Quiz EL207
Basic Power Amplifiers
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PROBLEMS

Problem 1 (Neamen, 2000)

Problem 1.1: A particular transistor is rated for a maximum power dissipation of 60 W if the case temperature is at 25°C. Above 25°C, the allowed power dissipation is reduced by 0.5 W/°C. Sketch the power derating curve.
Problem 1.2: What is the maximum allowed junction temperature?
Problem 1.3: What is the value of the thermal resistance from device to case, $\theta_{\text{dev-case}}$?

Problem 2 (Neamen, 2000)

A MOSFET has a rated power of 50 W and a maximum specified junction temperature of 150°C. The ambient temperature is T_{amb} = 25°C. Find the relationship between the actual operating power and the case-to-ambient thermal resistance $\theta_{\text{case-amb}}$.

Problem 3 (Neamen, 2000)

For a power MOSFET, the device-to-case resistance $\theta_{\text{dev=case}}$ = 1.75°C/W, the drain current is I_D = 4 A, and the average drain-to-source voltage is 5 V. The device is mounted on a heat sink with sink-to-ambient resistance $\theta_{\text{sink-amb}}$ = 3°C/W and case-to-sink resistance $\theta_{\text{case-sink}}$ = 0.8°C/W. If the ambient temperature is T_{amb} = 25°C, determine the temperature of the device, the case, and the heat sink.

Problem 4 (Neamen, 2000)

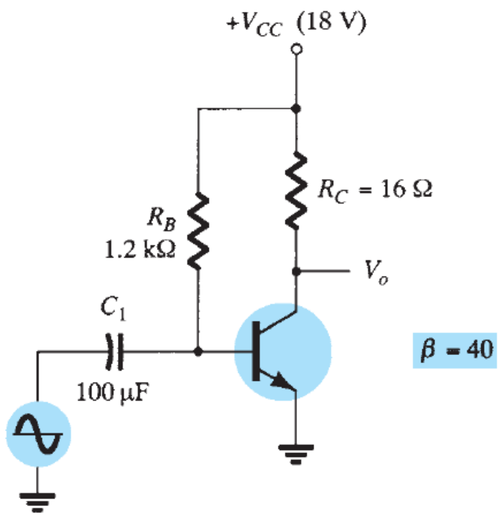
A BJT must dissipate 25 W of power. The maximum junction temperature is $T_{J,max}$ = 200°C, the ambient temperature is 25°C, and the device-to-case thermal resistance is 3°C/W. Determine the maximum permissible thermal resistance between the case and ambient.

Problem 5 (Neamen, 2000)

A BJT has a rated power of 15 W and a maximum junction temperature of 175°C. The ambient temperature is 25°C, and the thermal resistance parameters are sink-to-ambient resistance $\theta_{\text{sink-amb}}$ = 3°C/W and $\theta_{\text{case-sink}}$ = 1°C/W. Determine the actual power that can be safely dissipated in the transistor.

Problem 6 (Boylestad and Nashelsky, 2013, w/ permission)

Problem 6.1: Calculate the input and output power for the circuit illustrated to the side. The input signal results in a base current of 5 mA rms.
Problem 6.2: What is the maximum output power that can be delivered to the circuit of if R_B is changed to 1.5 kΩ?



Problem 7 (Boylestad and Nashelsky, 2013, w/ permission)

Problem 7.1: A transformer-coupled Class A amplifier drives a 16-Ω speaker through a 3.87:1 transformer. Using a power supply of V_{CC} = 36 V, the circuit delivers 2 W to the load. Determine:

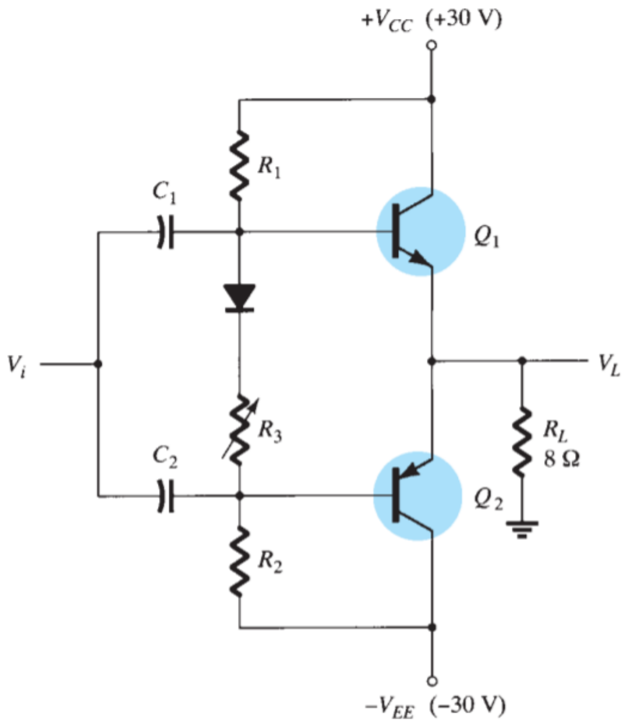
1. The power P(ac) across transformer primary
2. The voltage V_L(ac) appearing across the load
3. V(ac) at transformer primary
4. The rms values of load and primary current´

Problem 7.2: Calculate the efficiency of the circuit introduced in Problem 7.1 if the bias current is I_{C_Q} = 150 mA.

Problem 8 (Boylestad and Nashelsky, 2013, w/ permission)

For the Class B power amplifier illustrated to the side, calculate:

1. Maximum ac output power, $P_o(\text{ac})$
2. Maximum dc input power, $P_i(\text{dc})$
3. Maximum efficiency, η_{max}
4. Maximum power dissipated by both transistors, $P_{2Q,\text{max}}$.



Problem 9 (Boylestad and Nashelsky, 2013, w/ permission)

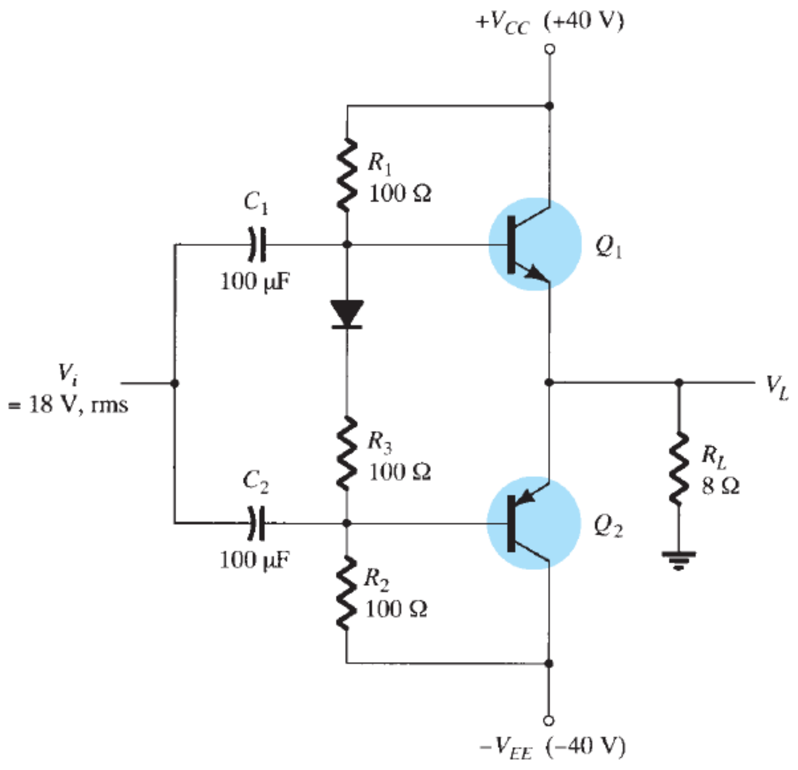
If the input voltage to the Class B power amplifier introduced in the previous problem is 8-V rms, calculate:

1. dc input power, $P_i(\text{dc})$
2. ac output power, $P_o(\text{ac})$
3. Efficiency, η
4. Power dissipated by both power output transistors, P_{2Q}.

Problem 10 (Boylestad and Nashelsky, 2013, w/ permission)

For the Class B power amplifier illustrated below, calculate:

1. dc input power, $P_i(\text{dc})$
2. ac output power, $P_o(\text{ac})$
3. Efficiency, η
4. Power dissipated by both power output transistors, P_{2Q}.



Problem 11 (Off-topic) (Boylestad and Nashelsky, 2013, w/ permission)

An output signal has fundamental amplitude equal to 2.1 V, a second harmonic amplitude of 0.3 V, a third harmonic component of 0.1 V, and a fourth harmonic component of 0.05 V. Compute the total harmonic distortion for this system.

Problem 12 (Off-topic) (Boylestad and Nashelsky, 2013, w/ permission)

Calculate the second harmonic distortion for an output waveform having measured values of minimum collector-emitter voltage amplitude $V_{CE_{\text{min}}}$ = 2.4 V, quiescent collector-emitter voltage amplitude V_{CE_Q} = 10 V, and maximum collector-emitter voltage amplitude $V_{CE_{\text{max}}}$ = 20 V.

Problem 13 (Boylestad and Nashelsky, 2013, w/ permission)

A system has second distortion component D_2 = 0.15, third distortion component D_3 = 0.01 and fourth distortion component D_4 = 0.05. The current associated with the fundamental component of the distorted signal is I_1 = 3.3 A, and the resistance of the load resistor is R_C = 4 Ω, calculate the total harmonic distortion fundamental power component and total power.

Problem 14 (Floyd, 2005)

Refer to the class AB amplifier illustrated below.

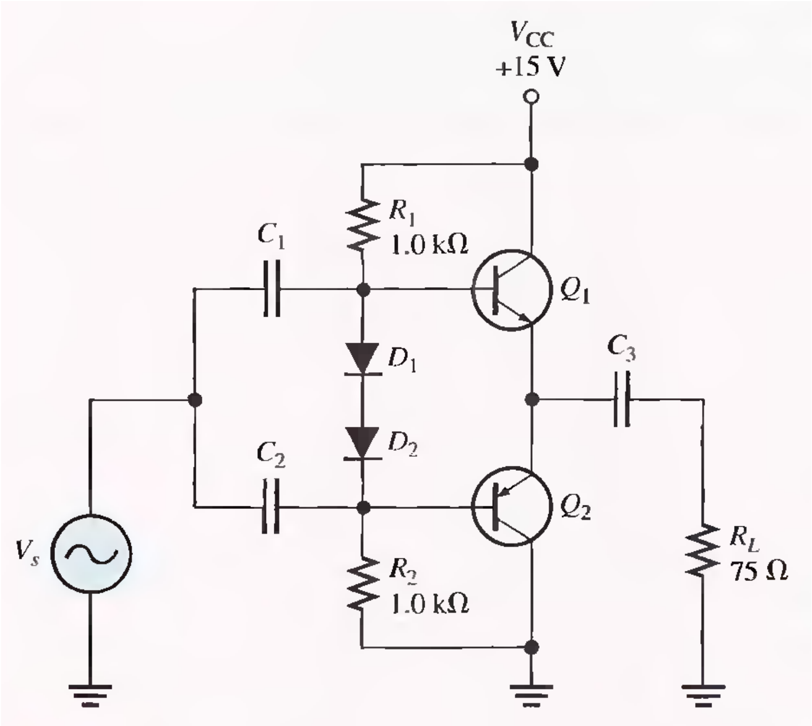
Problem 14.1: Determine $V_{B(Q1)}$ (the base voltage at transistor Q_1), $V_{B(Q2)}$ (the base voltage at transistor Q_2), V_E (the emitter voltage), I_{CQ} (the collector current), $V_{CEQ(Q1)}$ (the voltage at the collector-emitter junction of transistor Q_1), and $V_{CE(Q2)}$ (the voltage at the collector-emitter junction of transistor Q_2).

Problem 14.2: Assuming the input voltage is 10 V peak-to-peak, determine the power delivered to the load resistor.

Problem 14.3: For the Class AB power amplifier in question, what is the maximum power that could be delivered to the load resistor?

Problem 14.4: Refer to the class AB amplifier introduced in Problem 14.1. What fault or faults could account for each of the following troubles?

1. A positive half-wave output signal;
2. Zero volts on both bases and the emitters;
3. No output; emitter voltage = +15 V;
4. Crossover distortion observed on the output waveform;



ADDITIONAL INFORMATION

Equations

1 → Resistance transformation across a transformer

$$\frac{R_{\text{pri}}}{R_{\text{sec}}} = a^2$$

where R_{pri} is primary resistance, R_{sec} is secondary resistance (the resistance of the load to which the transformer delivers power), and a is turns ratio.

2 → Maximum output power for class B operation

$$P_{o,\max}\left(\text{ac}\right)=\frac{V_{CC}^{2}}{2R_L}$$

where V_{CC} is supply voltage and R_L is load resistance.

3 → Maximum input power for class B operation

$$P_{i,\max}\left(\text{dc}\right)=\frac{2V_{CC}^{2}}{\pi R_L}$$

where V_{CC} is supply voltage and R_L is load resistance.

4 → Maximum power dissipated by output transistors in class B operation

$$P_{2Q,\max}=\frac{2V_{CC}^{2}}{\pi^2 R_L}$$

where V_{CC} is supply voltage and R_L is load resistance.

5 → n-th harmonic distortion component

$$D_n=\left|\frac{A_n}{A_1}\right|\times 100\%$$

where A_1 is the amplitude of the fundamental component and A_n is the amplitude of the n-th frequency component.

6 → Total harmonic distortion

$$\%THD=\sqrt{D_2^2+D_3^2+D_4^2+\ldots+D_n^2}\times 100\%$$

where D_n is the n-th distortion component (equation 5).

7 → Second harmonic distortion as a function of measured collector-emitter voltages

$$D_2=\left|\frac{\frac{1}{2}\left(V_{CE_{\max}}+V_{CE_{\min}}\right)-V_{CE_Q}}{V_{CE_{\max}}-V_{CE_{\min}}}\right|\times 100\%$$

where $V_{CE_{\min}}$ is the minimum collector-emitter voltage, V_{CE_Q} is the quiescent collector-emitter voltage, and $V_{CE_{\max}}$ is the maximum collector-emitter voltage.

8 → Power delivered to a resistor R_C by a distorted signal

$$P=\left(1+\text{THD}^2\right)P_1$$

where THD is total harmonic distortion (equation 6) and P_1 is the power associated with the distorted signal, which can be determined as

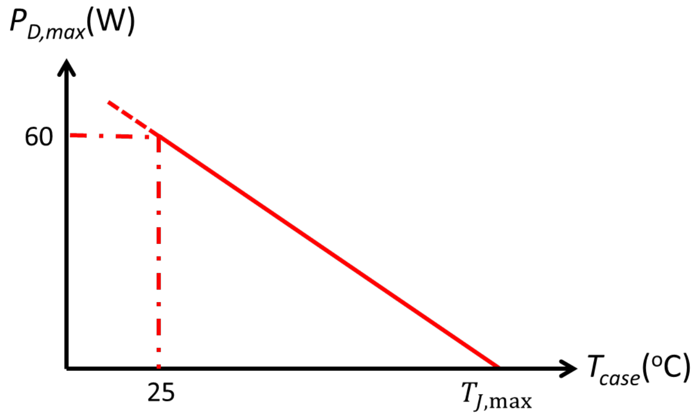
$$P=\frac{\left(I_1^2+I_2^2+\ldots+I_n^2\right)R_C}{2}$$

Here, I_n is the current component associated with the n-th distorted signal and R_C is the load resistance.

SOLUTIONS

P.1 ➡ *Solution*

Problem 1.1: The power derating curve is shown below.



Problem 1.2: The power dissipated is given by

$$P_D=P_{D,\max}-\text{Slope}\left(T_J-25\right)$$

Setting $P_D = 0$ and solving for $T_{J,max}$, we obtain

$$P_D = P_{D,\max} - \text{Slope}\left(T_J - 25\right) = 0 \rightarrow T_{J,\max} = \frac{P_{D,\max}}{\text{Slope}} + 25$$

$$\therefore T_{J,\max} = \frac{60}{0.5} + 25 = \boxed{145^{\circ}\text{C}}$$

Problem 1.3: Noting that the power dissipated by the transistor can be obtained by dividing the temperature gradient by thermal resistance, we can solve for $\theta_{\text{dev-case}}$ and obtain

$$P_{D,\max} = \frac{T_{J,\max} - T_{\text{case}}}{\theta_{\text{dev-case}}} \rightarrow \theta_{\text{dev-case}} = \frac{T_{J,\max} - T_{\text{case}}}{P_{D,\max}}$$

$$\therefore \theta_{\text{dev-case}} = \frac{145-25}{60} = \boxed{2\,^{\circ}\text{C/W}}$$

P.2 ➡ Solution

The temperature gradient from the device to the environment equals the product of dissipated power and thermal resistance,

$$T_{\text{dev}} - T_{\text{amb}} = P_D \theta_{\text{dev-amb}}$$

Breaking down the device-to-ambient temperature into $\theta_{\text{dev-case}}$ and $\theta_{\text{case-}amb}$, we obtain

$$T_{\text{dev}} - T_{\text{amb}} = P_D\left(\theta_{\text{dev-case}} + \theta_{\text{case-amb}}\right) \rightarrow P_D = \frac{T_{\text{dev}} - T_{\text{amb}}}{\theta_{\text{dev-case}} + \theta_{\text{case-amb}}}$$

$$\therefore P_D = \frac{150-25}{\theta_{\text{dev-case}} + \theta_{\text{case-amb}}} = \frac{125}{\theta_{\text{dev-case}} + \theta_{\text{case-amb}}} \quad \text{(I)}$$

Using the maximum junction temperature and the rated operating power, we obtain

$$\theta_{\text{dev-case}} = \frac{T_{J,\max} - T_{\text{amb}}}{P_{D,\max}} = \frac{150-25}{50} = 2.5^{\circ}\,\text{C/W}$$

so that, substituting in (I),

$$P_D = \frac{125}{\theta_{\text{dev-case}} + \theta_{\text{case-amb}}} = \boxed{\frac{125}{2.5 + \theta_{\text{case-amb}}}}$$

P.3 ➡ Solution

First of all, the power dissipated by the transistor is given by

$$P_D = I_D V_{DS} = 4 \times 5 = 20\text{ W}$$

The temperature of the device, accounting for the three given contributions to thermal resistance, follows as

$$T_{\text{dev}} - T_{\text{amb}} = P_D\left(\theta_{\text{dev-case}} + \theta_{\text{case-sink}} + \theta_{\text{sink-amb}}\right)$$

$$\therefore T_{\text{dev}} = P_D\left(\theta_{\text{dev-case}} + \theta_{\text{case-sink}} + \theta_{\text{sink-amb}}\right) + T_{\text{amb}} = 20 \times \left(1.75 + 3 + 0.8\right) + 25 = \boxed{136^{\circ}\,\text{C}}$$

The case temperature is, in turn,

$$T_{\text{dev}} - T_{\text{case}} = P_D \theta_{\text{dev-case}} \rightarrow T_{\text{case}} = T_{\text{dev}} - P_D \theta_{\text{dev-case}}$$

$$\therefore T_{\text{case}} = 136 - 20 \times 1.75 = \boxed{101^{\circ}\,\text{C}}$$

Lastly, the heat sink temperature is

$$T_{\text{case}} - T_{\text{sink}} = P_D \theta_{\text{case-sink}} \rightarrow T_{\text{sink}} = T_{\text{case}} - P_D \theta_{\text{case-sink}}$$

$$\therefore T_{\text{sink}} = 101 - 20 \times 0.8 = \boxed{85^{\circ}\,\text{C}}$$

P.4 ➡ Solution

Use the temperature-thermal resistance relationship and solve for $\theta_{\text{case-amb}}$,

$$T_{\text{dev}} - T_{\text{amb}} = P_D\left(\theta_{\text{dev-case}} + \theta_{\text{case-amb}}\right) \rightarrow \theta_{\text{case-amb,max}} = \frac{T_{J,\max} - T_{\text{amb}}}{P_D} - \theta_{\text{dev-case}}$$

$$\therefore \theta_{\text{case-amb}} = \frac{200-25}{25} - 3 = \boxed{4^{\circ}\,\text{C/W}}$$

P.5 ➡ *Solution*

The power dissipated in the transistor is given by

$$P_D = \frac{T_{J,\max} - T_{\text{amb}}}{\theta_{\text{dev-case}} + \theta_{\text{case-sink}} + \theta_{\text{sink-amb}}} \quad \text{(I)}$$

We have the sink-to-ambient resistance $\theta_{\text{sink-amb}}$ and the case-to-sink resistance $\theta_{\text{case-sink}}$, but $\theta_{\text{dev-case}}$ is missing; this latter variable can be determined as

$$\theta_{\text{dev-case}} = \frac{T_{J,\max} - T_{\text{amb}}}{P_{D,\text{rated}}} = \frac{175-25}{15} = 10^{\text{o}}\,\text{C/W}$$

so that, substituting in (I),

$$P_D = \frac{175-25}{10+1+3} = \boxed{10.7\,\text{W}}$$

P.6 ➡ *Solution*

Problem 6.1: The input power can be determined by multiplying the dc current I_{C_Q} into the collector node of the BJT by the supply voltage V_{CC}. We first determine base current I_{B_Q},

$$I_{B_Q} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{18-0.7}{1.2\times10^3} = 14.4\,\text{mA}$$

so that, using the current gain parameter β = 40,

$$I_{C_Q} = \beta I_{B_Q} = 40\times14.4 = 576\,\text{mA}$$

Finally,

$$P_i = V_{CC} I_{dc} = V_{CC}\left(I_{B_Q} + I_{C_Q}\right) \approx V_{CC} I_{C_Q} = 18\times\left(576\times10^{-3}\right) = \boxed{10.4\,\text{W}}$$

Now, if the input signal results in a base current of 5 mA rms, the corresponding collector current is

$$I_C(\text{rms}) = \beta I_B(\text{rms}) = 40\times5 = 200\,\text{mA}$$

and corresponds to an output power such that

$$P_o = I_C^2(\text{rms}) R_C = 0.2^2\times16 = 0.64\,\text{W}$$

$$\therefore \boxed{P_o = 640\,\text{mW}}$$

Problem 6.2: The Q-point base current now becomes

$$I_{B_Q} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{18-0.7}{1.5\times10^3} = 11.5\,\text{mA}$$

while the collector current is updated as

$$I_{C_Q} = \beta I_{B_Q} = 40\times11.5 = 460\,\text{mA}$$

The input power is

$$P_i = V_{CC} I_{dc} \approx V_{CC} I_{C_Q} = 18\times\left(460\times10^{-3}\right) = 8.28\,\text{W}$$

Lastly, noting that the efficiency of a Class A amplifier can be no greater than 25%, the maximum output power delivered by the circuit is

$$\eta_{\max} = \frac{P_o}{P_i}\times100\% = 25\% \rightarrow P_{o,\max} = 0.25P_i$$

$$\therefore P_{o,\max} = 0.25\times8.28 = \boxed{2.07\,\text{W}}$$

P.7 ➡ *Solution*

Problem 7.1: The power dissipation across the load is equal to the power at the primary side of the transformer, hence

$$P_{\text{pri}} = P_L = \boxed{2\,\text{W}}$$

Equipped with the load resistance and the power delivered to it, we can determine V_L,

$$P_L = \frac{V_L^2}{R_L} \to V_L = \sqrt{P_L R_L}$$

$$\therefore V_L = \sqrt{2.0 \times 16} = \boxed{5.66\ \text{V}}$$

The voltage at the transformer primary can be expressed as

$$P_{\text{pri}} = \frac{V_{\text{pri}}^2}{R_{\text{pri}}} \to V_{\text{pri}} = \sqrt{P_{\text{pri}} R_{\text{pri}}} \quad \text{(I)}$$

where P_{pri} = 2 W and the primary resistance R_{pri} can be determined from the turns ratio a = 3.87 and the secondary resistance R_{sec}, which is the resistance of the load to which the amplifier delivers power (see equation 1),

$$\frac{R_{\text{pri}}}{R_{\text{sec}}} = \left(\underbrace{\frac{N_1}{N_2}}_{=a}\right)^2 = a^2 \to R_{\text{pri}} = a^2 R_{\text{sec}}$$

$$\therefore R_{\text{pri}} = 3.87^2 \times 16 = 240\,\Omega$$

so that, substituting in (I),

$$V_{\text{pri}} = \sqrt{P_{\text{pri}} R_{\text{pri}}} = \sqrt{2.0 \times 240} = \boxed{21.9\ \text{V}}$$

The load current is given by

$$P_L = I_L^2 R_L \to I_L = \sqrt{\frac{P_L}{R_L}}$$

$$\therefore I_L = \sqrt{\frac{2.0}{16}} = 0.354\ \text{A} = \boxed{354\ \text{mA}}$$

Likewise, the primary current is

$$P_{\text{pri}} = I_{\text{pri}}^2 R_{\text{pri}} \to I_{\text{pri}} = \sqrt{\frac{P_{\text{pri}}}{R_{\text{pri}}}}$$

$$\therefore I_{\text{pri}} = \sqrt{\frac{2.0}{240}} = 0.0913\ \text{A} = \boxed{91.3\ \text{mA}}$$

Problem 7.2: Using the bias current given, the input power is calculated to be

$$P_i = V_{CC} I_{C_Q} = 36 \times 0.15 = 5.4\ \text{W}$$

The output power is the power delivered to the load, namely 2 W. The efficiency of the circuit follows as

$$\eta = \frac{P_o}{P_i} \times 100\% = \frac{2.0}{5.4} \times 100\% = \boxed{37.0\%}$$

P.8 ➡ *Solution*

The maximum ac output power with a supply voltage of 30 V and a load resistance of 8 Ω is given by equation 2,

$$P_{o,\max}(\text{ac}) = \frac{V_{CC}^2}{2R_L} = \frac{30^2}{2 \times 8} = \boxed{56.3\ \text{W}}$$

The maximum dc input power is given by the product of input voltage $V_i = V_{CC}$ and the peak dc current $I_{dc} = 2V_i/\pi R_L$ (see also equation 3)

$$P_{i,\max}(\text{dc}) = V_{CC} I_{dc,\text{peak}} = V_{CC} \times \frac{2V_{CC}}{\pi R_L} = 30 \times \left(\frac{2 \times 30}{\pi \times 8}\right) = \boxed{71.6\ \text{W}}$$

Dividing the maximum ac output power by the maximum dc input power yields the maximum circuit efficiency for class B operation,

$$\eta_{\max} = \frac{P_{o,\max}(\text{ac})}{P_{i,\max}(\text{dc})} \times 100\% = \frac{56.3}{71.6} \times 100\% = \boxed{78.6\%}$$

To establish the maximum power dissipated by both transistors, simply substitute the supply voltage V_{CC} and the load resistance R_L into equation 4,

$$P_{2Q,\max} = \frac{2V_{CC}^2}{\pi^2 R_L} = \frac{2\times 30^2}{\pi^2\times 8} = \boxed{22.8\ \mathrm{W}}$$

P.9 ➡ *Solution*

The peak input voltage is $\sqrt{2}V_i(\mathrm{rms}) = \sqrt{2}\times 8 = 11.3$ V, and the dc input power follows as

$$P_i(\mathrm{dc}) = V_{CC}\times\frac{2V_i}{\pi R_L} = 30\times\left(\frac{2\times 11.3}{\pi\times 8}\right) = \boxed{27.0\ \mathrm{W}}$$

(This equation is similar to equation 2, but can be distinguished by the fact that supply voltage V_{CC} is not equal to input voltage V_i.) To determine the ac output power, square the rms input voltage and divide the result by the load resistance,

$$P_o(\mathrm{ac}) = \frac{\left[V_i(\mathrm{rms})\right]^2}{R_L} = \frac{8.0^2}{8.0} = \boxed{8.0\ \mathrm{W}}$$

The efficiency η is determined as

$$\eta = \frac{P_o(\mathrm{ac})}{P_i(\mathrm{dc})}\times 100\% = \frac{8.0}{27}\times 100\% = \boxed{29.6\%}$$

The power dissipated by both power output transistors is given by difference between $P_i(\mathrm{dc})$ and $P_o(\mathrm{ac})$,

$$P_{2Q} = P_i(\mathrm{dc}) - P_o(\mathrm{ac}) = 27.0 - 8.0 = \boxed{19.0\ \mathrm{W}}$$

P.10 ➡ *Solution*

Inspecting the circuit, we see that the input voltage is 18-V rms, the load resistance is 8 Ω, and the supply voltage is 40 V. The peak input voltage is $\sqrt{2}V_i(\mathrm{rms}) = \sqrt{2}\times 18 = 25.5$ V, and the dc input power follows as

$$P_i(\mathrm{dc}) = V_{CC}\times\frac{2V_i}{\pi R_L} = 40\times\left(\frac{2\times 25.5}{\pi\times 8}\right) = \boxed{81.1\ \mathrm{W}}$$

(Note that the equation is similar to the one used in the determination of input power in Problem 9.) The ac output power is given by

$$P_o(\mathrm{ac}) = \frac{\left[V_i(\mathrm{rms})\right]^2}{R_L} = \frac{18^2}{8.0} = \boxed{40.5\ \mathrm{W}}$$

The efficiency η is given by

$$\eta = \frac{P_o(\mathrm{ac})}{P_i(\mathrm{dc})}\times 100\% = \frac{40.5}{81.1}\times 100\% = \boxed{49.9\%}$$

The power dissipated by the output transistors is expressed as the difference

$$P_{2Q} = P_i(\mathrm{dc}) - P_o(\mathrm{ac}) = 81.1 - 40.5 = \boxed{40.6\ \mathrm{W}}$$

P.11 ➡ *Solution*

We first compute harmonic distortion components D_2, D_3, and D_4 (equation 5)

$$D_2 = \left|\frac{A_2}{A_1}\right|\times 100\% = \left|\frac{0.3}{2.1}\right|\times 100\% = 14.3\%$$

$$D_3 = \left|\frac{A_3}{A_1}\right|\times 100\% = \left|\frac{0.1}{2.1}\right|\times 100\% = 4.77\%$$

$$D_4 = \left|\frac{A_4}{A_1}\right|\times 100\% = \left|\frac{0.05}{2.1}\right|\times 100\% = 2.38\%$$

Total harmonic distortion is then (equation 6)

$$\%THD = \sqrt{D_2^2 + D_3^2 + D_4^2}\times 100\% = \sqrt{0.143^2 + 0.0477^2 + 0.0238^2}\times 100\% = \boxed{15.3\%}$$

P.12 ➡ Solution

This is a straightforward application of equation 7,

$$D_2 = \left|\frac{\frac{1}{2}\left(V_{CE_{\max}} + V_{CE_{\min}}\right) - V_{CE_Q}}{V_{CE_{\max}} - V_{CE_{\min}}}\right| \times 100\% = \left|\frac{\frac{1}{2}(20+2.4)-10}{20-2.4}\right| \times 100\% = \boxed{6.82\%}$$

P.13 ➡ Solution

The fundamental power component of harmonic distortion is given by

$$P_1 = \frac{I_1^2 R_C}{2} = \frac{3.3^2 \times 4}{2} = \boxed{21.8\text{ W}}$$

To find the total power *P*, we first compute the total harmonic distortion *THD*,

$$THD = \sqrt{D_2^2 + D_3^2 + D_4^2} = \sqrt{0.15^2 + 0.01^2 + 0.05^2} = 0.158$$

Then, using this result and the power component determined above, we substitute into equation 8 to obtain

$$P = \left(1 + \text{THD}^2\right) P_1 = \left(1 + 0.158^2\right) \times 21.8 = \boxed{22.3\text{ W}}$$

P.14 ➡ Solution

Problem 14.1: The voltage at the base of transistor Q_1 equals one-half of the supply voltage V_{CC} = +15 V plus the base-emitter voltage $V_{BE} \approx$ 0.7 V,

$$V_{B(Q1)} = \frac{15}{2} + 0.7 = \boxed{8.2\text{ V}}$$

The voltage at the base of transistor Q_2 equals one-half of the supply voltage V_{CC} *minus* the base-emitter voltage V_{BE},

$$V_{B(Q2)} = \frac{15}{2} - 0.7 = \boxed{7.8\text{ V}}$$

The emitter voltage is simply one half of the supply voltage V_{CC},

$$V_E = \frac{V_{CC}}{2} = \frac{15}{2} = \boxed{7.5\text{ V}}$$

The collector current is given by

$$I_{CQ} = \frac{V_{CC} - 1.4}{R_1 + R_2} = \frac{15 - 1.4}{\left(1.0 \times 10^3\right) + \left(1.0 \times 10^3\right)} = \boxed{6.8\text{ mA}}$$

The voltage at the collector-emitter junction of transistor Q_1 is given by

$$V_{CE,Q_1} = 15 - 7.5 = \boxed{7.5\text{ V}}$$

Similarly, the voltage at the collector-emitter junction of transistor Q_2 is stated as

$$V_{CE,Q_2} = 0 - 7.5 = \boxed{-7.5\text{ V}}$$

Problem 14.2: The 10-V peak-to-peak input voltage can be converted to $10/2\sqrt{2}$ = 3.54 V rms. Squaring this input voltage and dividing by the load resistance R_L = 75 Ω yields the power output we're looking for,

$$P_o = \frac{\left[V_i(\text{rms})\right]^2}{R_L} = \frac{3.54^2}{75} = 0.167\text{ W} = \boxed{167\text{ mW}}$$

Problem 14.3: The maximum peak voltage delivered to the load resistor is one-half of the supply voltage V_{CC}, that is, 15/2 = 7.5 V. Converting to rms, we find $7.5/\sqrt{2}$ = 5.30 V rms, so that

$$P_{o,\max} = \frac{\left[V_{i,\max}(\text{rms})\right]^2}{R_L} = \frac{5.30^2}{75} = 0.375\text{ W} = \boxed{375\text{ mW}}$$

Problem 14.4:

1. A positive half-wave output signal indicates that capacitor C_2 or transistor Q_2 may be open.

2. Having emitters and bases with zero-volt readings obviously indicates that the power supply is off. Alternatively, resistance R_1 may be open or the base of Q_1 may be shorted to ground.

3. The emitter voltage will read +15 V and there will be no output if Q_1 has collector-to-emitter short.

4. The output waveform will exhibit crossover distortion if one or both diodes are shorted.

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