16 - A particle moves along the *x*axis according to the equation $x = (3.00t^2 - 2.00t + 3.00)$, where x is in meters and t is in seconds.

Determine

(a) the average speed between t = 2s and t = 3s,

(b) the instantaneous speed at t =2s and at t =3s,

(c) the average acceleration between t =2s and t =3s, and

(d) the instantaneous acceleration at t=2s and t =3s.

(a) At $t = 2.00$ s, $x = \left[3.00(2.00)^2 - 2.00(2.00) + 3.00\right]$ m $= 11.0$ m.

At $t = 3.00$ s, $x = \left[3.00(9.00)^2 - 2.00(3.00) + 3.00\right]$ m $= 24.0$ m

so

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{24.0\text{ m} - 11.0\text{ m}}{3.00\text{ s} - 2.00\text{ s}} = \boxed{13.0\text{ m/s}}.$$

(b) At all times the instantaneous velocity is

$$v = \frac{d}{dt}\left(3.00t^2 - 2.00t + 3.00\right) = (6.00t - 2.00)\text{ m/s}$$

At $t = 2.00$ s, $v = \left[6.00(2.00) - 2.00\right]$ m/s $= \boxed{10.0\text{ m/s}}$.

At $t = 3.00$ s, $v = \left[6.00(3.00) - 2.00\right]$ m/s $= \boxed{16.0\text{ m/s}}$.

(c) $\bar{a} = \frac{\Delta v}{\Delta t} = \frac{16.0\text{ m/s} - 10.0\text{ m/s}}{3.00\text{ s} - 2.00\text{ s}} = \boxed{6.00\text{ m/s}^2}$

(d) At all times $a = \frac{d}{dt}(6.00 - 2.00) = \boxed{6.00\text{ m/s}^2}$. (This includes both $t = 2.00$ s and $t = 3.00$ s).

33. An electron in a cathode ray tube (CRT) accelerates from 2 x 10 ^{4} m/s to 6 x 10^6 m/s over 1.50 cm.

(a) How long does the electron take to travel this 1.50 cm?

(b) What is its acceleration?

We have $v_i = 2.00 \times 10^4 \text{ m/s}$, $v_f = 6.00 \times 10^6 \text{ m/s}$, $x_f - x_i = 1.50 \times 10^{-2} \text{ m}$.

(a) $$x_f - x_i = \frac{1}{2}(v_i + v_f)t : t = \frac{2(x_f - x_i)}{v_i + v_f} = \frac{2(1.50 \times 10^{-2} \text{ m})}{2.00 \times 10^4 \text{ m/s} + 6.00 \times 10^6 \text{ m/s}} = \boxed{4.98 \times 10^{-9} \text{ s}}$$

(b) $$v_f^2 = v_i^2 + 2a_x(x_f - x_i):$$

$$a_x = \frac{v_f^2 - v_i^2}{2(x_f - x_i)} = \frac{(6.00 \times 10^6 \text{ m/s})^2 - (2.00 \times 10^4 \text{ m/s})^2}{2(1.50 \times 10^{-2} \text{ m})} = \boxed{1.20 \times 10^{15} \text{ m/s}^2}$$

43. A student throws a set of keys vertically upward to her sorority sister, who is in a window 4.00 m above. The keys are caught 1.50 s later by the sister's outstretched hand.

(a) With what initial velocity were the keys thrown?

(b) What was the velocity of the keys just before they were caught?

(a) $$y_f - y_i = v_i t + \frac{1}{2}at^2 : 4.00 = (1.50)v_i - (4.90)(1.50)^2 \text{ and } v_i = \boxed{10.0 \text{ m/s upward}}.$$

(b) $$v_f = v_i + at = 10.0 - (9.80)(1.50) = -4.68 \text{ m/s}$$

$$v_f = \boxed{4.68 \text{ m/s downward}}$$