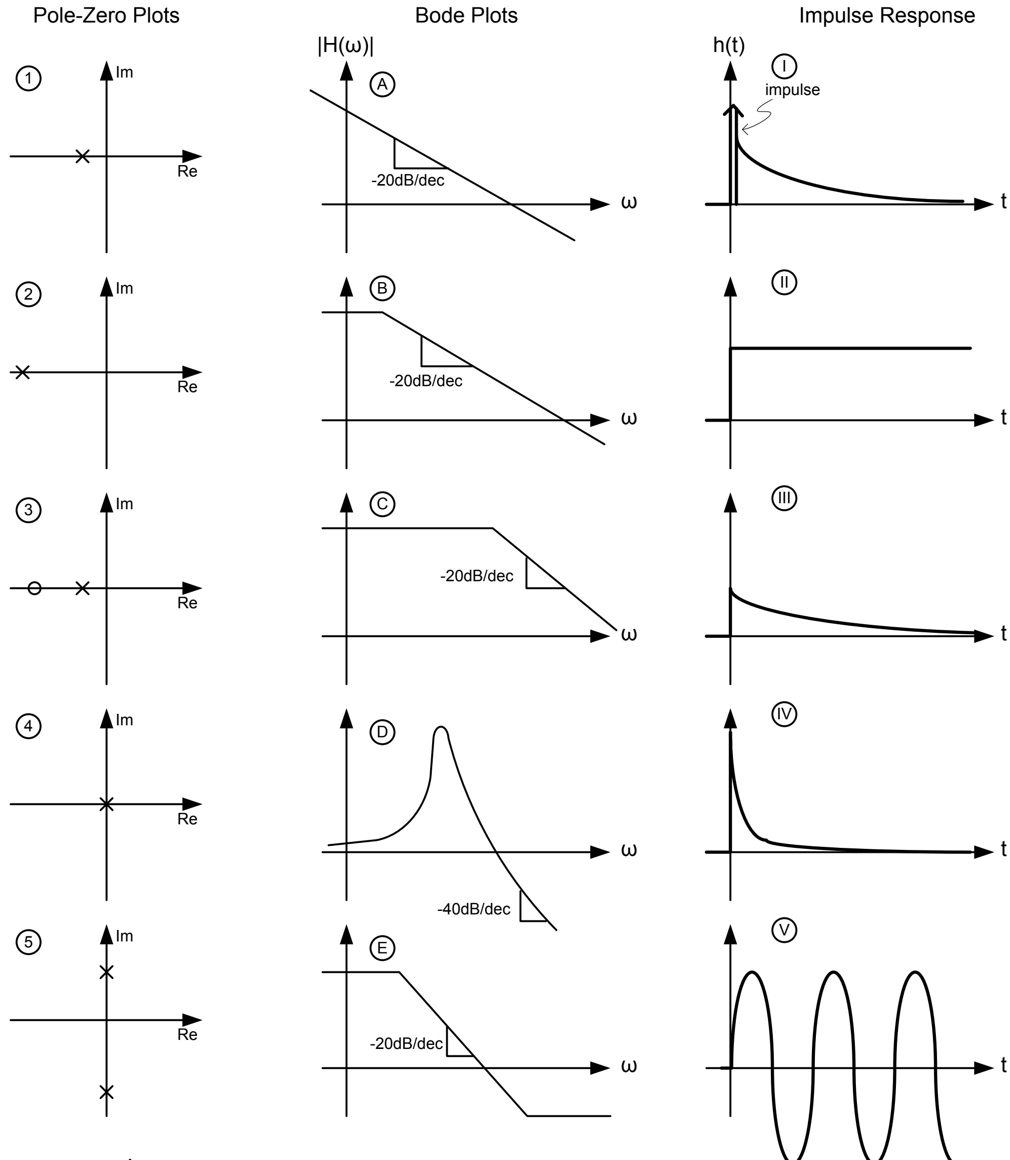
Problem 1
Match each pole-zero plot with a Bode plot, and a time-domain plot of h(t). Hint: try recreating H(s) given the pole-zero plot.



① eg $H(s) = \frac{1}{s+1}$ could be Ⓑ or Ⓒ. But ② $H(s)$ is, eg $\frac{1}{s+10}$ so ① is Ⓑ, Ⅲ

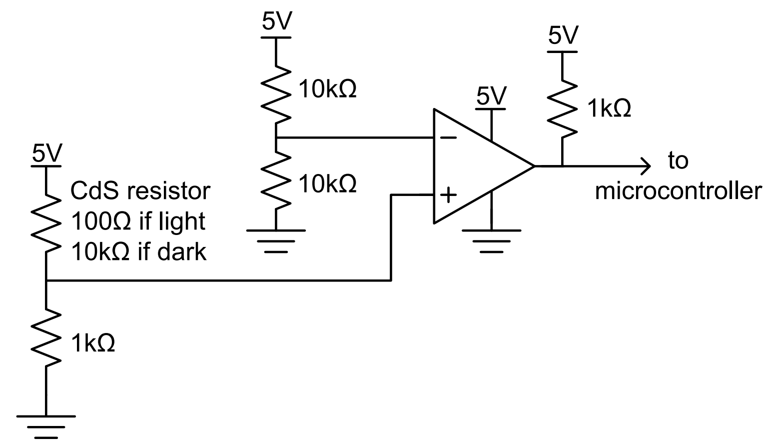
$\boxed{①\ Ⓑ\ Ⅲ}$

② By above reasoning, $\boxed{②\ Ⓒ\ Ⅳ}$

③ $\frac{s+1}{s+5}$ so Ⓔ. Divide through, get $H(s) = 1 + \frac{\text{something}}{s+5}$ ⇒ Ⅰ so $\boxed{③\ Ⓔ\ Ⅰ}$

④ $\frac{1}{s}$ ⇒ $\boxed{④\ Ⓐ\ Ⅱ}$ Leaving $\boxed{⑤\ Ⓓ\ Ⅴ}$

Problem 2
You are designing a sensor system for an automatically-closing microprocessor-controlled miniblind system. The light sensor outputs a digital signal to a microprocessor. You design the following circuit:



It works well when exposed to sunlight and in an office lit by incandescent light, but works unreliabily in an office lit by fluorescent lights.

a) Why? Fluorescent lights flicker at 120 Hz.
($v(t)$ is 60Hz, so $p(t) = v^2(t)/R$ is 120Hz since $\cos^2(\omega t) = \frac{1}{2} + \frac{1}{2}\cos(2\omega t)$)

b) What kind of filter (LP, BP, BS, HP) would prevent this? $\boxed{\text{LP}}$

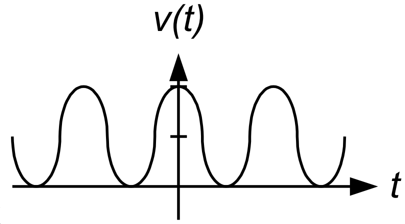
c) Where would you put the filter? What order would you use? $\boxed{\text{Long lower wire}}$ (not after the comparator or else giving μC an analog input). Not critical to have sharp cutoff, so keep it simple with $\boxed{\text{first order}}$ RC filter.

d) What would you design its cutoff frequency to be?
Anything in range 0.01 - 12 Hz is fine

e) Why would 10kHz be a poor choice for filter cutoff frequency? Would let through 120Hz noise

f) Why would 100µHz be a poor choice for filter cutoff frequency?
① Would take on order of $\frac{1}{100\mu} = \frac{1}{0.1m} = 10ks \approx 3$ hours to react
② Would require huge capacitors

Problem 3



b) Find numeric values for the Fourier Series coefficients a_0, a_1, a_2, b_1, and b_2 for $v(t) = 1 + \cos(2t)$ as shown:

OK way: evaluate integrals, eg $\begin{cases} a_n = \frac{2}{T}\int_{<T>} v(t)\cos(n\omega_0 t)\,dt \\ b_n = \frac{2}{T}\int_{<T>} v(t)\sin(n\omega_0 t)\,dt \end{cases}$

Smarter way: recognize $v(t)$ is even, so $b_n = 0$

Best way: recognize $v(t) = A_0 + A_1\cos(\omega_0 t + \phi_1)$ so $\begin{cases} A_0 = 1 \\ A_1 = 1 \\ \phi_1 = 0 \end{cases}$

then $\boxed{a_0 = A_0 = 1}$

$a_1 - jb_1 = A_1 \angle\phi_1$

$= 1\angle 0^\circ$

$= 1 + j0$

$\boxed{a_1 = 1,\ b_1 = 0}$

b) If the waveform was very slightly shifted to the right, which components would increase, decrease, or stay the same?

One way: $v(t)$ to right by t_0 is $v(t - t_0) = 1 + \cos(2t - t_0)$

say "slight shift" $\Rightarrow t_0 = 0.1$ so new function is $1 + \cos(2t - 0.1)$

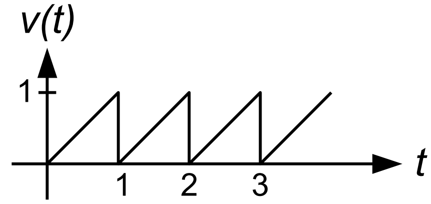
So $A_0 = 1 = \boxed{a_0 \text{ unchanged}}$

$A_1 \angle\phi_1 = 1\angle{-0.1} = \underbrace{0.999}_{\boxed{a_1 \text{ decrease}}} - j\underbrace{0.001}_{\boxed{b_1 \text{ increase}}}$

Very clever way: recognize that as right shift get to $\frac{\pi}{2}$, function becomes $1 + \sin(2t)$ so

$\boxed{\begin{array}{ll} a_0 & \text{same} \\ a_1 & \text{decreases} \\ b_1 & \text{increases} \end{array}}$ $\begin{array}{l} (0 \text{ for } \frac{\pi}{2} \text{ shift}) \\ (1 \text{ for } \pi/2 \text{ shift}) \end{array}$

Problem 4



Find c_{-2}, c_{-1}, c_0, c_1, and c_2 in complex polar form for the complex Fourier Series coefficients of the waveform.

$f(t) = t$, $T = 1$, $\omega_0 = \frac{2\pi}{T} = 2\pi$

$C_0 = \boxed{\frac{1}{2}}$ by inspection (average)

$C_1 = \frac{1}{T}\int_{\langle T \rangle} f(t)\, e^{-j\omega_0 n t}\, dt$

$= \int_0^1 t\, e^{-j2\pi t}\, dt$

$= \frac{1}{4\pi^2} e^{-j2\pi t} + \frac{j}{2\pi} t\, e^{-j2\pi t} \Big]_{t=0}^{1}$

$= \frac{j}{2\pi} = \boxed{j0.159}$

$C_{-1} = C_1^* = \boxed{-j0.159}$

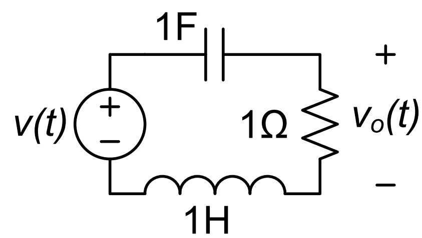
$C_2 = \int_0^1 t\, e^{-j4\pi t}\, dt$

$= \frac{1}{16\pi^2} e^{-j4\pi t} + \frac{j}{4\pi} t\, e^{-j4\pi t} \Big]_{t=0}^{1}$

$= \frac{j}{4\pi} = \boxed{j0.0796}$

$C_{-2} = C_2^* = \boxed{-j0.0796}$

Problem 5



The waveform from Problem 4 is applied to this circuit: Find the DC and first two harmonics of $v_o(t)$

$H(s) = \frac{1}{\frac{1}{s} + 1 + s} = \frac{s}{s^2 + s + 1}$

n	$\omega = n\omega_0$	$A_n \angle \phi_n$	$H(\omega)$	$A_n' \angle \phi_n' = A_n \angle \phi_n H(\omega)$
0	0	$= C_0 = 1/2$	$\frac{0}{1} = 0$	0
1	2π	$= 2C_1 = j/\pi$	$\frac{j2\pi}{(j2\pi)^2 + j2\pi + 1}$	$0.0513 \angle 9.27°$
2	4π	$= 2C_2 = \frac{j}{2\pi}$	$\frac{j4\pi}{(j4\pi)^2 + j4\pi + 1}$	$0.0127 \angle 4.58°$

$\boxed{v(t) = 0.0513 \cos(2\pi t + 9.27°) + 0.0127 \cos(4\pi t + 4.58°)\ \text{V}}$