

***Engineering Mechanics - Dynamics 16th edition
Hibbeler Solutions Manual***

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12-1.

A baseball is thrown downward from a 50-ft tower with an initial speed of 18 ft/s. Determine the speed at which it hits the ground and the time of travel.

SOLUTION

$$(+\downarrow) \quad v_2^2 = v_1^2 + 2a_c(s_2 - s_1)$$

$$v_2^2 = (18)^2 + 2(32.2)(50 - 0)$$

$$v_2 = 59.532 = 59.5 \text{ ft/s } \downarrow$$

Ans.

$$(+\downarrow) \quad v_2 = v_1 + a_c t$$

$$59.532 = 18 + 32.2(t)$$

$$t = 1.29 \text{ s}$$

Ans.

Ans:

$$v_2 = 59.5 \text{ ft/s}$$

$$t = 1.29 \text{ s}$$

12-2.

Starting from rest, a particle moving in a straight line has an acceleration of $a = (2t - 6) \text{ m/s}^2$, where t is in seconds. What is the particle's velocity when $t = 6 \text{ s}$, and what is its position when $t = 11 \text{ s}$?

SOLUTION

$$a = 2t - 6$$

$$dv = a \, dt$$

$$\int_0^v dv = \int_0^t (2t - 6) \, dt$$

$$v = t^2 - 6t$$

$$ds = v \, dt$$

$$\int_0^s ds = \int_0^t (t^2 - 6t) \, dt$$

$$s = \frac{t^3}{3} - 3t^2$$

When $t = 6 \text{ s}$,

$$v = 0$$

Ans.

When $t = 11 \text{ s}$,

$$s = 80.7 \text{ m}$$

Ans.

Ans:

$$v = 0$$

$$s = 80.7 \text{ m}$$

12-3.

From approximately what floor of a building must a car be dropped from an at-rest position so that it reaches a speed of 80.7 ft/s (55 mi/h) when it hits the ground? Each floor is 12 ft higher than the one below it. (*Note:* You may want to remember this when traveling 55 mi/h.)

SOLUTION

$$(+\downarrow) \quad v^2 = v_0^2 + 2a_c(s - s_0)$$

$$80.7^2 = 0 + 2(32.2)(s - 0)$$

$$s = 101.13 \text{ ft}$$

$$\# \text{ of floors} = \frac{101.13}{12} = 8.43$$

The car must be dropped from the 9th floor.

Ans.

Ans:
 $n = 9$

***12–4.**

A car is traveling at 15 m/s when the traffic light 50 m ahead turns yellow. Determine the required constant deceleration of the car and the time needed to stop the car at the light.

SOLUTION

Kinematics:

$$v_0 = 0, s_0 = 0, s = 50 \text{ m and } v_0 = 15 \text{ m/s.}$$

$$\left(\begin{array}{l} \pm \\ \rightarrow \end{array} \right) \quad v^2 = v_0^2 + 2a_c(s - s_0)$$

$$0 = 15^2 + 2a_c(50 - 0)$$

$$a_c = -2.25 \text{ m/s}^2 = 2.25 \text{ m/s}^2 \leftarrow$$

Ans.

$$\left(\begin{array}{l} \pm \\ \rightarrow \end{array} \right) \quad v = v_0 + a_c t$$

$$0 = 15 + (-2.25)t$$

$$t = 6.67 \text{ s}$$

Ans.

Ans:

$$a_c = -2.25 \text{ m/s}^2$$

$$t = 6.67 \text{ s}$$

12-5.

The velocity of a particle traveling in a straight line is given by $v = (6t - 3t^2)$ m/s, where t is in seconds. If $s = 0$ when $t = 0$, determine the particle's deceleration and position when $t = 3$ s. How far has the particle traveled during the 3-s time interval, and what is its average speed?

SOLUTION

$$\frac{ds}{dt} = v$$

$$ds = (6t - 3t^2) dt$$

$$\int_0^s ds = \int_0^t (6t - 3t^2) dt$$

$$s = 3t^2 - t^3$$

At $t = 3$ s, $s = 3(3)^2 - 3^3 = 0$

When $v = 0$; $0 = 6t - 3t^2$ $t = 0$ and 2 s

At $t = 2$ s, $s = 3(2)^2 - 2^3 = 4$ m

From the figure $s_T = 2(4) = 8$ m

$$(v_{\text{avg}})_{\text{sp}} = \frac{s_T}{\Delta t} = \frac{8}{3} = 2.67 \text{ m/s}$$

$$a = \frac{dv}{dt} = 6 - 6t$$

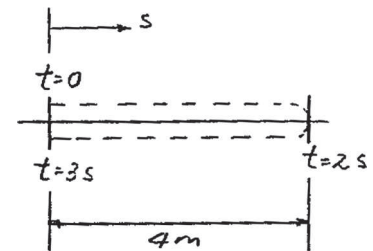
At $t = 3$ s, $a = 6 - 6(3) = -12 \text{ m/s}^2$

Ans.

Ans.

Ans.

Ans.



Ans:

$$s = 0$$

$$s_T = 8 \text{ m}$$

$$(v_{\text{avg}})_{\text{sp}} = 2.67 \text{ m/s}$$

$$a = -12 \text{ m/s}^2$$

12–6.

A particle moves along a straight line with a velocity $v = (200s)$ mm/s, where s is in millimeters. Determine the acceleration of the particle at $s = 2000$ mm. How long does the particle take to reach this position if $s = 500$ mm when $t = 0$?

SOLUTION

Acceleration:

$$\left(\pm \right) \quad \frac{dv}{ds} = 200$$

$$\text{Thus, } a = v \frac{dv}{ds} = (200s)(200) = \{40(10^3)s\} \text{ mm/s}^2$$

When $s = 2000$ mm,

$$a = 40(10^3)(2000) = 80(10^6) \text{ mm/s}^2 = 80 \text{ km/s}^2 \rightarrow \quad \textbf{Ans.}$$

Position:

$$\left(\pm \right) \quad dt = \frac{ds}{v}$$

$$\int_0^t dt = \int_{500 \text{ mm}}^s \frac{ds}{200s}$$

$$t \Big|_0^t = \frac{1}{200} \ln s \Big|_{500 \text{ mm}}^s$$

$$t = \frac{1}{200} \ln \frac{s}{500}$$

At $s = 2000$ mm,

$$t = \frac{1}{200} \ln \frac{2000}{500} = 6.93(10^{-3}) \text{ s} = 6.93 \text{ ms} \quad \textbf{Ans.}$$

$$\textbf{Ans:}$$

$$a = 80 \text{ km/s}^2$$

$$t = 6.93 \text{ ms}$$

12-7.

A car has an initial speed of 25 m/s and a constant deceleration of 3 m/s^2 . Determine the velocity of the car when $t = 4 \text{ s}$. What is the displacement of the car during the 4-s time interval? How much time is needed to stop the car?

SOLUTION

$$v = v_0 + a_c t$$

$$v = 25 + (-3)(4) = 13 \text{ m/s}$$

Ans.

$$\Delta s = s - s_0 = v_0 t + \frac{1}{2} a_c t^2$$

$$\Delta s = s - 0 = 25(4) + \frac{1}{2}(-3)(4)^2 = 76 \text{ m}$$

Ans.

$$v = v_0 + a_c t$$

$$0 = 25 + (-3)(t)$$

$$t = 8.33 \text{ s}$$

Ans.

Ans:

$$v = 13 \text{ m/s}$$

$$\Delta s = 76 \text{ m}$$

$$t = 8.33 \text{ s}$$

***12–8.**

A particle is moving along a straight line such that its position is defined by $s = (10t^2 + 20)$ mm, where t is in seconds. Determine (a) the displacement of the particle during the time interval from $t = 1$ s to $t = 5$ s, (b) the average velocity of the particle during this time interval, and (c) the acceleration when $t = 1$ s.

SOLUTION

$$s = 10t^2 + 20$$

$$(a) \quad s|_{1 \text{ s}} = 10(1)^2 + 20 = 30 \text{ mm}$$

$$s|_{5 \text{ s}} = 10(5)^2 + 20 = 270 \text{ mm}$$

$$\Delta s = 270 - 30 = 240 \text{ mm}$$

Ans.

$$(b) \quad \Delta t = 5 - 1 = 4 \text{ s}$$

$$v_{\text{avg}} = \frac{\Delta s}{\Delta t} = \frac{240}{4} = 60 \text{ mm/s}$$

Ans.

$$(c) \quad a = \frac{d^2s}{dt^2} = 20 \text{ mm/s}^2 \quad (\text{for all } t)$$

Ans.

Ans:

$$(a) \quad \Delta s = 240 \text{ mm}$$

$$(b) \quad v_{\text{avg}} = 60 \text{ mm/s}$$

$$(c) \quad a = 20 \text{ mm/s}^2$$

12–9.

A particle moves along a straight path with an acceleration of $a = (5/s) \text{ m/s}^2$, where s is in meters. Determine the particle's velocity when $s = 2 \text{ m}$, if it is released from rest when $s = 1 \text{ m}$.

SOLUTION

$$a \, ds = v \, dv$$

$$\frac{5}{s} \, ds = v \, dv$$

$$5 \int_1^2 \frac{ds}{s} = \int_0^v v \, dv$$

$$5 (\ln s) \Big|_1^2 = \frac{v^2}{2}$$

$$v = 2.63 \text{ m/s}$$

Ans.

Ans:
 $v = 2.63 \text{ m/s}$

12–10.

A particle moves along a straight line with an acceleration of $a = 5/(3s^{1/3} + s^{5/2})$ ft/s², where s is in feet. Determine the particle's velocity when $s = 2$ ft, if it starts from rest when $s = 1$ ft. Use a numerical method to evaluate the integral.

SOLUTION

$$a = \frac{5}{(3s^{1/3} + s^{5/2})}$$

$$a \, ds = v \, dv$$

$$\int_1^2 \frac{5 \, ds}{(3s^{1/3} + s^{5/2})} = \int_0^v v \, dv$$

$$0.8351 = \frac{1}{2} v^2$$

$$v = 1.29 \text{ ft/s}$$

Ans.

Ans:
 $v = 1.29 \text{ ft/s}$

12–11.

A particle is moving along a straight line such that its velocity is defined as $v = (-4s^2) \text{ m/s}$, where s is in meters. If $s = 2 \text{ m}$ when $t = 0$, determine the velocity and acceleration as functions of time.

SOLUTION

$$v = -4s^2$$

$$\frac{ds}{dt} = -4s^2$$

$$\int_2^s s^{-2} ds = \int_0^t -4 dt$$

$$-s^{-1} \Big|_2^s = -4t \Big|_0^t$$

$$t = \frac{1}{4} (s^{-1} - 0.5)$$

$$s = \frac{2}{8t + 1}$$

$$v = -4 \left(\frac{2}{8t + 1} \right)^2 = -\frac{16}{(8t + 1)^2} \text{ m/s}$$

Ans.

$$a = \frac{dv}{dt} = \frac{16(2)(8t + 1)(8)}{(8t + 1)^4} = \frac{256}{(8t + 1)^3} \text{ m/s}^2$$

Ans.

Ans:

$$v = -\frac{16}{(8t + 1)^2} \text{ m/s}$$

$$a = \frac{256}{(8t + 1)^3} \text{ m/s}^2$$

***12–12.**

The speed of a particle traveling along a straight line within a liquid is measured as a function of its position as $v = (100 - s)$ mm/s, where s is in millimeters. Determine (a) the particle's deceleration when it is located at point A , where $s_A = 75$ mm, (b) the distance the particle travels before it stops, and (c) the time needed to stop the particle.

SOLUTION

(a) $a \, ds = v \, dv$

$$a = v \frac{dv}{ds} = (100 - s)(-1) = s - 100$$

When $s = s_A = 75$ mm, $a = 75 - 100 = -25$ mm/s²

Ans.

(b) $v = 100 - s$

$$0 = 100 - s \quad s = 100 \text{ mm}$$

Ans.

(c) $v = \frac{ds}{dt}$

$$dt = \frac{ds}{v} = \frac{ds}{100 - s}$$

$$\int_0^t dt = \int_0^{100} \frac{ds}{100 - s}$$

$$t = -\ln(100 - s)|_0^{100} \rightarrow \infty$$

Ans.

Ans:

(a) $a_A = -25$ mm/s²

(b) $s = 100$ mm

(c) $t \rightarrow \infty$