\[ R_i = R_{iA} = 3 \, k\Omega \]
\[ R_o = R_{oB} = 20 \, \Omega \]

\[ A_{vo} = A_{voA} A_{voB} \frac{R_{iB}}{R_{oA} + R_{iB}} = 4.998 \times 10^4 \]

On the other hand for the B-A cascade we have:

\[ R_i = R_{iB} = 1 \, M\Omega \]
\[ R_o = R_{oA} = 400 \, \Omega \]

\[ A_{vo} = A_{voA} A_{voB} \frac{R_{iA}}{R_{oB} + R_{iA}} = 4.967 \times 10^4 \]

**Problem 1.22**

\[ |A_{vo}| = \frac{v_{oB}}{v_{iA}} = |A_{voA}| \times \frac{R_{iB}/n^2}{R_{oA} + R_{iB}/n^2} \times n \times |A_{voB}| \]

\[ |A_{vo}| = |A_{voA}| \times |A_{voB}| \times \frac{R_{iB}n}{n^2 R_{oA} + R_{iB}} \]
\[
\frac{d|A_{\text{vo}}|}{dn} = 0 = \left| A_{\text{voa}} \right| \times \left| A_{\text{vob}} \right| \times \frac{R_{iB}^2 - n^2 R_{oA} R_{iB}}{(n^2 R_{oA} + R_{iB})^2}
\]

Solving for \( n \) we have:

\[
\sqrt{\frac{R_{iB}}{R_{oA}}} = \sqrt{\frac{R_{iB}}{R_{oA}}}
\]

**Problem 1.23**

The internal source impedance is:

\[
R_s = \frac{\text{open-circuit voltage}}{\text{short-circuit current}} = \frac{20 \times 10^{-3}}{10^{-6}} = 20 \text{ k}\Omega
\]

The desired voltage gain is required to be at least:

\[
A_{\text{vs}} = \frac{V_o}{V_s} = \frac{10}{20 \times 10^{-3}} = 500
\]

If we cascade \( n \) stages, connect the source to the input, and connect the load to the output, the voltage gain is given by:

\[
A_{\text{vs}} = \frac{R_i}{R_i + R_s} \times \left( \frac{R_i}{R_i + R_o} \right)^{n-1} \times \frac{R_L}{R_L + R_o} \times A_{\text{vo}}
\]

Substituting values and reducing we obtain:

\[
A_{\text{vs}} = 0.02381 \times (0.9091)^{n-1} \times (10)^n
\]

By trial and err we determine that we must have \( n = 5 \) to achieve \( A_{\text{vs}} \) in excess of 500.

**Problem 1.24**

To avoid excessive loading effects at the input, we should choose the first stage such that its input resistance is larger than the source resistance. Therefore we choose type A as the input stage. To avoid excessive loading effects at the output,
\[
\frac{d|A_{vo}|}{dn} = 0 = \left| A_{voA} \right| \times \left| A_{voB} \right| \times \frac{R_i^2 - n^2 R_o R_i B}{(n^2 R_o + R_i B)^2}
\]

Solving for \( n \) we have:
\[
n = \sqrt{\frac{R_i B}{R_o}}
\]

**Problem 1.23**

The internal source impedance is:
\[
R_s = \frac{\text{open-circuit voltage}}{\text{short-circuit current}} = \frac{20 \times 10^{-3}}{10^{-6}} = 20 \text{ k}\Omega
\]

The desired voltage gain is required to be at least:
\[
A_{vs} = \frac{V_o}{V_s} = \frac{10}{20 \times 10^{-3}} = 500
\]

If we cascade \( n \) stages, connect the source to the input, and connect the load to the output, the voltage gain is given by:
\[
A_{vs} = \frac{R_i}{R_i + R_s} \times \left( \frac{R_i}{R_i + R_o} \right)^{n-1} \times \frac{R_L}{R_L + R_o} \times A_{vo}
\]

Substituting values and reducing we obtain:
\[
A_{vs} = 0.02381 \times (0.9091)^n \times (10)^n
\]

By trial and error we determine that we must have \( n = 5 \) to achieve \( A_{vs} \) in excess of 500.

**Problem 1.24**

To avoid excessive loading effects at the input, we should choose the first stage such that its input resistance is larger than the source resistance. Therefore we choose type A as the input stage. To avoid excessive loading effects at the output,
we should choose the last stage such that its output impedance is much less than the load impedance. Therefore we choose type B as the output stage.

To achieve output power of 1 W we need \( P_o = 1 = V_o^2 / R_L \). Solving we determine that \( V_o = 4.472 \text{ V rms} \). Thus we require an overall gain of \( A_{VS} = V_o / V_s = 4.472 / (20 \times 10^{-3}) = 223.6 \) as a minimum value.

To attain the required gain with the least number of stages we use intermediate stages of type C. Thus the amplifier diagram is:

```
  20V
  rms
  +
  \[ R_s = 2 M_n \]

\[
\begin{array}{c}
A \\
C \\
C \\
B \\
R_L \[ 20 \text{V} \]
\end{array}
\]
```

The cascade has \( R_i = 10 \text{ M} \Omega \), \( R_o = 1 \text{ \Omega} \), and \( A_{vo} = 376.9 \). The resulting loaded gain is

\[
A_{vo} \frac{R_L}{R_L + R_o} \frac{R_i}{R_i + R_s} = 299.1
\]

which is in excess of the required minimum value.

**Problem 1.25**

The source impedance is lower than the input impedances of any of the stage types. Therefore we choose type C as the input stage to achieve the highest gain. To avoid excessive loading effects at the output, we should choose the last stage such that its output impedance is much less than the load impedance. Therefore we choose type B as the output stage.

To achieve output power of 1 W we need \( P_o = 1 = V_o^2 / R_L \). Solving we determine that \( V_o = 4.472 \text{ V rms} \). Thus we require an overall gain of \( A_{VS} = V_o / V_s = 4.472 / (20 \times 10^{-3}) = 223.6 \) as a minimum value.
To attain the required gain with the least number of stages we use intermediate stages of type C. Thus the amplifier diagram is:

![Amplifier Diagram]

The cascade has $R_i = 20 \text{ k}\Omega$, $R_o = 1 \text{ } \Omega$, and $A_{vo} = 452.2$. The resulting loaded gain is

$$A_{vo} \frac{R_L}{R_L + R_o} \frac{R_i}{R_i + R_s} = 428.6$$

which is in excess of the required minimum value.

**Problem 1.26**

The efficiency $\eta$ of an amplifier is the output power divided by the supply power times 100%.

$$\eta = \frac{P_{out}}{P_{supply}} \times 100\%$$

Dissipated power is the power converted to heat.

**Problem 1.27**

$$P_{in} = \frac{V_{in}^2}{R_{in}} = (0.1)^2/10^5 = 0.1 \mu\text{W}$$

$$P_{out} = \frac{V_o^2}{R_L} = (10)^2/8 = 12.5 \text{ W}$$

$$P_{supply} = V_{cc}I_{cc} = 15 \times 2 = 30 \text{ W}$$

$$P_{dissipated} = P_{supply} + P_{in} - P_o = 17.5 \text{ W}$$

$$\eta = \frac{P_{out}}{P_{supply}} \times 100\% = \frac{12.5}{30} \times 100\% = 41.67\%$$
\[ G_{\text{msc}} = \frac{i_o}{v_i} = \frac{v_o/R_o}{v_i} = \frac{A_{v_o}}{R_o} = \frac{100}{10^6} = 10^{-4} \text{ s} \]

**Problem 1.47**

We need \( R_i \gg R_s \) and \( R_o \gg R_L \). Therefore we must have an approximately ideal transconductance amplifier.

\[ i_L = \frac{R_i}{R_i + R_s} \frac{R_o}{R_o + R_L} G_{\text{msc}} v_s \]

For a 1% change in \( i_L \) when \( R_s \) increases from 1 kΩ to 2 kΩ, we must have

\[ 0.99 \times \frac{R_i}{R_i + 1000} = \frac{R_i}{R_i + 2000} \]

Solving we find that \( R_i = 98 \text{ kΩ} \).

For a 1% change in \( i_L \) when \( R_L \) increases from 100 Ω to 300 Ω, we must have

\[ 0.99 \times \frac{R_o}{R_o + 100} = \frac{R_o}{R_o + 300} \]

Solving we find that \( R_o = 19.7 \text{ kΩ} \).

**Problem 1.48**

We need \( R_i < 10 \Omega \), \( R_o < 10 \text{ kΩ} \) and a transresistance gain of \( R_{\text{msc}} = (1 \text{ V})/(1 \text{ mA}) = 1000 \Omega \). Therefore we must have an approximately ideal transresistance amplifier.
To achieve approximately ±3% accuracy we will allow ±1% each for load resistance variations, amplifier gain variations, and strip chart recorder gain variations.

Allowing for a 1% increase in \( V_o \) as \( R_L \) increases from 10 k\( \Omega \) to an open circuit, we require

\[
\frac{10 \text{ k}\Omega}{R_o + 10 \text{ k}\Omega} = 0.99
\]

Solving we find that \( R_o = 101 \text{ \Omega} \), therefore we specify an amplifier with

\[
R_{\text{moc}} = 1000 \text{ \Omega} \pm 1%
\]

\[
R_i < 10 \text{ \Omega}
\]

\[
R_o \leq 101 \text{ \Omega}
\]

*Problem 1.49*

We need an amplifier with high input resistance, low output resistance, and a voltage gain of 10. Thus a nearly ideal voltage amplifier is needed. Let us allow for ±1% variations in the output voltage due to changes in source resistance, in amplifier gain, and in load resistance. The equivalent circuit for the system is: