14.5

(a) $V_{out} = i_D R_L$

Given a large enough value of V_D,
$V_{out} = 0.5 \times 10^{-6} H R_L$; hence, varies linearly with H.

(b) $1 = 0.5 \times 10^{-6}(1500) R_L$

$R_L = 1333\Omega$

14.8

$$mean = \frac{\sum measurements}{20} = 9.945 \pm 2\%$$

max. = 10.144

min. = 9.746

$$average\ deviation = \frac{\sum |deviations|}{20} = 0.225$$

$$standard\ deviation = \sqrt{\frac{\sum |deviations|^2}{20}} = 0.427$$

Measurement #1 exceeds the standard deviation $\Rightarrow$ probability<0.99 $\Rightarrow$ roller speed will be adjusted

14.10

(a) (b) and (c) are precise, (a) and (d) are not.

(b) (a) and (c) are accurate, (b) and (d) are not.

14.11

$$A = 1 + \frac{2R_2}{R_1} = 1 + \frac{1(5k\Omega)}{1k\Omega} = 1 + 10 = 11$$

14.17

$$CMRR_{dB} = 20\log_{10}\left|\frac{A_{dif}}{\frac{R_F}{R}\left(\frac{R+R_F}{R_F+R+\Delta R}-1\right)A}\right|$$

$$A_{dif} = A \times \frac{R_F}{R}$$

$$\Delta R = 0.02 \times R = 0.02 \times 1k\Omega = 20\Omega$$

$$CMRR_{dB} = 20\log_{10}\left|\frac{A\frac{R_F}{R}}{\frac{R_F}{R}\left(\frac{R+R_F}{R_F+R+\Delta R}\right)A}\right|$$

$$= 20\log_{10}\left|\frac{1}{\frac{R+R_F}{R_F+R+\Delta R}-1}\right|$$

$$= 20\log_{10}\left|\frac{1}{\frac{1000+200000}{200000+1000+20}-1}\right|$$

$$\approx 80dB$$

14.32

$$f_C = 10\,Hz = \frac{1}{2\pi RC}$$

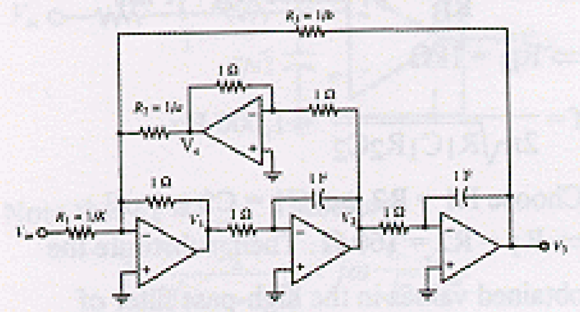
$$\Rightarrow \omega_C = \frac{1}{RC} = 2\pi \times 10 = 20\pi \frac{rad}{s}$$

Choose $R = 20k\Omega$. Then,

$$\frac{1}{(20k\Omega)C} = 20\pi \Rightarrow C = \frac{1}{20\times 10^3 \times 20\pi} = 796nF$$

and the two capacitors have values given by $\sqrt{2}C = 1.125\mu F$ and $\frac{C}{\sqrt{2}} = 563nF$.

14.34



Using Laplace transforms, note that

$$V_2 = -\frac{1}{s}V_1$$

$$V_3 = -\frac{1}{s}V_2 = \frac{1}{s^2}V_1$$

and

$$V_4 = -V_2 = \frac{1}{s}V_1$$

Writing a KCL equation at the inverting input to the leftmost op-amp,

$$-KV_{in} - V_1 - aV_4 - bV_3 = 0$$

or

$$-KV_{in} - V_1 - \frac{a}{s}V_1 - \frac{b}{s^2}V_1 = 0$$

$$\Rightarrow \quad \frac{V_1}{V_{in}} = -\frac{Ks^2}{s^2+as+b}$$

which is a second-order high-pass function.

Also,

$$\frac{V_2}{V_{in}} = -\frac{1}{s}\frac{V_1}{V_{in}} = \frac{Ks}{s^2+as+b}$$

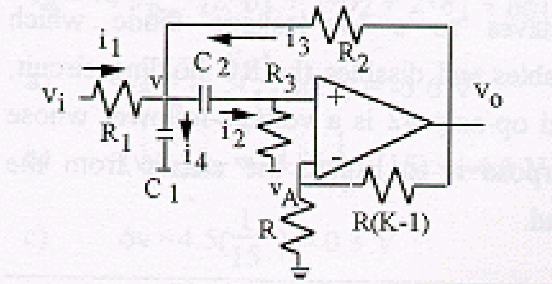
which is a bandpass function, and

$$\frac{V_3}{V_{in}} = \frac{1}{s^2}\frac{V_1}{V_{in}} = -\frac{K}{s^2+as+b}$$

which is a low-pass function.

14.36

The circuit is shown below:



We have

$$v_A = \frac{R\,v_o}{R + R(K-1)} = \frac{v_o}{K}$$

$$i_1 = \frac{v_i - v}{R_1}$$

$$i_2 = \frac{v - v_A}{1/j\omega C_2} = \frac{v_A}{R_3}$$

$$i_3 = \frac{v_o - v}{R_2}$$

$$i_4 = \frac{v}{1/j\omega C_1}$$

From $i_2 = \frac{v_A}{R_3} = \frac{v - v_A}{1/j\omega C_2}$, we have

$$v = \frac{v_A}{j\omega C_2 R_3} + v_A = \left(\frac{1}{j\omega C_2 R_3} + 1\right)\frac{v_o}{K}$$

From $i_1 + i_3 = i_2 + i_4$, we have

$$\frac{v_i}{R_1} - \left(\frac{1}{j\omega C_2 R_3} + 1\right)\frac{v_o}{KR_1}$$

$$+ \frac{v_o}{R_2} - \left(\frac{1}{j\omega C_2 R_3} + 1\right)\frac{v_o}{KR_2}$$

$$= \frac{v_o}{KR_3} + \left(\frac{j\omega C_1}{j\omega C_2 R_3} + j\omega C_1\right)\frac{v_o}{K}$$

The frequency response therefore is:

$$\frac{v_o(j\omega)}{v_i(j\omega)} = \frac{j\omega K/C_1R_1}{(j\omega)^2 + K_1 j\omega + K_2}$$

where

$$K_1 = \frac{1}{C_1R_1} + \frac{1}{C_2R_3} + \frac{1}{R_1C_1} - \frac{K}{R_2C_1} + \frac{1}{R_2C_1}$$

and

$$K_2 = \frac{R_1 + R_2}{R_1R_2R_3C_1C_2}$$