Solution 1

1.

```
#define PBIN (volatile unsigned char *) 0xFFFFFFF3
#define PBOUT (volatile unsigned char *) 0xFFFFFFF4
#define PBDIR (volatile unsigned char *) 0xFFFFFFF5
#define PSTAT (volatile unsigned char *) 0xFFFFFFF6
#define CNTM (volatile unsigned int *) 0xFFFFFFD0
#define CTCON (volatile unsigned char *) 0xFFFFFFD8
#define CTSTAT (volatile unsigned char *) 0xFFFFFFD9
#define IVECT (volatile unsigned int *) (0x20)

interrupt void intserv();

volatile unsigned char digit = 0;          /* digit for display */

int main() {
  unsigned char sample = 0;                /* Port B input sample */

  *PBDIR = 0xF0;                           /* Set Port B direction */
  *CTCON = 0x2;                            /* Stop Timer (if running) */
  *CTSTAT = 0x0;                           /* Clear "Reached 0" flag */
  *CNTM = 100000000;                       /* Initialize: 1-s timeout */
  *IVECT = (unsigned int *) &intserv;      /* Set interrupt vector */
  asm("MoveControl PSR,#0x40");            /* CPU responds to IRQ */
  *CTCON = 0x1;                            /* Start Timer, disable
                                              interrupts for now */
  *PBOUT = 0x0;                            /* Display 0 */
  while (1) {
    while ((*PSTAT & 0x4) == 0);           /* Wait for PBIN update */
    sample = *PBIN & 0x3;      /* Sample PBIN, isolate bits [1:0] */
    if (sample == 0x1)         /* E = 0, D = 1 */
      *CTCON |= 0x10;          /* Enable Timer interrupts */
    else if (sample == 0x2)    /* E = 1, D = 0 */
      *CTCON &= 0xEF;          /* Disable Timer interrupts */
  }

  exit(0);
}

interrupt void intserv() {
  *CTSTAT = 0x0;               /* Clear "Reached 0" flag */
  digit = (digit + 1)%10;      /* Increment digit */
  *PBOUT = digit << 4;         /* Update display */
}
```

2.

```
#define PBIN (volatile unsigned char *) 0xFFFFFFF3
#define PBOUT (volatile unsigned char *) 0xFFFFFFF4
#define PBDIR (volatile unsigned char *) 0xFFFFFFF5
```

```
#define PCONT (volatile unsigned char *) 0xFFFFFFF7
#define CNTM (volatile unsigned int *) 0xFFFFFFD0
#define CTCON (volatile unsigned char *) 0xFFFFFFD8
#define CTSTAT (volatile unsigned char *) 0xFFFFFFD9
#define IVECT (volatile unsigned int *) (0x20)

interrupt void intserv();

int main() {
  char digit = 0;                          /* Digit to be displayed */

  *PBDIR = 0xF0;                           /* Set Port B direction */
  *IVECT = (unsigned int *) &intserv;      /* Set interrupt vector */
  asm("MoveControl PSR,#0x40");            /* CPU responds to IRQ */
  *PCONT = 0x40;                           /* Enable PBIN interrupts */
  *CTCON = 0x2;                            /* Stop Timer */
  *CSTAT = 0x0;                            /* Clear "reached 0" flag */
  *CNTM = 100000000;                       /* Initialize Timer */
  *PBOUT = 0x0;                            /* Display 0 */

  while (1) {
    while ((*CTSTAT & 0x1) == 0);          /* Wait until 0 is reached */
    *CSTAT = 0x0;                          /* Clear "reached 0" flag */
    digit = (digit + 1)%10;                /* Increment digit */
    *PBOUT = digit << 4;                   /* Update display */
  }

  exit(0);
}

interrupt void intserv() {
  unsigned char sample;       /* Port B input sample */
  sample = *PBIN & 0x3;       /* Sample PBIN, isolate bits [1:0] */
  if (sample == 0x1) *CTCON = 0x1;         /* Start Timer */
  else if (sample == 0x2) *CTCON = 0x2;    /* Stop Timer */
}
```

3.
Let **x** denote the I/O device activity percentage to be determined.

Maximum I/O data rate for DMA transfer is $\mathbf{R_{I/O}/d_{I/O\text{-}DMA} = 1K}$ transfers/s. DMA cost: $\mathbf{(x*1K)(N_{DMA\text{-}start} + N_{DMA\text{-}end}) = x*2.4M}$ cycles/s.

Maximum I/O data rate for polling is $\mathbf{R_{I/O}/d_{I/O} = 128K}$ transfers/s. Polling cost: $\mathbf{(x*128K)N_{poll\text{-}ready} + ((1-x)*128K)N_{poll\text{-}not\text{-}ready} = x*51.2M + 51.2M}$ cycles/s.

We know that the DMA cost is 400 times cheaper than the polling cost; therefore, **400*(x*2.4M) = x*51.2M + 51.2M**, which yields **x ≈ 0.056** (i.e., **5.6%**).

(Note: $\mathbf{1K = 2^{10}}$ and $\mathbf{1M = 2^{20}}$.)