Part I (15 minutes, 10 points)

1) Name one of the possible breakdown mechanisms that can occur in a reverse biased pn junction.
   Answer: Avalanche & Zener diode

2) A single diode carries a current of 1 mA and features a voltage drop of $V_d=0.7$ V. What is the voltage drop $V_{dz}$ across 2 such identical diodes switched in parallel that share the current of 1 mA? (Assume $V_T=26$ mV for both diodes).
   $V_{dz}=682$ mV

3) The operating temperature of a diode is changing from 290 K to 310 K. How does this affect the diode current $I_d$ if we were to assume that the ratio $V_d/V_T$ would remain constant over this 20 K temperature interval?
   A) $I_d$ remains about the same ○
   B) $I_d$ increases by about 7% ○
   C) $I_d$ decreases by about 7% ○
   D) $I_d$ increases by more than a factor of 20 ×

4) A diode carries a current of 1 mA while $V_d=700$ mV. Find its reverse saturation current $I_s$ if you know that $V_T=26$ mV.
   $I_s=2.0 \times 10^{-15}$ A

5) Two identical diodes feature voltage drops of $V_{dz}=690$ mV and $V_{d2}=664$ mV, respectfully. Find the corresponding current ratio $I_{d1}/I_{d2}$ (Assume $V_T=26$ mV for both diodes).
   $I_{d1}/I_{d2}=2.72$
Part II (55 minutes, 30 points)

1) Linear Circuit Theory

a) Find the short circuit current $I_s$ for the network on the left. (Note: The depicted current source is ideal).

b) What is the value of the current ratio $I_1/I_2$ if the network terminal remains open?

c) Find values for the ideal voltage source $V_x$ and the resistance $R_x$ such that the two depicted networks show the exact same terminal behavior.

2) Voltage Limiter with Diodes

a) What is the maximum value of the output voltage $V_o$?

b) Find the maximum and the minimum value of the source current $I_1$?

c) Assume that the swing of the input voltage source $V_s$ is increased from 6 V to 10 V. What is the maximum power dissipated by the diode located in the vertical branch under this modified operating condition?
3) CE Amplifier

V_s is an ideal ac source and the transistor is biased in the **forward active** region (the biasing circuit is not shown).

a) Find a value for the equivalent **input resistance** \( r_i = V_i/I_1 \) of the depicted BJT amplifier.

b) Sketch the **small signal** equivalent circuit for this BJT amplifier with the 2 external resistors included and list the numerical value of the transconductance \( g_m \).

c) Derive a **symbolic expression** and find a value for the voltage gain \( A_V = V_2/V_s \).

| \( V_{BEQ} = 0.7 \) V |
| \( I_{CQ} = 0.5 \) mA |
| \( \beta = 150 \) |
| \( V_A = \infty \) |
| \( V_T = 30 \) mV |
1) a) \[ \begin{align*}
I_1 \cdot 2h &= I_2 \cdot 2h \\
I_1 + I_2 &= I_1 \\
I_o &= I_1 = 12 \text{ mA}
\end{align*} \]
\[ I_o = \text{Current Source} \]
\[ \begin{align*}
I_2 &= \frac{1}{2} I_1 = 6 \text{ mA}
\end{align*} \]

b) If terminal is open, \( I_1 = I_2 \)
\[ \frac{I_1}{I_2} = 1 \]

(c) \[ \begin{align*}
V_x &= V_{OL} = I_0 \cdot 2h = 24 \text{ V} \\
R_x &= \frac{V_x}{I_2} = 4 \text{ k}\Omega
\end{align*} \]
2) a) If vertical diode is off (Hypothesis i)
\[ V_{omx} = (V_{smax} - 0.7V) \cdot \frac{1}{2} = 2.65V \]
Since \( V_{omx} < 2.3V + 0.7V \), the vertical branch remains off and
\[ V_{omx} = 2.65V \]

b) \[ I_{omx} = \frac{V_{smax} - V_{omx} - 0.7V}{1k\Omega} = 2.65mA \]
\[ I_{omx} = 0 \] \hspace{1cm} Horizontal diode prevents negative current flow

C) \[ V_{omx} = (V_{smax} - 0.7) \cdot \frac{1}{2} = 4.65V \]
Since \( V_{omx} > 3V \), the vertical branch conducts and \( V_{omx} = 3V \)
\[ P_{omx} = (I_{omx} - I_{2omx}) \cdot 0.7V \]
\[ I_{omx} = \frac{V_{smax} - 0.7V - V_{omx}}{1k\Omega} = 0.3mA \]
\[ I_{2omx} = \frac{V_{omx}}{1k\Omega} = 3mA \]
\[ P_{omx} = 2.5mW \]
3) a) \[ \tau_i = \frac{g}{\beta m} = \sqrt{\frac{V_i}{I_{CA}}} = 9\ h\ \Omega \]

b) \[
\begin{align*}
V_i & \quad \cdot \quad \frac{1}{L} \\
V_i & \quad \cdot \quad \frac{1}{R} \\
\bigcirc & \quad \cdot \quad \frac{1}{g_m V_i} \\
V_2 & \quad \cdot \quad \frac{1}{5h} \\
V_2 & \quad \cdot \quad \frac{1}{R}
\end{align*}
\]

\[ g_m = \frac{I_{CA}}{V_i} = 16.7 \ mS \]

c) \[
\begin{align*}
V_2 &= -g_m V_i \cdot 5h = -V_i \cdot 83.5 \\
V_i &= V_s \cdot \frac{\tau_i}{1h + \tau_i} = V_s \cdot \frac{9}{10} \\
A_v &= \frac{V_2}{V_s} = -75
\end{align*}
\]