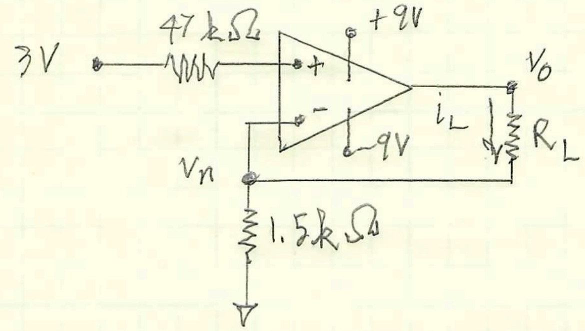
1) 5.39)



3V source tied to v_p. So $v_p = 3V$.
In linear region $v_n = v_p = 3V$.

a) Voltage division: $v_n = 3V = \frac{1.5k\Omega}{R_L + 1.5k\Omega} v_o$

Using $R_L = 2.5k\Omega \Rightarrow v_o = \frac{4}{1.5} 3V = 8V \Rightarrow i_L = \frac{8V - 3V}{2.5k} = \underline{\underline{2mA}}$

b) Output voltage is bound by ±9V. (Because input voltage is positive, the −9V limit isn't a factor.)

Voltage division when $v_o = 9V$: $v_n = 3V = \frac{1.5k}{R_L + 1.5k} 9V$

$\Rightarrow R_L + 1.5k = 4.5k \Rightarrow R_{L\,max} = \underline{\underline{3k\Omega}}$

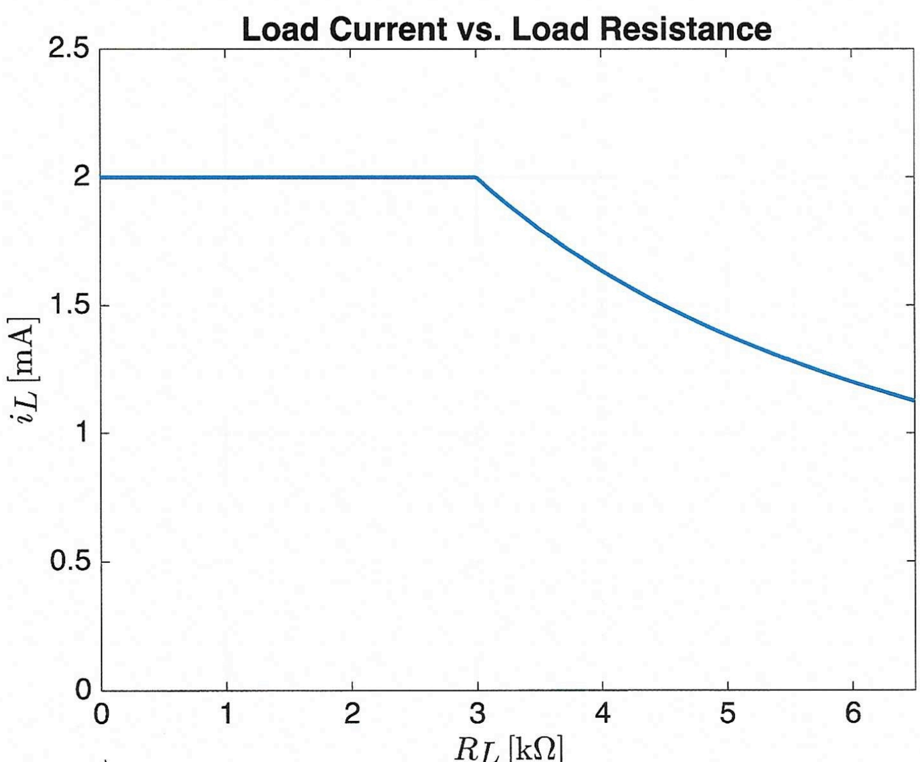
c) Beyond $R_L = 3k\Omega$, v_o will be pegged at 9V. As R_L increases, more of this voltage, i.e., more of the 9V, would be dropped across R_L and less across the 1.5kΩ resistor. Thus, v_n would drop below 3V, but the op-amp couldn't do anything more to try to bring v_n and v_p back together.

d) See plot on next page.

1) d) (continued)

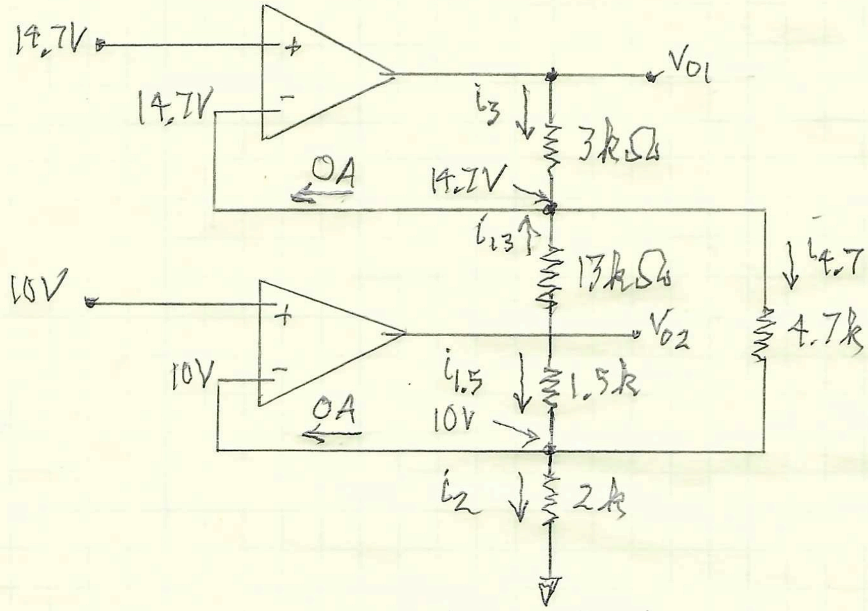
```
% N&R Prob. 5.39(d).
% Create resistances between 0 and 6.5k, but will leave "k" understood.
rl = linspace(0, 6.5, 351);
% Current for R_L less than 3k is a constant 2 mA.
il = (2) * (rl < 3);
% Add current for R_L greater than 3k when output fixed at 9 V.
il = il + (9 ./ (rl + 1.5)) .* ~(rl < 3);

plot(rl, il, 'LineWidth', 2 )
grid on
set(gca, 'FontSize', 16)
xlabel('$R_L$ [k$\Omega$]', 'Interpreter', 'latex')
ylabel('$i_L$ [mA]', 'Interpreter', 'latex')
title('Load Current vs. Load Resistance')
axis([0 6.5 0 2.5])
```



Circuit acts like a constant current source for loads in this range.

2) 5.42



$i_2 = 10V/2000 = 5mA, \quad i_{4.7} = (14.7-10)V/4700 = 1mA$

$i_{1.5} + i_{4.7} = i_2 \Rightarrow i_{1.5} = i_2 - i_{4.7} = 4mA$

$\Rightarrow V_{O2} = 10V + i_{1.5}\, 1500\Omega = 10 + 6 = \underline{\underline{16V = V_{O2}}}$

$i_{13} = (V_{O2} - 14.7V)/13000\Omega = 0.1mA$

$i_3 + i_{13} = i_{4.7} \Rightarrow i_3 = i_{4.7} - i_{13} = 1mA - 0.1mA = 0.9mA$

$\Rightarrow V_{O1} = 14.7V + i_3\, 3000\Omega = 14.7 + 2.7 = \underline{\underline{17.4V = V_{O1}}}$

3)
$$i(t) = \begin{cases} 10\ \text{A}, & t < 0 \\ 10(t+1)e^{-2t}\ \text{A}, & 0 \le t \le 1\,\text{s} \\ 20e^{-2}\ \text{A}, & 1\,\text{s} < t \end{cases}$$

$L = 15\ \text{mH}$, $\quad v(t) = L\dfrac{di(t)}{dt}$

$$\Rightarrow v(t) = \begin{cases} 0, & t < 0 \\ 0.15\left(10e^{-2t} - 20(t+1)e^{-2t}\right) = -0.15(2t+1)e^{-2t}\ \text{V}, & 0 < t < 1\,\text{s} \\ 0, & 1\,\text{s} < t \end{cases}$$

The voltage is discontinuos and undefined at $t=0$ and $t=1$.
Plot (optional) is shown on next page.

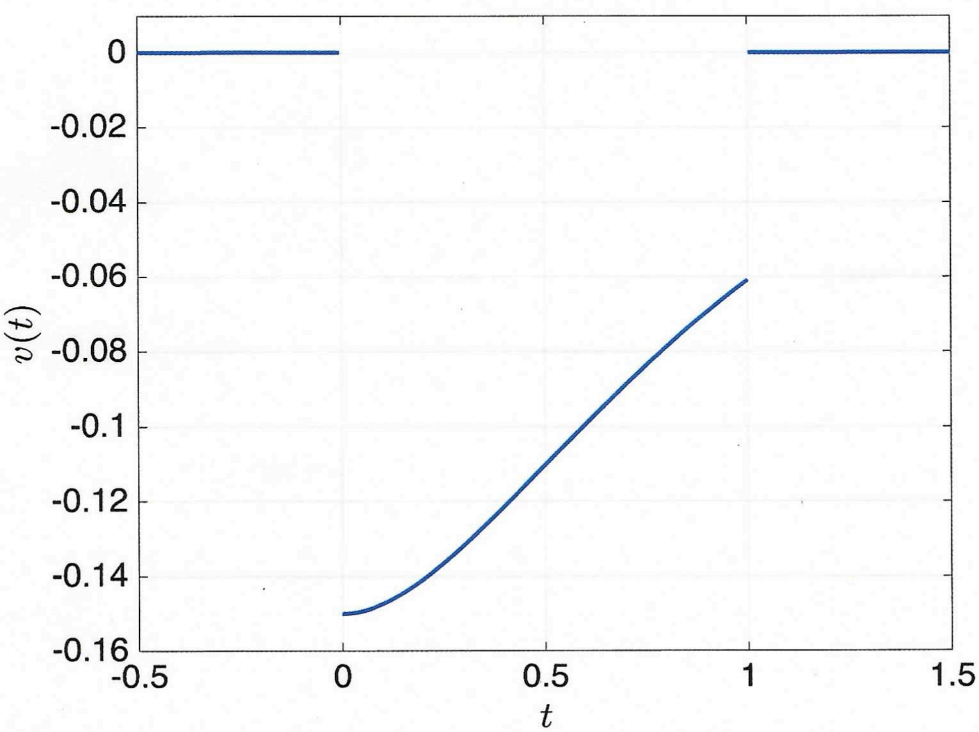
3) (continued, optional)

```
% EE 261, HW 7, Problem 3

t = linspace(-0.5, 1.5, 601);

v0 = zeros(1,length(t));
v1 = -0.15 * (2 * t + 1) .* exp(-2 * t);

plot(t(t<0),v0(t<0), 'b', 'LineWidth', 2)
hold on
plot(t(all([t >= 0; t <= 1])), v1(all([t >= 0; t <= 1])), ...
    'b', 'LineWidth', 2)
plot(t(t>1),v0(t>1), 'b', 'LineWidth', 2)
xlabel('$t$', 'Interpreter', 'latex')
ylabel('$v(t)$', 'Interpreter', 'latex')
grid on
axis([-0.5 1.5 -0.16 0.01])
set(gca, 'FontSize', 18)
```



4) $C = 100\,\mu F = 10^{-4} F$. Initially uncharged.

$$v_c(t) = \frac{1}{C}\int_{t_0}^{t} i(t)\,dt + v_c(t_0)$$

For $t<0$, $v_c(t) = \cancel{10^4\int_{-\infty}^{t} 0\,d\tau}^{\,0} + \cancel{v_c(-\infty)}^{\,0} = 0\,V$

For $0<t<1s$, $v_c(t) = 10^4\int_0^t (-5\times10^{-4})\,d\tau + v_c(0) = -5\tau\Big]_0^t + 0 = -5t\ V$

Note: $v_c(1) = -5V$

For $1<t<2s$, $v_c(t) = \cancel{10^4\int_1^t 0\,d\tau}^{\,0} + v_c(1) = 0 - 5V = -5V$

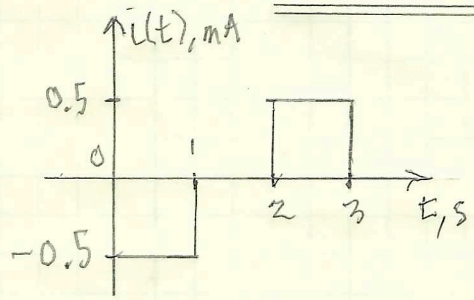
Note: $v_c(2) = -5V$

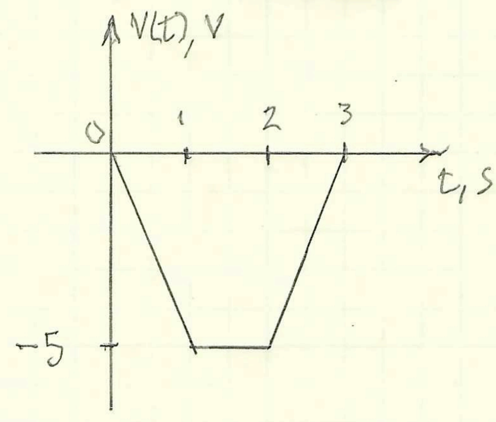
For $2<t<3s$, $v_c(t) = 10^4\int_2^t (5\times10^{4})\tau + v_c(2) = 5\tau\Big]_2^t - 5 = 5(t-2) - 5 = 5(t-3)\ V$

Note: $v_c(3) = 0\,V$

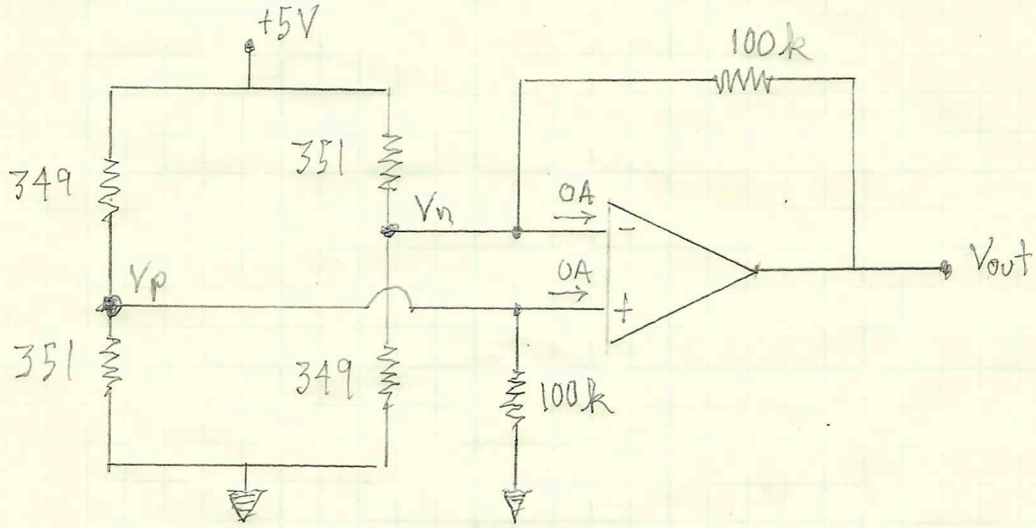
For $t>3$, $v_c(t) = \cancel{10^4\int_3^t 0\,d\tau}^{\,0} + v_c(3) = 0 + 0 = 0$

$$\Rightarrow v_c(t) = \begin{cases} 0V & \text{for } t\le 0 \\ -5t\,V & \text{for } 0\le t\le 1s \\ -5V & \text{for } 1\le t\le 2s \\ 5(t-3)\,V & \text{for } 2\le t\le 3s \\ 0 & \text{for } t\ge 3s \end{cases}$$





5)



Can obtain voltage at V_p from voltage division. Note that the 351Ω resistor is in parallel with the 100kΩ at non-inverting terminal.

$$351\Omega \,||\, 100k\Omega = 349.772\,\Omega$$

$$\Rightarrow V_p = \frac{349.772}{349 + 349.772}(5V) = 2.50276\,V = V_n$$

$V_n = V_p$. Now write KCL at inverting terminal.

$$\frac{V_n - 5}{351} + \frac{V_n}{349} + \frac{V_n - V_{out}}{100k} = 0$$

$$\Rightarrow \underline{\underline{V_{out}}} = 10^5\left[\frac{V_n - 5}{351} + \frac{V_n}{349}\right] + V_n = \underline{\underline{8.163\ V}}$$

Aside: If there is no strain, so that each of the resistors in the bridge (presumably) have a resistance of 350Ω, then the output voltage is zero.