PHYS I

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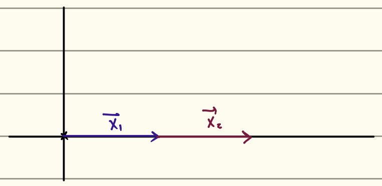
Chapter 2 :- "Motion along a straight line."

1.. Position : (موقع الجسم)

↳ Vector Quantities.

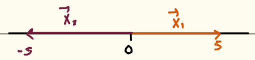
→ intial Position : $\vec{x}_1$

→ final Position : $\vec{x}_2$



Ex :- let $\vec{x}_1 = 5$ m in the $(x+)$.

$\vec{x}_2 = 5$m in the $(x-)$.



2.. Displacement : (الإزاحة) وهي المتجه المستقيم الذي يصل بين نقطة البداية والنهاية.

↳ Vector Quantities.

→ Displacement = change in Position.

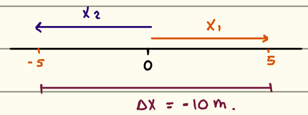
$\Delta\vec{x} = \vec{x}_2 - \vec{x}_1$

* Ex:- Suppose $\vec{x}_1 = 5$m at t_1 , $\vec{x}_2 = -5$m at t_2 , find the displacement ??

$D = \vec{x}_2 - \vec{x}_1$

$= -5 - 5$

$= -10$ m , or 10 m to the left.



3.. Distance : (المسافة) وهي طول المسار الذي يقطعه الجسم.

↳ Scalar Quantities.

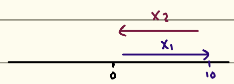
⚠ Distance ≠ Displacement.

Ex:- suppose $\vec{x}_1 = 10$m at t_1 , $\vec{x}_2 = 0$ m at t_2 , find the Distance ?

$D = x_1 + x_2$

$= 10 + 10$

$= 20$m.



Ex:- a particle moves from $\vec{x}_1 = -2$m (at t_1) to $\vec{x}_2 = 2$m (at t_2) , along a semi circle . (نصف دائرة)

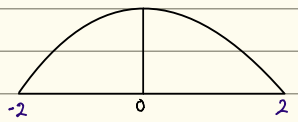
Find :- 1. The Displacement ?

Displacement ($\Delta\vec{x}$) = change in Position

$\Delta\vec{x} = \vec{x}_2 - \vec{x}_1$

$= 2 - (-2)$

$= 4m$. (to the right).



2. The Distance ?

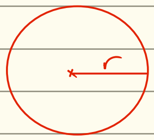
Distance = نصف محيط الدائرة.

$= \frac{2\pi r}{2} \rightarrow \pi r$

$= 3.14 \times 2$

$= 6.3$m .

Note :-



* Distance = $2\pi r$
* Displacement = zero.

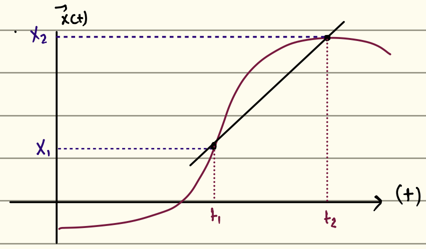
4 .. Average Velocity : (متوسط متجه السرعة)

↳ to Find the average velocity you have to know $\vec{x}(t)$ graphically or as equation.

* Average velocity = $\frac{\text{Displacement}}{\text{time interval}} = \frac{\Delta \vec{x}}{\Delta t}$. → (dir of $\vec{V}_{avg}$ = dir of $\Delta\vec{x}$).

↳ vector Quantity.

$V_{avg} = \frac{\Delta X}{\Delta t}$ = ميل القاطع



5 .. Average Speed : (متوسط السرعة)

↳ scalar Quantity.

* Average speed = $\frac{\text{Total Distance}}{\text{time interval}}$ → S_{avg} → always Positive.

6 .. instantaneous Velocity & Speed : (السرعة عند لحظة معينة)

1. From the graph (x vs. t) by plotting the tangent of the curve at a certain Point, then Find the tangent slope.

$\vec{V}_{inst}$ = slope of the tangent.

2. From the equation x(t) :-

$\vec{V}_{inst} = \frac{dx}{dt}$ → (First derivative of the Position).

2 Compute your average velocity in the following two cases: (a) You walk 73.2 m at a speed of 1.22 m/s and then run 73.2 m at a speed of 2.85 m/s along a straight track. (b) You walk for 1.00 min at a speed of 1.22 m/s and then run for 1.00 min at 3.05 m/s along a straight track. (c) Graph x versus t for both cases and indicate how the average velocity is found on the graph.

a)

D = 73.2 m — S = 1.22 m/s | D = 73.2 m — S = 2.85 m/s

$S_1 = \frac{D_1}{t_1}$	$S_2 = \frac{D_2}{t_2}$
$1.22 = \frac{73.2}{t_1}$	$2.85 = \frac{73.2}{t_2}$
$t_1 = 60$ sec.	$t_2 = 25.6$ sec.

$\therefore \vec{V}_{avg} = \frac{73.2 + 73.2}{60 + 25.6}$ 146.4

$= 1.71$ m/s.

b)

t = 1 min — S = 1.22 m/s. | t = 1 min — S = 3.05 m/s.

$S_1 = \frac{D_1}{t_1}$	$S_2 = \frac{D_2}{t_2}$
$1.22 = \frac{D_1}{60}$	$3.05 = \frac{D_2}{60}$
$D_1 = 73.2$ m	$D_2 = 183$ m.

$\therefore \vec{V}_{avg} = \frac{D}{t}$

$= \frac{73.2 + 183}{60+60}$

$= 2.135$ m/s

7 .. Average Acceleration:

↳ Vector Quantity.

* → It depends on the change in velocity.

* $\vec{a}_{avg} = \frac{\Delta \vec{v}}{\Delta t} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} \rightarrow m/s^2$.

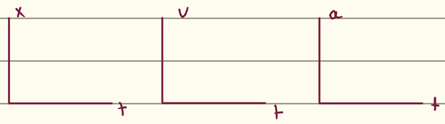
8 .. Instantaneous Acceleration: (التسارع عند لحظة معينة).

* $\vec{a}_{inst} = \frac{d\vec{v}}{dt} = \frac{d^2\vec{x}}{dt^2}$

* Note :

$x(t) \rightarrow v(t) \rightarrow a(t)$ ∴ Diff (slope).

$a(t) \rightarrow v(t) \rightarrow x(t)$ ∴ integration (area under the curve).



Graph. → طبعاً بعرف المنطقة اللي تحت محور السينات (-) واللي فوقه (+).

* speeding up or slowing down.

vi	a	Motion
+	+	up
−	−	up
+	−	down
−	+	down
+, -	0	const v
0	+, -	up
0	0	at rest

* vi, a the same direction → speeding up.
* vi, a the opp direction → slowing down.

Sample Problem 2.03 **Acceleration and dv/dt**

A particle's position on the x axis of Fig. 2-1 is given by

$$x = 4 - 27t + t^3,$$

with x in meters and t in seconds.

(a) Because position x depends on time t, the particle must be moving. Find the particle's velocity function $v(t)$ and acceleration function $a(t)$.

$v(x) = -27 + 3t^2$

$a(x) = 6t$.

(b) Is there ever a time when $v = 0$?

$v(x) = -27 + 3t^2$

$0 = -27 + 3t^2$

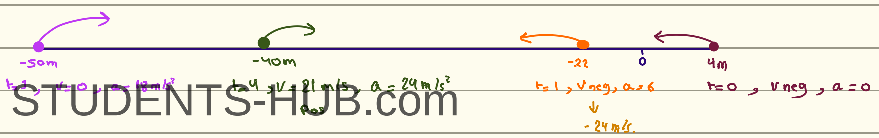
$27 = 3t^2$

$t^2 = 9 \rightarrow t = 3$ sec.

(c) Describe the particle's motion for $t \geq 0$.

$t=0 \rightarrow x = 4m$, $v = -27 m/s$, $a = 0$

$t=1 \rightarrow x = -22m$, $v = -24 m/s$, $a = 6 m/s^2$



5 The position of an object moving along an x axis is given by $x = 3t - 4t^2 + t^3$, where x is in meters and t in seconds. Find the position of the object at the following values of t: (a) 1 s, (b) 2 s, (c) 3 s, and (d) 4 s. (e) What is the object's displacement between $t = 0$ and $t = 4$ s? (f) What is its average velocity for the time interval from $t = 2$ s to $t = 4$ s? (g) Graph x versus t for $0 \le t \le 4$ s and indicate how the answer for (f) can be found on the graph.

$x = 3t - 4t^2 + t^3$

a) $x(1) = 3(1) - 4(1)^2 + (1)^3$

$= 0 \text{ m}$

b) $x(2) = 3(2) - 4(2)^2 + (2)^3$

$= -2 \text{ m}$

c) $x(3) = 3(3) - 4(3)^2 + (3)^3$

$= 0 \text{ m}.$

d) $x(4) = 3(4) - 4(4)^2 + (4)^3$

$= 12 \text{ m}$

e) $D = \frac{\Delta x}{\Delta t}$

$= \frac{12-0}{4-0}$

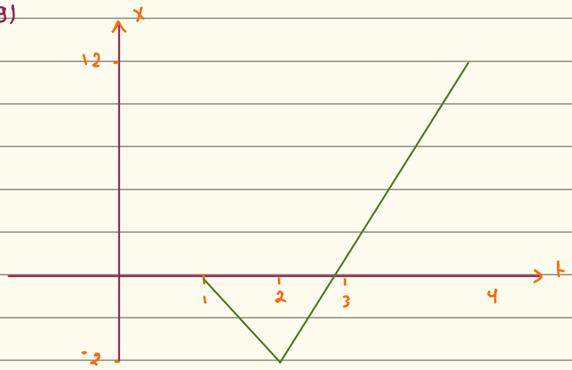
$= 3 \text{ m}.$

f) $\vec{V}_{avg} = \frac{D}{\Delta t}$

$= \frac{12-(-2)}{4-2}$

$= 7 \text{ m/s}$

g)



14 An electron moving along the x axis has a position given by $x = 16te^{-t}$ m, where t is in seconds. How far is the electron from the origin when it momentarily stops?

$x = 16te^{-t}$

$v = 16t(-e^{-t}) + (e^{-t})16$

$0 = 16e^{-t}(-t+1)$

$\therefore 16e^{-t} \neq 0$

$-t+1 = 0$

$t = 1 \text{ sec.}$

$x = 16(1)e^{(-1)}$

$= \frac{16}{2.72} \longrightarrow 5.88 \text{m}.$

9 .. Constant Acceleration:

لـ التسارع له اتجاه.

$v_f = v_i + at$

$d = v_i t + \frac{1}{2}at^2$ → معادلات الحركة بتسارع ثابت ← السرعة تزداد او تقل بشكل منتظم

$v_f^2 = v_i^2 + 2ad.$

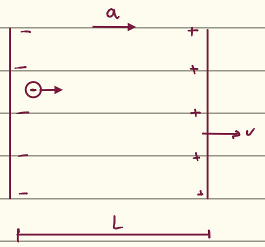
*ex :-

$v_i = 1.5 \times 10^5$ m/s

$L = 1cm \longrightarrow 1 \times 10^{-2}$ m

$v_f = 5.7 \times 10^6$ m/s

Find a ??

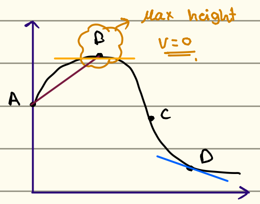


$v_f^2 = v_i^2 + 2ad$

$(5.7 \times 10^6)^2 = (1.5 \times 10^5)^2 + (2)(1 \times 10^{-2})(a)$

$a = 1.51 \times 10^{15}$ m/s.

* Variable acceleration :-



Vavg = slope of Joining line between two Points.

V = slope of a tangent line at the Point.

$\vec{V}avg\ (A \to B)$ = slope of solid line.

V(t=B) = zero (مماس أفقي)

V(t=D) = Slop at D.

ex :-

let $a = 5t$

at $t = 2$ sec, $V = 17$ m/s.

$t = 4$ sec, find V_2 ?

$a = 5t \longrightarrow \int a = \int 5t$

$V = \frac{5}{2}t^2 + c$

$v(2) = 10 + c$

$17 = 10 + c \longrightarrow c = 7$

$\therefore V = \frac{5}{2}t^2 + 7$

$v(4) = 47 m/s^2.$

10 .. Free fall Acceleration:

* the best example of const. acceleration is the free falling.

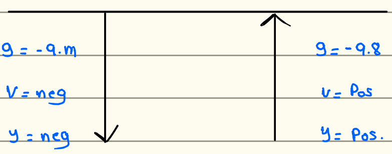
$a = -g = -9.8\ m/s^2.$

دائماً التسارع بعوض سالب بغض النظر عن اتجاه حركة الجسم.

$v_f = v_i - gt$

$v_f^2 = v_i^2 - 2gd.$

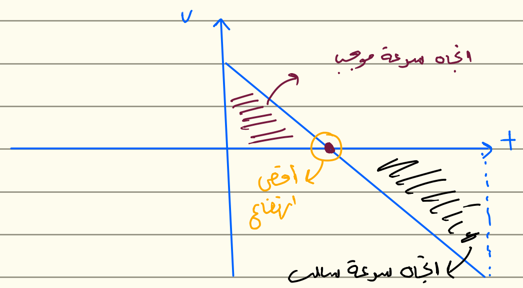
$d = v_i t - \frac{1}{2}gt^2$



V=0 . (أقصى إرتفاع)

ولكنه التسارع ≠ صفر

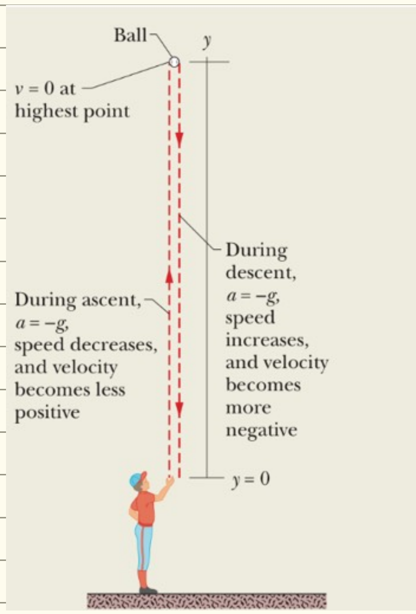
* أما متجهات السرعة و الإزاحة نعوض الإشارة بالإعتماد على نقطة الإسناد.



Sample Problem 2.05 **Time for full up-down flight, baseball toss**

In Fig. 2-13, a pitcher tosses a baseball up along a y axis, with an initial speed of 12 m/s.

(a) How long does the ball take to reach its maximum height?



V at maximum height = 0

$v_f = v_i - gt$

$0 = 12 - (9.8)t$

$12 = 9.8t \longrightarrow t = 1.2$ sec.

(b) What is the ball's maximum height above its release point?

$\Delta y = v_i t - \frac{1}{2} g t^2$

$= (12)(1.2) - \frac{1}{2}(9.8)(1.2)^2$

$\Delta y = 7.3$ m.

(c) How long does the ball take to reach a point 5.0 m above its release point?

$\Delta y = v_i t - \frac{1}{2} g t^2$

$5 = 12t - \frac{1}{2}(9.8)t^2$

$4.9t^2 - 12t + 5 = 0$

$t = \frac{+12 \mp \sqrt{(12)^2 - (4)(4.9)(5)}}{2(4.9)}$

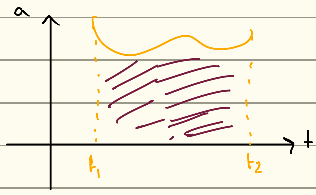
$t = 0.53$ sec (up) & $t = 1.9$ sec (down).

II .. Graphical Integration in motion Analysis :

$a = \frac{dv}{dt} \longrightarrow dv = a\,dt$

$\int_{v_1}^{v_2} dv = \int_{t_1}^{t_2} a.\,dt$ (the area under the acceleration curve).

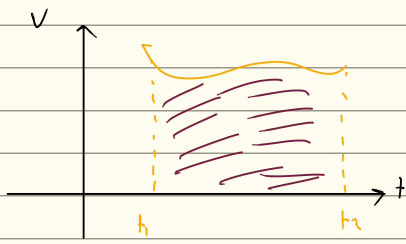
$\therefore v_2 - v_1 = \int_{t_1}^{t_2} a\,dt$



$V = \frac{dx}{dt} \longrightarrow dx = v\,dt$

$\int_{x_i}^{x_f} dx = \int_{v_i}^{v_f} v\,dt$

$x_f - x_i = \int_{v_i}^{v_f} v\,dt. \longrightarrow$ the area under the velocity curve.



ex :-

a) find x at $t = 4$ sec ?

$$\Delta x = \int_0^4 v\,dt$$

= Area under the curve (v vs.t) from $0 \rightarrow 4$.

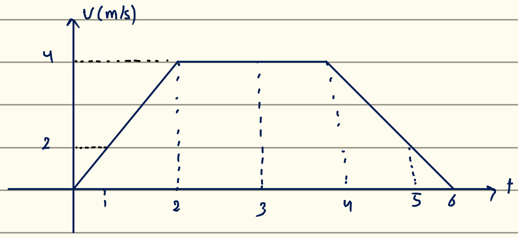
$$x_4 = \frac{1}{2}(4+2) \times 4$$

$= 12 m.$

b) at $t = 4s$, find v, a?

$v_4 = 4 \ m/s$

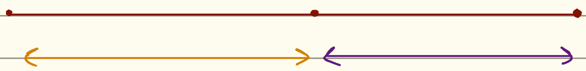
a = slope = 0.



Lecture problems:

2 Compute your average velocity in the following two cases: (a) You walk 73.2 m at a speed of 1.22 m/s and then run 73.2 m at a speed of 2.85 m/s along a straight track. (b) You walk for 1.00 min at a speed of 1.22 m/s and then run for 1.00 min at 3.05 m/s along a straight track. (c) Graph x versus t for both cases and indicate how the average velocity is found on the graph.

a)



D = 73.2 m　　　D = 73.2 m

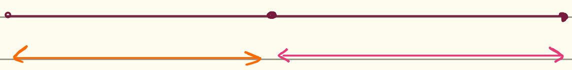
S = 1.22 m/s　　　S = 2.85 m/s

$S_1 = \frac{D_1}{t_1}$	$S_2 = \frac{D_2}{t_2}$
$1.22 = \frac{73.2}{t_1}$	$2.85 = \frac{73.2}{t_2}$
$t_1 = 60$ sec .	$t_2 = 25.6$ sec .

$$\therefore \vec{V}_{avg} = \frac{73.2 + 73.2}{60 + 25.6}$$　　146.4

$= 1.71 \ m/s.$

b)



t = 1 min　　　t = 1 min

S = 1.22 m/s.　　　S = 3.05 m/s .

$S_1 = \frac{D_1}{t_1}$	$S_2 = \frac{D_2}{t_2}$
$1.22 = \frac{D_1}{60}$	$3.05 = \frac{D_2}{60}$
$D_1 = 73.2 \ m$	$D_2 = 183 \ m$

$$\therefore \vec{V}_{avg} = \frac{D}{t}$$

$$= \frac{73.2 + 183}{60 + 60}$$

2.135 m/s

5 The position of an object moving along an x axis is given by $x = 3t - 4t^2 + t^3$, where x is in meters and t in seconds. Find the position of the object at the following values of t: (a) 1 s, (b) 2 s, (c) 3 s, and (d) 4 s. (e) What is the object's displacement between $t = 0$ and $t = 4$ s? (f) What is its average velocity for the time interval from $t = 2$ s to $t = 4$ s? (g) Graph x versus t for $0 \le t \le 4$ s and indicate how the answer for (f) can be found on the graph.

$x = 3t - 4t^2 + t^3$

a) $x(1) = 3(1) - 4(1)^2 + (1)^3$

$= 0 \ m$

b) $x(2) = 3(2) - 4(2)^2 + (2)^3$

$= -2 \ m$

c) $x(3) = 3(3) - 4(3)^2 + (3)^3$

$= 0 \ m.$

d) $x(4) = 3(4) - 4(4)^2 + (4)^3$

$= 12 \ m$

e) $D = \frac{\Delta x}{\Delta t}$

$= \frac{12 - 0}{4 - 0}$

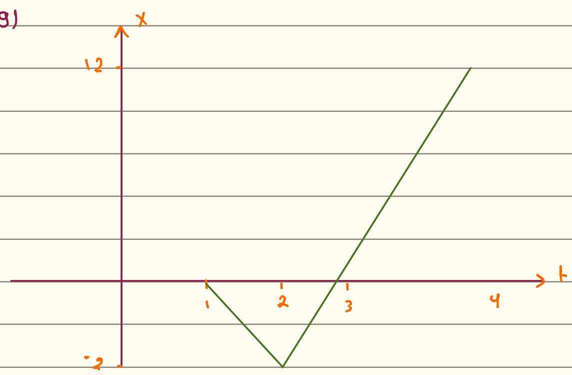
$= 3 \ m.$

f) $\vec{V}_{avg} = \frac{D}{\Delta t}$

$= \frac{12 - (-2)}{4 - 2}$

$= 7 \ m/s$

g)



14 An electron moving along the x axis has a position given by $x = 16te^{-t}$ m, where t is in seconds. How far is the electron from the origin when it momentarily stops?

$x = 16te^{-t}$

$v = 16t(-e^{-t}) + (e^{-t})16$

$0 = 16e^{-t}(-t+1)$

$\therefore 16e^{-t} \neq 0$

$-t+1 = 0$

$t = 1$ sec.

$x = 16(1)e^{(-1)}$

$= \frac{16}{2.72} \longrightarrow 5.88\,m$

21 Along a straight road, a car moving with a speed of 130 km/h is brought to a stop in a distance of 210 m. (a) Find the magnitude of the deceleration of the car (assumed uniform). (b) How long does it take for the car to stop?

$\frac{130\,km}{h} \times \frac{h}{3600} \times \frac{1000\,m}{km}$

$= 36.1\ m/s.$

a) $v_f^2 = v_i^2 + 2ad$

$0 = (36.1)^2 + 2(a)(210)$

$-1303.21 = 420a$

$a = -3.1\ m/s^2.$

b) $v_f = v_i + at$

$0 = 36.1 + (-3.1)t$

$36.1 = 3.1t$

$t = 11.6$ sec

39 A car moving at a constant velocity of $\boxed{46\ m/s}$ passes a traffic cop who is readily sitting on his motorcycle. After a reaction time of 1.0 s, the cop begins to chase the speeding car with a constant acceleration of 4.0 m/s². How much time does the cop then need to overtake the speeding car?

Car :-

$\vec{V}_{const} = 46\,m/s$

$\vec{a} = 0$

Cop :-

$\vec{a} = 4\,m/s^2 \longrightarrow$ const.

$\hookrightarrow D = v_i t + \frac{1}{2}at^2$

$D = (46)(1) + 0$

$D = 46\,m.$

$* \Delta x = v_i t + \frac{1}{2}at^2$

$x_f = x_i + v_i t + \frac{1}{2}at^2.$

$x_f\ car = x_f\ cop$

$x_i + v_i t + \frac{1}{2}at^2 = x_i + v_i t + \frac{1}{2}at^2$

$46 + 46(t) = 0 + 0 + \frac{1}{2}(4)t^2$

$46 + 46t = 2t^2$

$t^2 - 23t - 23 = 0$

$t = \frac{B \mp \sqrt{B^2 - 4AC}}{2A} \longrightarrow = \frac{(23) \mp \sqrt{(23)^2 - 4(1)(-23)}}{2(1)}$

$= \frac{23 + 24.9}{2}$

23.95 sec.

45 A man releases a stone at the top edge of a tower. During the last second of its travel, the stone falls through a distance of $(9/25)H$, where H is the tower's height. Find H.

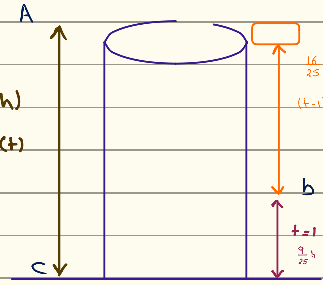
$\Delta y = v_i t + \frac{1}{2}gt^2$

top $\rightarrow$ down $A \rightarrow C$

$\therefore H = 0 + \frac{1}{2}gt^2 \quad \ldots 1$

top $\rightarrow \frac{16}{25}H \quad A \rightarrow B$

$\frac{16}{25}H = 0 + \frac{1}{2}g(t-1)^2$



$\therefore -5t^2 = -5(t-1)^2\left(\frac{25}{16}\right)$

$\therefore 0.36t^2 - 2t + 1 = 0$

$t = \frac{2 \mp \sqrt{4 - 4(0.36)(1)}}{2(0.36)}$

$t = 5$ sec.

$t = 0.5 \longrightarrow \alpha$

Discussion problems:

3 Rachel walks on a straight road from her home to a gymnasium 2.80 km away with a speed of 6.00 km/h. As soon as she reaches the gymnasium, she immediately turns and walks back home with a speed of 7.70 km/h as she finds the gymnasium closed. What are the (a) magnitude of average velocity and (b) average speed of Rachel over the interval of time 0.00–35.0 min? $\rightarrow$ 0.58 h.

home $\qquad$ $D = 2.8$ km. $\qquad$ gym.

$S = 6$ km/h.

$D = ??$

$S = 7.7$ km.

a) $S_1 = \dfrac{D_1}{t_1}$

$6 = \dfrac{2.8}{t_1} \longrightarrow t_1 = 0.46$ h.

$t = t_1 + t_2$

$0.58 = 0.46 + t_2$

$t_2 = 0.12$ h.

$\therefore S_2 = \dfrac{D_2}{t_2}$

$7.7 = \dfrac{D_2}{0.12} \longrightarrow D_2 = 0.924$ km.

$\therefore \vec{V}_{aug} = \dfrac{D}{\Delta t}$

$= \dfrac{2.8 - 0.924}{0.58} \longrightarrow V = 3.23$ km/h.

b) $s = \dfrac{D}{\Delta t}$

$= \dfrac{2.8 + 0.942}{0.58}$

$= 6.45$ km/h.

15 The displacement of a particle moving along an x axis is given by $x = 18t + 5.0t^2$, where x is in meters and t is in seconds. Calculate (a) the instantaneous velocity at $t = 2.0$ s and (b) the average velocity between $t = 2.0$ s and $t = 3.0$ s.

$X = 18t + 5t^2$

a) $V = 18 + 10t$

$= 18 + 10(2)$

$= 38$ m/s.

b) $X(2) = 18(2) + 5(2)^2$

$= 56$ m

$X(3) = 18(3) + 5(3)^2$

$= 99$

$\therefore \vec{V}_{aug} = \dfrac{\Delta X}{\Delta t}$

$= \dfrac{99 - 56}{3 - 2}$

$= 43$ m/s.

23 A body starting from rest moves with constant acceleration. What is the ratio of distance covered by the body during the fifth second of time to that covered in the first 5.00 s?

Start from rest $\rightarrow v_i = 0$

$D = v_i t + \frac{1}{2}at^2 \longrightarrow D = \frac{1}{2}at^2$

* D in the fifth sec $\rightarrow$ [4, 5].

$D = \dfrac{X_5 - X_4}{1}$

$= (0.5(a)(5)^2) - (0.5(a)(4)^2)$

$= (\frac{9}{2}a)$ m

* D in the first 5 sec $\rightarrow$ [0, 5]

$D` = (0.5(a)(5)^2)$.

$= (\dfrac{25a}{2})$ m

$\therefore \dfrac{D}{D`} = \dfrac{9}{2}a \times \dfrac{2}{25a}$

$= \dfrac{9}{25}$

33 A stone is thrown from the top of a building with an initial velocity of 20 m/s downward. The top of the building is 60 m above the ground. How much time elapses between the instant of release and the instant of impact with the ground?

$D = v_i t + \frac{1}{2} a t^2$

$-60 = -20t + \frac{1}{2}(-10)t^2$

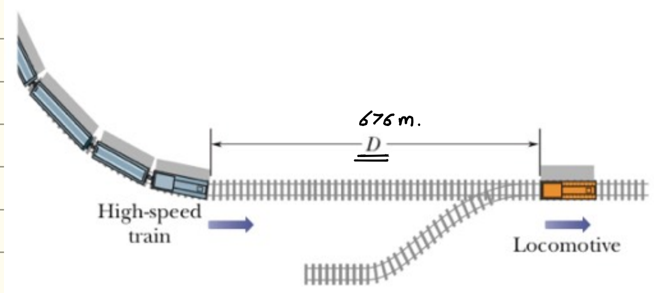
$-60 = -20t - 5t^2 \longrightarrow 5t^2 + 20t - 60 = 0$

$t^2 + 4t - 12 = 0$

$(t - 2)(t + 6)$

$t = 2\ sec$ ✓ $\quad t = -6$ ✗.

43 When a high-speed passenger train traveling at 161 km/h rounds a bend, the engineer is shocked to see that a locomotive has improperly entered onto the track from a siding and is a distance $D = 676$ m ahead (Fig. 2-20). The locomotive is moving at 29.0 km/h. The engineer of the high-speed train immediately applies the brakes. (a) What must be the magnitude of the resulting constant deceleration if a collision is to be just avoided? (b) Assume that the engineer is at $x = 0$ when, at $t = 0$, he first spots the locomotive. Sketch $x(t)$ curves for the locomotive and high-speed train for the cases in which a collision is just avoided and is not quite avoided.



train:

$v_i = 161$ km/h

$v_f = ?$

Local motive:

$v_i = 29$ km/h $\longrightarrow$ const

$a = 0$

لم القطار انتبه للعربة لما كانت المسافة بينهم 0.676 km.

For the train:

$\Delta x = v_i t + \frac{1}{2} a t^2$

$x_f - x_i = v_i t + \frac{1}{2} a t^2$

$x_f = 161t + \frac{1}{2} a t^2 \longrightarrow \underline{\underline{1}}$

For the Loco motive:

$\Delta x = v_i t + \frac{1}{2} a t^2$

$x_f - x_i = v_i t + \frac{1}{2} a t^2$

$x_f - 0.676 = 29t \longrightarrow x_f = 0.676 + 29t \longrightarrow \underline{\underline{2}}$

$\therefore x_f(t) = x_f(L)$

$161t + \frac{1}{2} a t^2 = 0.676 + 29t$

$132t + \frac{1}{2}\left(\frac{-132}{t}\right)t^2 = 0.676$

$66t = 0.676 \longrightarrow t = 0.01$ h

$\therefore a = \frac{-132}{0.01} \longrightarrow -13200$ km/h^2

* $v_f = v_i + at \longrightarrow$ For train. * $v_f(t) = v_f(L)$.

$29 = 161 + at$

$a = \frac{-132}{t} \longrightarrow \underline{\underline{3}}$

47 A hot-air balloon is ascending at a rate of 14 m/s at a height of 98 m above the ground when a packet is dropped from it. (a) With what speed does the packet reach the ground, and (b) how much time does the fall take?

a) $v_f^2 = v_i^2 + 2ad$

$v_f^2 = (14)^2 + 2(-10)(-98)$

$v_f^2 = 2156$

$v_f = 46.43$ m/s.

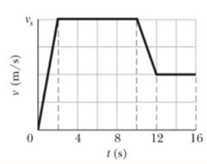
b) $v_f = v_i + at$

$-46.43 = 14 + (-10)t$

$-60.43 = -10t$

$t = 6.043$ sec.

69 How far does the runner whose velocity–time graph is shown in Fig. 2-25 travel in 16 s? The figure's vertical scaling is set by $v_s = 8.0$ m/s.



D = Area under the carve.

$= \int_0^{16} v\,dt$

$= A_1 + A_2 + A_3$

$= \frac{1}{2}(10+8)8 + \frac{1}{2}(4+8)2 + (4 \times 4)$

$= 100$ m.