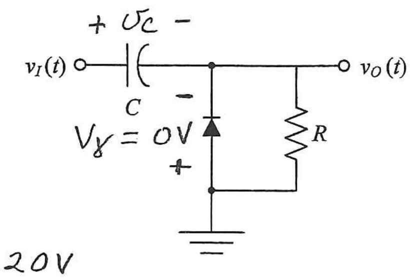
ECE 3200
Test 2
Solutions

A) The parameters of the diode in the circuit below are $V_\gamma = 0$ and $r_f = 0$. The input voltage $v_I(t) = 20 \sin[2\pi(60)t]$ V, and the capacitor is uncharged at $t = 0$. Which of the following is closest to the maximum value of $v_O(t)$ after the capacitor becomes fully charged?

a: 40 V
b: 30 V
c: 20 V
d: 10 V
e: 0 V

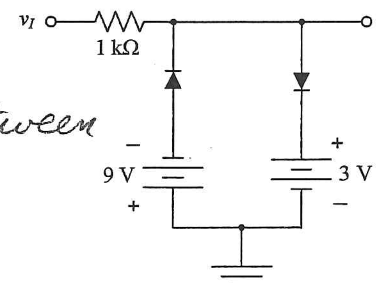
(Clamper circuit)
Capacitor charges fully when $v_I(t) = -20V$
$\Rightarrow v_c = -20V$ (max)
$\Rightarrow v_O(t)(max) = v_I(t)(max) + 20V$
$= 20V + 20V = 40V$



B) The parameters of the diodes in the circuit below are $V_\gamma = 0.7$ V and $r_f = 0$. Which of the following are possible values of the output voltage v_O?

a: 8 V
b: 6 V
c: Both a and b
d: −10 V
e: None of the above

(Parallel-based clipper)
v_O must stay between $-9V - V_\gamma = -9.7V$
and $3V + V_\gamma = 3.7V$



C) Which of the following is used to shift the dc level of a signal voltage without modifying the shape of the signal's waveform?

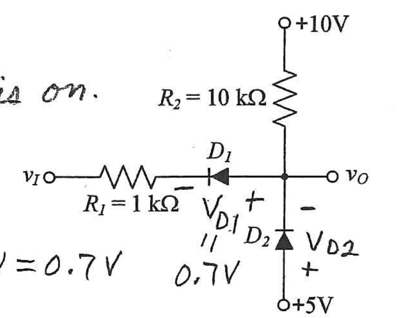
a: Clipper
b: Rectifier
c: Clamper
d: Passive limiter
e: Voltage doubler

See text sec. 2.3.2

D) The parameters of the diodes in the circuit below are $V_\gamma = 0.7$ V and $r_f = 0$. Which of the following is closest to the value of the output voltage v_O when $v_I = 0$ V?

a: 6.0 V
b: 4.5 V
c: 3.0 V
d: 1.5 V
e: 0 V

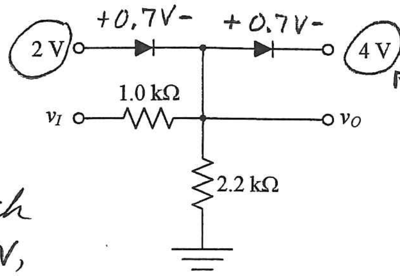
Assume D2 is off.
$10V - v_I = 10V \geq V_\gamma \Rightarrow$ D1 is on.
$\Rightarrow V_{D1} = V_\gamma = 0.7V$
$\Rightarrow v_O = (9.3V)\left(\frac{1k\Omega}{11k\Omega}\right) + 0.7V \cong 1.55V$
$\Rightarrow V_{D2} \cong 5V - 1.55V = 3.45V > V_\gamma = 0.7V$
$\Rightarrow$ D2 is ON $\Rightarrow V_{D2} = 0.7V \Rightarrow v_O = 5V - 0.7V = 4.3V$



E) The parameters of the diodes in the circuit below are $V_\gamma = 0.7$ V and $r_f = 0$. Which of the following conditions is impossible for this circuit?

a: Both diodes are off.
b: Both diodes are on.
c: One diode is on and the other is off.
d: The output voltage is positive.
e: Current flows through both resistors.

Note



Note

If both diodes were on, each would have a drop of $V_\gamma = 0.7V$, but $2V - 4V \neq 2(0.7V) = 1.4V$

F) The base-collector junction of a bipolar transistor is reverse biased. Which of the following must be true?

a: The transistor is in the forward-active mode.
b: The transistor is in either the forward-active mode or cutoff.
c: The transistor is in the saturation mode.
d: The transistor is in either the forward-active mode or saturation.
e: None of the above

Forward-active mode: B-E is forward biased, B-C is reverse biased

Cutoff: Both junctions reverse biased

G) A bipolar junction transistor has an Early voltage of 80 V. Its collector current is 0.60 mA when $V_{CE} = 2$ V for a certain base current. If its base current remains constant, which of the following is closest to the value of the transistor's collector current when $V_{CE} = 5$ V?

a: 0.618 mA
b: 0.622 mA
c: 0.626 mA
d: 0.630 mA
e: 0.634 mA

$$r_o = \frac{V_A}{I_{CQ}} = \frac{80V}{0.60mA} \cong 133.3\ k\Omega$$

$$\Delta I_c = \frac{\Delta V_{CE}}{r_o} \cong \frac{(5V-2V)}{133.3\ k\Omega} \cong 0.0225\ mA$$

$$\Rightarrow I_c(new) \cong 0.60mA + 0.0225mA = 0.6225\ mA$$

H) The common-base current gain of a bipolar junction transistor is equal to 0.993. If the base current is 10 μA and the transistor is in saturation, which of the following is a possible value of the collector current?

a: 1.0 mA
b: 1.5 mA
c: 2.0 mA
d: Both b and c
e: None of the above

$$\alpha = 0.993$$

$$\beta = \frac{\alpha}{1-\alpha} = \frac{0.993}{1-0.993} \cong 141.86$$

In saturation, $I_c < \beta I_B$

$$\Rightarrow I_c < (141.86)(0.010mA) \cong 1.42\ mA$$

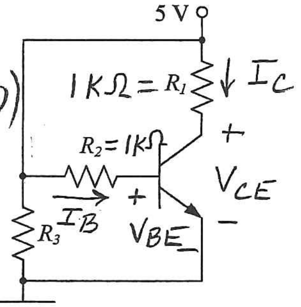
I) An npn transistor having $\beta = 120$ has an open-emitter breakdown voltage BV_{CBO} of 200 V. If the empirical constant is $n = 3$, which of the following is closest to the open-base breakdown voltage BV_{CEO}?

a: 50 V
b: 40 V
c: 30 V
d: 20 V
e: 10 V

$$BV_{CEO} = \frac{BV_{CBO}}{\sqrt[n]{\beta}}$$

$$= \frac{200V}{\sqrt[3]{120}} \cong 40.5V$$

J) In the circuit shown below, all resistors have values of 1 kΩ, and $\beta = 90$ for the transistor. Which of the following is closest to the value of the collector current?



a: 25 mA
b: 20 mA
c: 15 mA
d: 10 mA
e: 5 mA

Maximum possible I_C flows in saturation (when $V_{CE} = V_{CE}(sat)$)

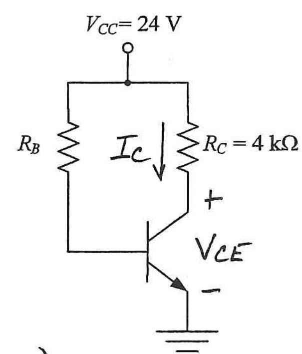
$\Rightarrow I_C(max) = \frac{5V - 0.2V}{1K\Omega} = 4.8\,mA$

(It is impossible for I_C to be larger)

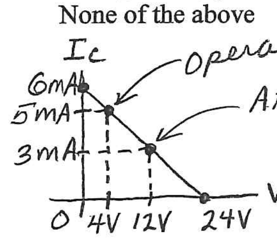
Check: $I_B = \frac{5V - 0.7V}{1K\Omega} = 4.3\,mA$

$\beta I_B = (90)(4.3mA) = 387mA \Rightarrow I_C < \beta I_B$ ✓ (Saturation)

K) The collector current for the transistor in the circuit below is 5 mA. Which of the following describes the transistor's operating point?



a: The operating point is in the saturation region.
b: The operating point is above the center of the load line.
c: The operating point is at the center of the load line.
d: The operating point is below the center of the load line.
e: None of the above



operating point

At center of load line,

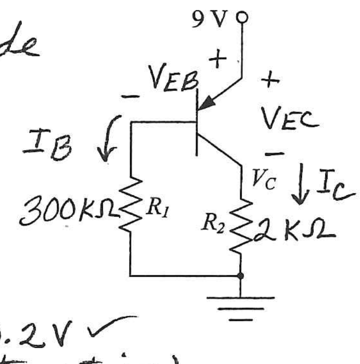
$I_C = \frac{V_{CC}}{2R_C} = \frac{24V}{2(4K\Omega)} = 3mA$

Note $V_{CE} = V_{CC} - I_C R_C$

$= 24V - (5mA)(4K\Omega)$

$= 4V > 0.2V \Rightarrow$ Forward-active mode

L) In the circuit shown below, $R_1 = 300$ kΩ, $R_2 = 2$ kΩ, and $\beta = 100$ for the transistor. Which of the following is closest to the value of the collector voltage (V_C)?



a: 8 V
b: 6 V
c: 4 V
d: 2 V
e: 0 V

Assume forward-active mode

$\Rightarrow V_{EB} = V_{EB}(on) = 0.7V$

$\Rightarrow I_B = \frac{9V - 0.7V}{300K\Omega} \cong 0.0277mA$

$I_C = \beta I_B \cong (100)(0.0277mA) = 2.77mA$

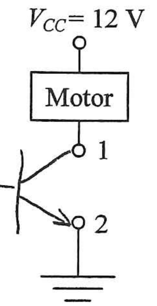
$V_C = I_C R_2 \cong (2.77mA)(2K\Omega) = 5.53V$

Check: $V_{EC} \cong 9V - 5.53V = 3.47V > 0.2V$ ✓

(Not in saturation)

M) An npn bipolar junction transistor is to be used as a switch to control current flowing through an electric motor. The transistor will be connected between terminals 1 and 2 in the diagram below. Which transistor terminals will be connected to terminals 1 and 2 in the circuit?

a: 1 connects to collector and 2 connects to emitter
b: 1 connects to collector and 2 connects to base
c: 1 connects to base and 2 connects to emitter
d: 1 connects to base and 2 connects to collector
e: None of the above



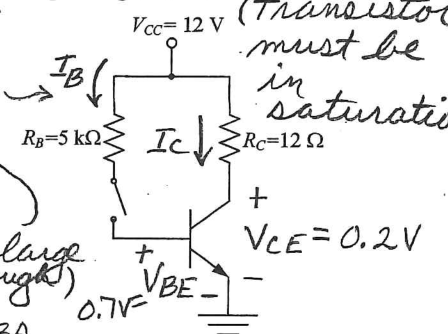
(npn transistor as switch) →
See text sec. 5.3.1

N) For the transistor in the circuit shown below, $\beta = 90$. The transistor is intended to function as a switch, but the circuit has been designed incorrectly. Which of the following changes would correct the design?

a: Replace R_B with a 3 kΩ resistor.
b: Replace R_B with a 2 kΩ resistor.
c: Both a and b
d: Use a different transistor, for which $\beta = 200$.
e: None of the above

$I_B = \frac{12\,V - 0.7\,V}{5\,k\Omega} \cong 2.26\,mA$

(Transistor must be in saturation)



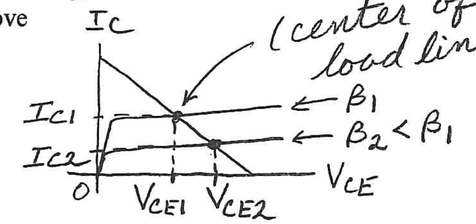
In saturation, $I_C = \frac{12\,V - 0.2\,V}{12\,\Omega} \cong 0.983\,A$

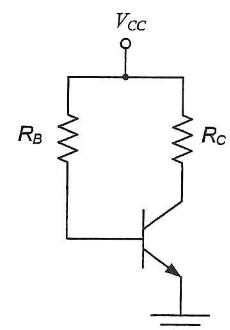
and $I_B > \frac{I_C}{\beta} \cong \frac{0.983A}{90} \cong 10.9\,mA$ ← (I_B not large enough)

$\Rightarrow R_B < \frac{12V - 0.7V}{10.9mA} \cong 1.03\,K\Omega$, or $\beta > \frac{I_C}{I_B} \cong \frac{0.983A}{2.26mA} \cong 435$

O) The values of the resistors in the circuit below have been chosen to set the transistor's operating point at the center of the load line. If the value of β decreases, which of the following will occur?

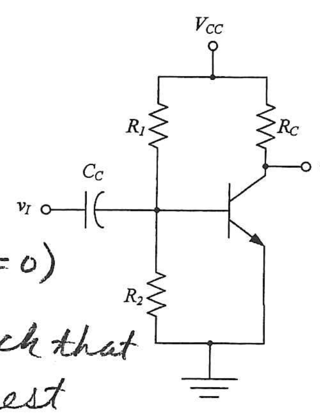
a: Both I_C and V_{CE} will increase.
b: Both I_C and V_{CE} will decrease.
c: I_C will increase and V_{CE} will decrease.
d: I_C will decrease and V_{CE} will increase.
e: None of the above





P) The circuit below is an audio amplifier. Which of the following should be true for capacitor C_C?

a: Its impedance should be low at DC.
b: Its impedance should be high at audio frequencies.
c: both a and b
d: Its impedance should be low at audio frequencies.
e: None of the above



(See text sec. 5.4.1)

Impedance $= \frac{1}{j\omega C_c} = \infty$ @ DC ($\omega = 0$)

C_c should be sufficiently large such that $\frac{1}{\omega C_c}$ is small for signals of interest (i.e. audio frequencies, ω).

Q) A pnp BJT is biased in the forward-active mode. If $\beta > 100$, and the diffusion resistance of the emitter-base junction is less than 4 kΩ, which of the following is true?

a: $g_m > 25$ mA/V
b: $g_m < 25$ mA/V
c: $g_m > 40$ mA/V
d: $g_m < 40$ mA/V
e: None of the above

$$g_m = \frac{\beta \leftarrow\ >100}{r_\pi \leftarrow\ < 4K\Omega}$$

$$\Rightarrow g_m > \frac{100}{4K\Omega} = 25\ \frac{mA}{V}$$

R) A voltage amplifier whose output resistance is R_o drives a load whose resistance is R_L. Which of the following conditions normally would be desired in this situation?

a: R_o is large and R_L is small.
b: R_o is small and R_L is large.
c: R_o and R_L are both large.
d: R_o and R_L are both small.
e: None of the above

See text sec. 6.3

$R_o << R_L$ is preferred for a voltage amplifier.

S) For the transistor in the circuit below, $V_A = 100$ V and $\beta = 150$. The transistor's temperature is 300 K, its quiescent base current is 10.0 μA, and the capacitors have negligible impedance at signal frequencies. Which of the following is closest to the small-signal ac voltage gain of the circuit?

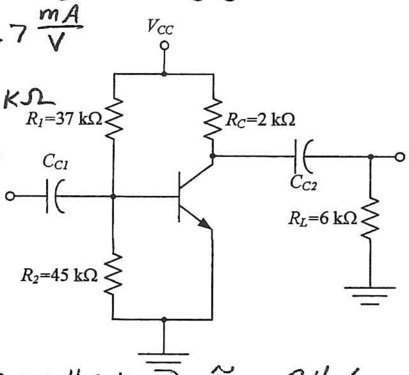
a: −65
b: −85
c: −105
d: −125
e: −145

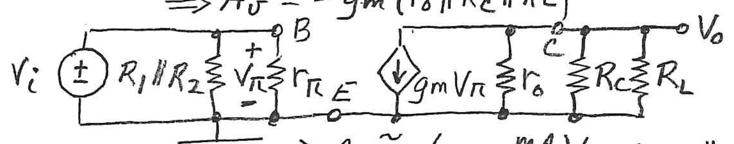
$$g_m = \frac{\beta I_{BQ}}{V_T} \cong \frac{(150)(0.01mA)}{0.026V} \cong 57.7\ \frac{mA}{V}$$

$$r_o = \frac{V_A}{\beta I_{BQ}} = \frac{100V}{(150)(0.01mA)} \cong 66.7K\Omega$$

$$A_v = \frac{V_o}{V_i} = \frac{-g_m \cancel{V_\pi}(r_o \| R_C \| R_L)}{\cancel{V_\pi}}$$

$$\Rightarrow A_v = -g_m (r_o \| R_C \| R_L)$$





$$\Rightarrow A_v \cong -(57.7\ \tfrac{mA}{V})(66.7K\Omega \| 2K\Omega \| 6K\Omega) \cong -84.6$$

T) If the circuit below is modified by adding an emitter resistor, which of the following will happen?

a: Both R_i and $|A_v|$ will increase.
b: Both R_i and $|A_v|$ will decrease.
c: R_i will decrease and $|A_v|$ will increase.
d: R_i will increase and $|A_v|$ will decrease.
e: None of the above

See text sec. 6.4.2