Problem 1

From the data sheets, the gain-bandwidth product ($B_{W_0}$) is

LMV324, $B_{W_0} = 1 \text{ MHz}$
LF347, $B_{W_0} = 4 \text{ MHz}$

**Circuit 1**

$\text{gain} = 2 \Rightarrow f = \frac{B_{W_0}}{2} = \frac{1 \text{ MHz}}{2} = 500 \text{ kHz}$

Also acceptable, $\text{gain} = 1$ and $f = 1 \text{ MHz}$

**Circuit 2**

$\text{gain} = 10 \Rightarrow f = \frac{B_{W_0}}{10} = \frac{4 \text{ MHz}}{10} = 400 \text{ kHz}$

**Circuit 3**

$\text{gain} = 1 \Rightarrow f = \frac{B_{W_0}}{1} = \frac{1 \text{ MHz}}{1} = 1 \text{ MHz}$
Problem 2
To Solve
1) Set $V_0$ to ground
2) Set independent voltage sources to short
3) Set independent current sources to open
4) Find resistance at $(+)$ term to gnd $(R_+)$
5) $(-) -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= -= ''.
Circuit 2

\[ R_+ = R_x \]
\[ R_- = R_1 || R_2 || R_F \]
\[ R_x = R_1 || R_2 || R_F \]

- To find gain, note that current through \( R_x = 0 \) ⇒ Replace \( R_x \) by a short.

\[ I = 0 \]

\[ V_m = 0 \]

because of C.F.B.
Since we have (-) F.B. \( V_+ = V_- = 0 \) and \( V_+ = 0 \) so \( V_- = 0 \)

Use KCL at \( V_- \) node

\[
KCL \quad I_S = I_t + I_F
\]

\[
I_S = \frac{V_{in} - 0}{R_S} = \frac{V_{in}}{R_S} \quad \Rightarrow \quad I_t = \frac{0 - 0}{R_1} = 0
\]

\[
I_F = \frac{0 - V_0}{R_F} = -\frac{V_0}{R_F}
\]

Plug into KCL

\[
\frac{V_{in}}{R_S} = 0 - \frac{V_0}{R_F} \quad \Rightarrow \quad \frac{V_0}{V_{in}} = -\frac{R_F}{R_S}
\]
Circuit 3 : $R_X$ has no current = 0 Rep by Short

\[ \frac{V_o}{V_X} = (1 + \frac{110}{20}) \quad \text{and} \quad V_X = (10K) I_S \]

\[ \Rightarrow \frac{V_0}{I_S} = (10,000)(1 + \frac{110}{20}) \]

To find $R_X$, set $I_S = 0$ (open) and Short $V_o$

\[ R_+ = R_X + 10K \]
\[ R_- = 20K \parallel 110K \]
\[ R_X = \left( \frac{20K}{110K} \right) - 10K \]
\[ = 6923 \Omega \]
Circuit 4

First find gain. Rx has no current

Replace Rx by a Short

\[ I_s = I_f \]

\[ I_f = \frac{0 - V_o}{R_f} = -\frac{V_o}{R_f} \]

Plug into KCL

\[ I_s = -\frac{V_o}{R_f} \]

\[ \frac{V_o}{I_s} = -R_f \]

OR \[ V_o = -I_sR_f \]

To find Rx, set \[ I_s = 0 \] (open) and short \[ V_o \]
\[ R_+ = R_x \quad R_- = R_f \]

So \[ R_x = R_f \]

**Problem 3**

\[ V_1 = -5 \]

\[ V_2 = 5V \]

\[ V_3 = -0.7 \text{ or } 0 \text{ if you use Ideal diode} \]

\[ V_4 = V_3 - V_2 = -5.7V \text{ or } -5V \text{ if you used Ideal Diode} \]

\[ V_5 = (-5.7V) \cdot 10 = +57V = 0 \text{ can't go that high, } V_5 = 15V \]

\[ V_0 = 5V \]
Problem

For any opamp it must be true that \( \frac{dV_o}{dt} \) ≤ SR, where SR is the Slew Rate Spec for the op-Amp. For both circuits, \( \frac{V_o}{V_{in}} = 1 \) so \( V_o = A \sin(\omega t) \).

Thus, \( \frac{dV_o}{dt} = AW \cos(\omega t) \). The maximum value for \( \frac{dV_o}{dt} \) occurs when \( \cos(\omega t) = 1 \) so

\[
\left. \frac{dV_o}{dt} \right|_{\text{max}} = AW
\]

For our circuits, to not see Slew Rate distortion, we need

\[
\left. \frac{dV_o}{dt} \right|_{\text{max}} < \text{SR} \quad \text{or} \quad AW < \text{SR}
\]
Circuit (A)

For the LF347

SR = 13V/μs

or SR = 13,000,000V/s

i) For \( w = 100,000 \) ρ/s

\[ AW \leq SR \]

or \( A \leq \frac{SR}{W} \)

or \( A \leq \frac{13,000,000}{100,000} \)

or \( A \leq 130V \)

- Since our largest possible input is ±15V, we will never see SR distortion at this frequency.

ii) For \( A = 10V \)

\[ AW \leq SR \]

or \( W \leq \frac{SR}{A} \)

or \( W \leq \frac{13,000,000}{10} \)

\( \Rightarrow W \leq 1.3 \text{ MHz} \)
Since \( w = 2\pi f \) we get
\[
F = \frac{w}{2\pi} = \frac{1,300,000 \text{ rls}}{2\pi \text{ r/cycle}} = 207,006 \text{ Hz}
\]
So for \( F \leq 207,006 \text{ Hz} \), we will not see any SR distortion for a 10V amplitude output sine wave, \( V_0 = 10 \sin \omega t \).

**Circuit B**

For the LMV324, \( SR = 1 \text{V/}\mu\text{s} = 1,000,000 \text{ V/s} \)

\( w \) for \( w = 100,000 \text{ rls} \)

\[
A_w \leq SR
\]

OR

\[
A \leq \frac{SR}{w}
\]

OR

\[
A \leq \frac{1,000,000}{100,000} = 10
\]

So, for \( w = 100,000 \text{ rls} \), the largest output we can have is \( 10 \sin \omega t \).
ii) For $A = 10\text{V}$

$$AW \leq SR$$

or

$$W \leq \frac{SR}{A}$$

or

$$W \leq \frac{1,000,000}{10}$$

or

$$W \leq 100,000 \text{ r/s}$$

or

$$F \leq 15,915 \text{ Hz}$$

So for $F \leq 15,915 \text{ Hz}$, we will not see any $\&$ SR distortion for $V_0 = 10 \sin \omega t$