1. This is the *differential amplifier* (page 200 of text).

   $V_O = \frac{18k(30k+20k)}{30k(6k+18k)}(12V) - \frac{20k}{30k}(24V) = -1V \to i_L = \frac{-1V}{5k} = -0.2mA.$

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2. $i_n = 0 \to V_o = V_n + (1mA)(9k) = 9V$ since $V_n = V_p = 0.$

   $-i_O = \frac{9V}{15k||6k} + 1mA = 3.1mA \to i_O = -3.1mA.$

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3. Thevenin equivalent of input is $V_T = v_g(\frac{4.8}{3.2+4.8}) = 0.3V, \quad R_T = 4.8k||3.2k = 1.92k\Omega.$

   Inverting amplifier (text p.196)$\to$ $V_O = -\frac{30k+\sigma 170k}{1.92k}(0.3V) = -(26.5625\sigma + 4.6875).$

   This reaches -10 when $\sigma = 0.20$. Hence no saturation for $0 < \sigma < 0.20$.

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4. Inverting summer: $v_o = -(\frac{72k}{R_a}v_a + \frac{72k}{R_b}v_b + \frac{72k}{R_c}v_c + \frac{72k}{R_d}v_d) = -(6v_a + 9v_b + 4v_c + 3v_d).$

   $\to R_a = 12k\Omega; \quad R_b = 8k\Omega; \quad R_c = 18k\Omega; \quad R_d = 24k\Omega.$

5a. $P_{16k\Omega} = \frac{(0.32V)^2}{16k\Omega} = 6.4\mu W$.(b) $(0.32V)(\frac{16k}{48k+16k}) = 0.08V.P_{16k\Omega} = \frac{(0.08V)^2}{16k\Omega} = 0.4\mu W.$

5c. Ratio$=\frac{6.4\mu W}{0.4\mu W} = 16$. (d) This circuit isolates the weak 320 mV source from the load. The op-amp supplies current and voltage so that its output *follows* the input.

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6. Noninverting amp with input $v_g\frac{5.6k}{2.4k+5.6k} = 0.7v_g$ and gain $1 + \frac{75k}{15k} = 6$.

   Without saturation, $v_o(t) = 6(0.7)10\sin(\pi/3)t = 42\sin(\pi/3)t$ for $t > 0$.
   With saturation at $\pm 21V$, the sine wave *clips* at $\pm 21V$.

7a. $i_n = 0 \to v = v_p = v_n = v_o(\frac{R}{R+R}) = \frac{v_o}{2} \to v_o = 2v.$

   $i_p = 0 \to v_o = v - iR$. Combining these$\to$ $2v = v - iR \to v = -iR$. QED.

7b. But this relation only holds as long as the op-amp doesn't saturate, i.e., $|v_o| < 15V$. So the circuit acts like a negative resistor only over a limited range of v and i.

EECS 210 PROBLEM SET #7 Winter 2001

ASSIGNED: March 2, 2001. **Read:** Sects. 9.1-9.5 (skip Chaps. 7 & 8) and Appendix B of the text.
DUE DATE: March 9, 2001. **In Lab Book:** Read Unit #4, Lab Lecture #4 and Lab Experiment #4.

THIS WEEK: Inductors and capacitors and complex numbers.

1. Text #6.4. Just apply the integral counterpart to v=L(di/dt), but watch units! Use Matlab for (b). Note that inductor current must be continuous at t=0.001 and t=0.002 seconds--a useful check.
2. Text #6.7. Compute **numerical values** for A_1 and A_2. Let $x=e^{5000t}$ in (b)
3. Text #6.19. Requires a nasty derivative; otherwise easy. You should already know answer to (c).
4. Text #6.21. Combining inductors in series and parallel. All integers after the beginning.
5. Text #6.26a-e. Careful on (c) and (d)--the initial currents must match the given values.

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6. For each of the following pairs of complex numbers, do the following:
   - Multiply them directly in rectangular form, getting an answer in rectangular form;
   - Convert to polar form, multiply in polar form, convert product back to rectangular form.
   - {4+j3,5+j12}; {4+j3,$(5+j12)^*$}; {4+j3,1/(5+j12)}; {1/(4+j3),1/(5+j12)}; {$(4+j3)^*$,(5+j12)}

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7. Show complex number [5(8+j)(8+j6)(5+j12)(5+j10)]/[26(7+j4)(7+j24)(2+j11)] has magnitude=1.

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8. Use trig identity from Problem Set #1 to show 5cos(3t+30°)+5sin(3t)+5cos(3t-210°)=0 exactly! Now use phasor representations of the sinusoids to show it. Plot the phasors in the complex plane.

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9. **Ungraded:** We are given two unmarked boxes, each with a pair of wires sticking out of it. One contains the Thevenin equivalent of a circuit; the other contains its Norton equivalent. Explain how to **distinguish** the Thevenin equivalent box from the Norton equivalent box. HINT: This *cannot* be done using i-v characteristics of the two boxes; need something else.

"An optimist is an accordion player with a beeper"--Ted Koppel.