Problem 1. Timed Spec

a)
PROC TimedP() =
VAR t: Time := now + minLatency |
P();
DO now < t => SKIP OD

b) Initialization:
<< deadlines := { now } + deadlines >>

Delay implementation:
PROC delay(k: Int) =
VAR t: Time := now |
<< deadlines := deadlines - { t } + { t + k }; >>
DO (now < t+k) => SKIP OD

c) In the implementation from c) time passes if any of the user threads is in its delay action, as opposed to time passing only when all user threads are in their delay actions.

Problem 2. Optimizing for the Uncommon Case

Average running time after the transformation A is:
\[
\frac{(1-x)9+1}{10} = 1 - 0.9x
\]

Average running time after the transformation B is:
\[
\frac{7 + (1-y)3}{10} = 1 - 0.3y
\]

a) A is better iff \( y < 3x \), B is better iff \( y > 3x \) and they are equally bad iff \( y = 3x \).

b) When \( 3x \geq 1 \) i.e. \( x \geq 1/3 \) then B cannot be better than A. There is no value of B that guarantees that A can never be better.

Problem 3. Web Server

CPU utilization is \( u_c = cn \). The request needs to be served first by CPU, which takes \( c/(1 - nc) \). There is no queue on the disk because all requests must first pass through CPU. So the total average response time is:
\[
\frac{c}{1 - nc} + d
\]
Problem 4. Widgets

Each transaction requires
\[ 6ms + \frac{2KB}{50MB/s} = 6.04ms \]
of disk time. Each transaction requires:
\[ \frac{200K}{800M/s} = 0.25ms \]
of processor time.

a) \[ \frac{6.04ms}{0.25ms} = 24.16 \]
so we need 25 disks.

b) Now the latency is averaged over a batch of 10 transactions, so latency becomes 0.6ms per transaction and total disk time per transaction is 0.64ms.
\[ \frac{0.64ms}{0.25ms} = 2.56 \]
so we need 3 disks.

c) Now the CPU is the bottleneck so it determines the bottleneck. The rate is the inverse of time spent by the processor per request.
\[ n = \frac{1}{0.25ms} = 4(ms)^{-1} \]
So the rate is 4 transactions per millisecond.