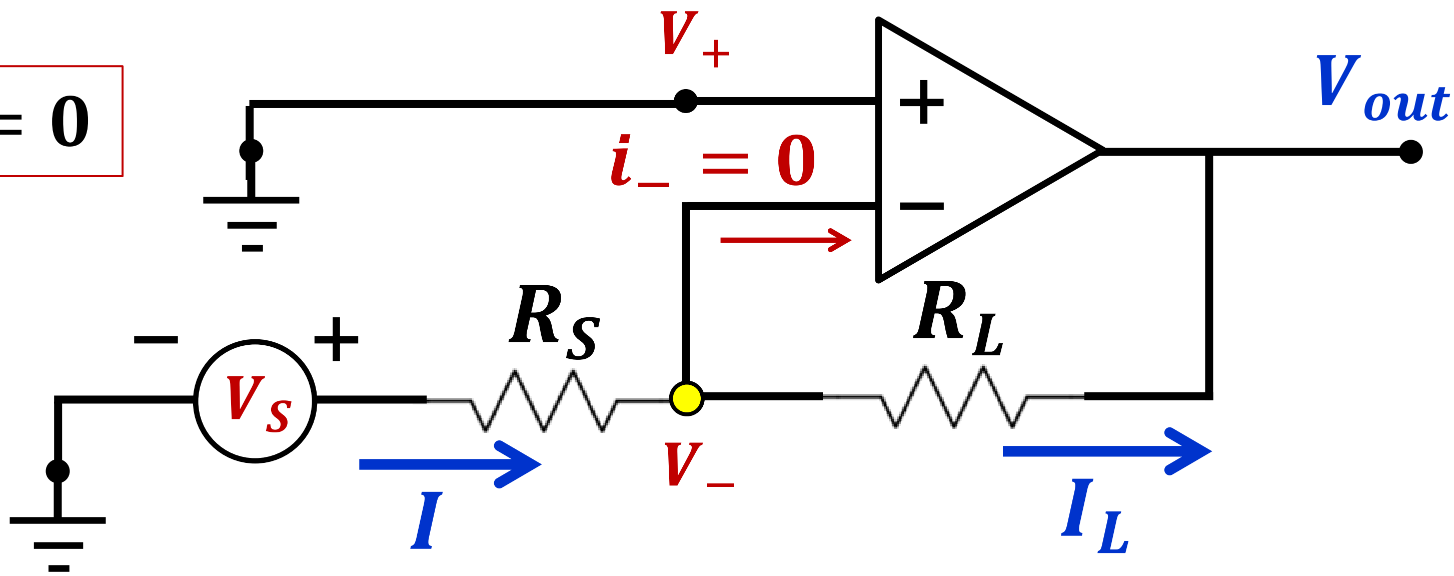
$$I_E = I_B + I_C = I_B + \beta I_B = 101 I_B$$

$$I_B = 4\text{m}/101 = 39.6\mu\text{A}$$

$$I_C = 100 I_B = 3.96\text{mA}$$

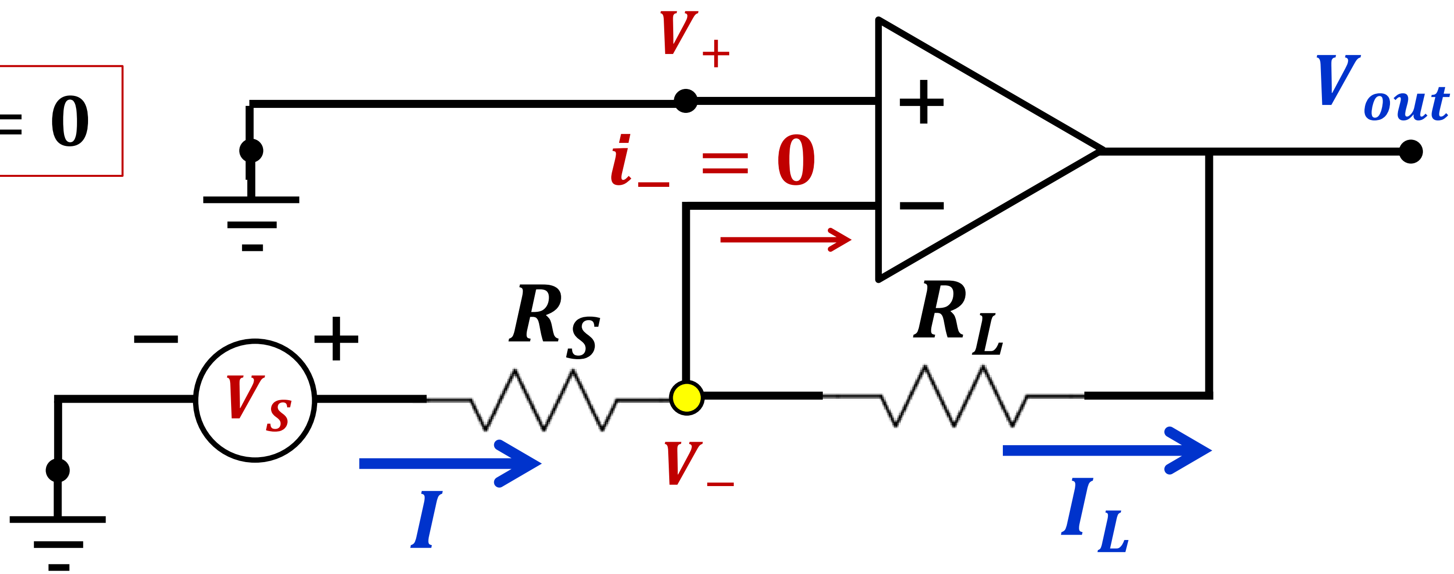
OP AMP Current Source

$$V_+ = V_- = 0$$



OP AMP Current Source

$$V_+ = V_- = 0$$

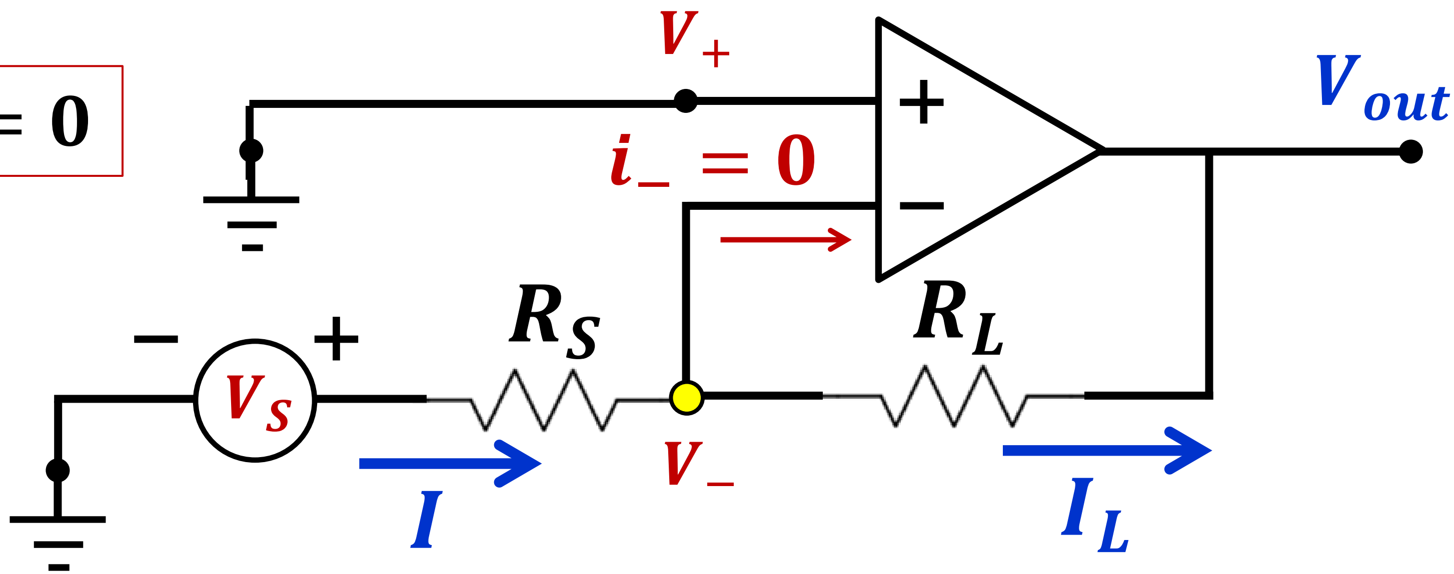


$$I = \underbrace{i_-}_{=0} + I_L = I_L$$

$$I_L = \frac{V_S - V_-}{R_S} = \frac{V_S}{R_S}$$

OP AMP Current Source

$$V_+ = V_- = 0$$



$$I = \overbrace{i_-}^{=0} + I_L = I_L$$

$$I_L = \frac{V_S - V_-}{R_S} = \frac{V_S}{R_S}$$

Example: $V_S = 1\text{V};\ R_S = 1\text{k}\Omega$

$$\Rightarrow \quad I_L = \frac{1 - 0}{1\text{k}\Omega} = 1\text{mA}$$

Independent of R_L

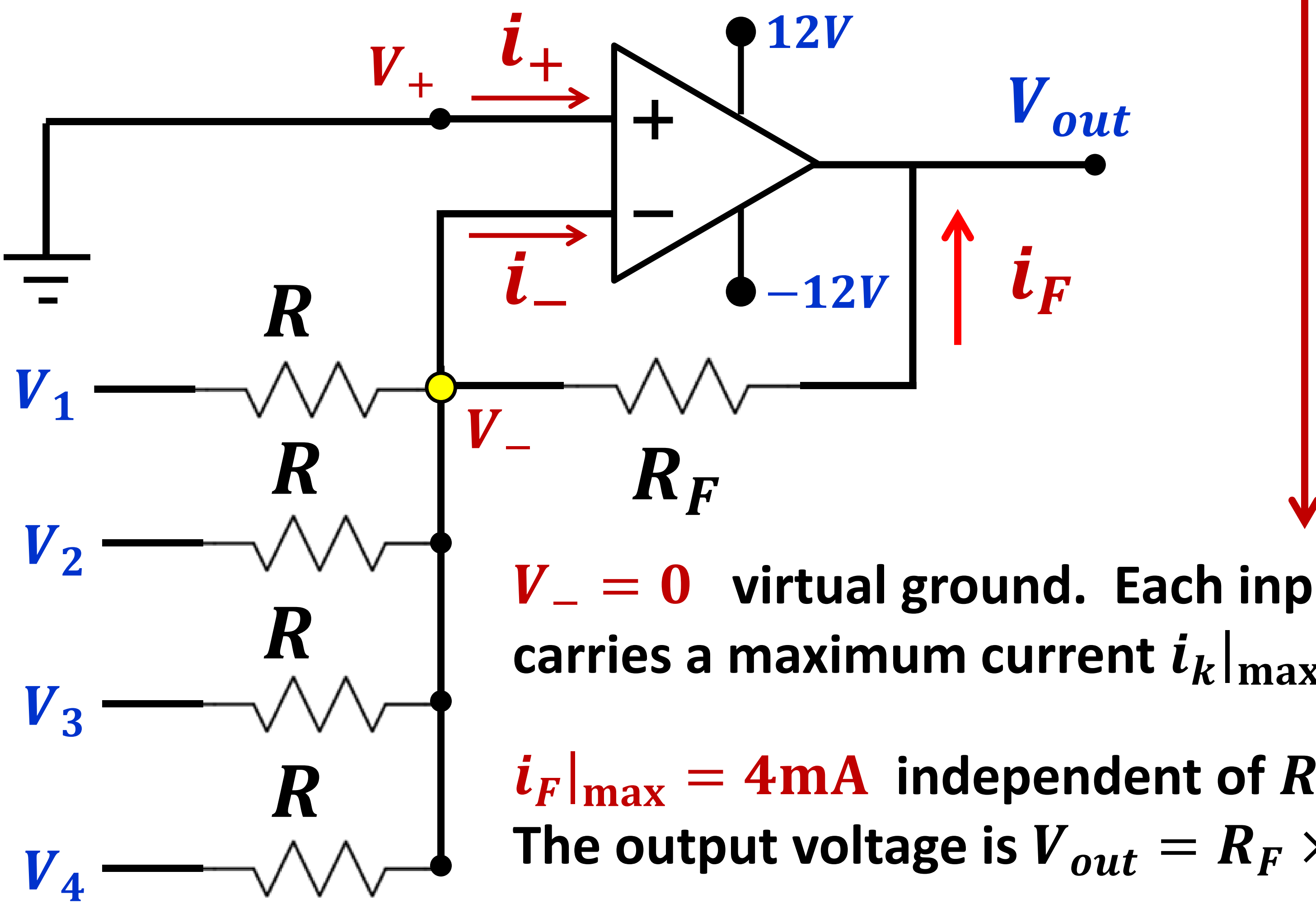
Example – Four equal resistors in input

$V_+ = V_- = 0$

$i_+ = i_- = 0$

$R = 1\text{k}\Omega$

$V_i\big|_{\max} = 1\text{V}$



$V_- = 0$ virtual ground. Each input resistor carries a maximum current $i_k|_{\max} = 1\text{mA}$

$i_F|_{\max} = 4\text{mA}$ independent of R_F.

The output voltage is $V_{out} = R_F \times i_F|_{\max}$

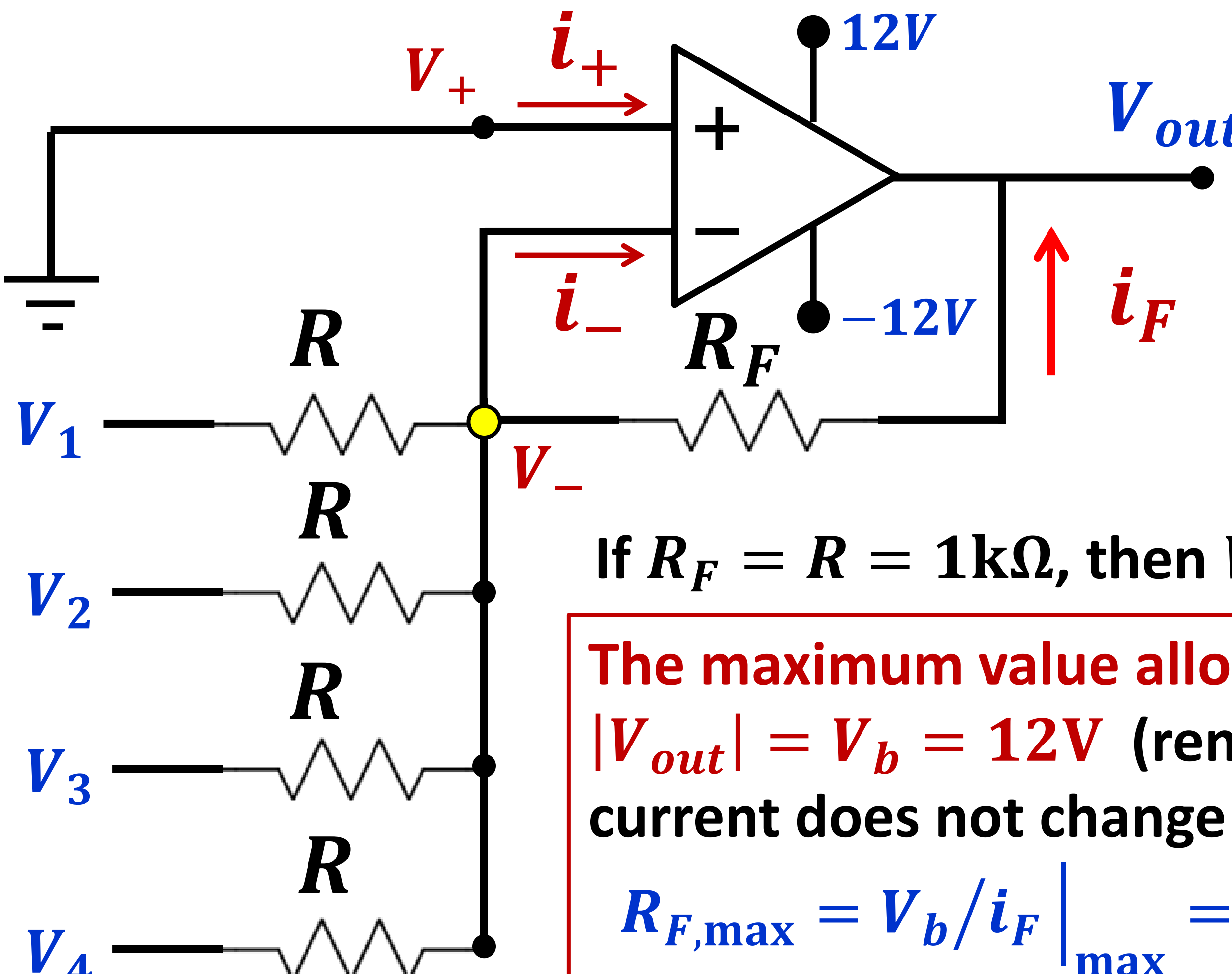
Example – Equal input resistors

$V_+ = V_- = 0$

$i_+ = i_- = 0$

$R = 1\text{k}\Omega$

$V_i\big|_{\max} = 1\text{V}$



If $R_F = R = 1\text{k}\Omega$, then $V_{out} = 4\text{V}$ at most.

The maximum value allowed for R_F is when $|V_{out}| = V_b = 12\text{V}$ (remember, the input current does not change with R_F)

$$R_{F,\max} = V_b / i_F\big|_{\max} = 12\text{V}/4\text{mA} = 3\text{k}\Omega$$

ICES Survey Online

There is still time to complete the course evaluation

go.illinois.edu/ices-online

or you can use the link sent to you by email.

The survey closes soon.

QUESTIONS