---

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

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

---

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

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

---

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)$\rightarrow V_O = -\frac{30k+\sigma 170k}{1.92k}(0.3V) = -(26.5625\sigma + 4.6875).$

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

---

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

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

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.

---

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

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