FISIKA DASAR

MODUL 3: KINEMATIKA 1

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2018

OUTLINE MODUL 3

PRINSIP KINEMATIKA
(*KINEMATICS*)

GERAK SATU DIMENSI
(*MOTION IN ONE DIMENTION*)

DEFINISI KINEMATIKA (1)

- **Kinematika** adalah cabang ilmu fisika yang mempelajari gerak titik partikel secara geometris, yaitu meninjau gerak partikel tanpa meninjau penyebab geraknya.
- **Kinematika** adalah cabang dari ilmu mekanika, yaitu ilmu yang mempelajari gerak benda.

CAT:

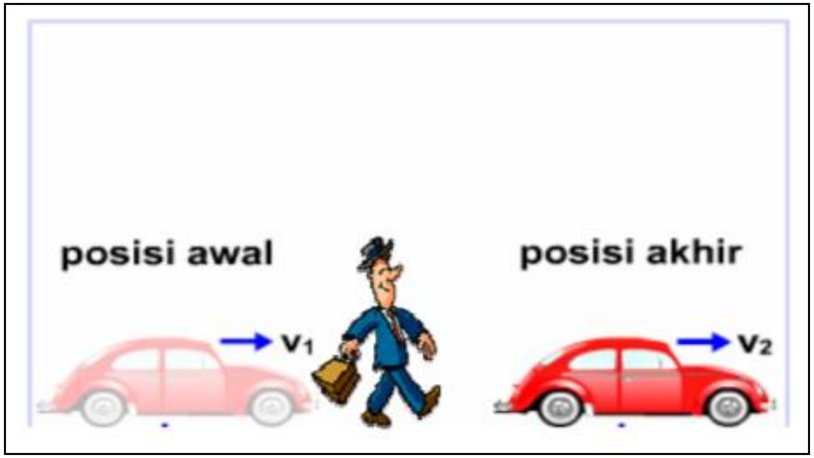
- Benda diasumsikan sebagai titik
- Walaupun kita hanya meninjau gerak titik partikel, tetapi dapat dimanfaatkan juga untuk mempelajari gerak benda maupun sistem yang bukan titik. Karena selama pengaruh penyebab gerak partikel hanya pengaruh eksternal, maka gerak keseluruhan benda dapat diwakili oleh gerak titik pusat massanya.

BESARAN-BESARAN GERAK

Besaran gerak ada yang berupa besaran vektor dan ada yang berupa besaran skalar

Besaran gerak dapat diturunkan dengan mudah dari besaran gerak lainnya, melalui: PERKALIAN atau PEMBAGIAN biasa; melalui proses INTEGRAL; melalui proses DIFERENSIAL

PRINSIP DASAR GERAK



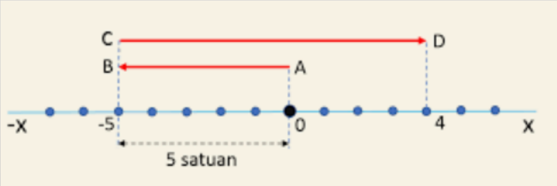
- Andaikan Anda berada di dalam mobil yang bergerak meninggalkan teman Anda. Dari waktu ke waktu teman Anda yang berdiri di sisi jalan itu semakin tertinggal di belakang mobil. Artinya posisi Anda dan teman Anda berubah setiap saat seiring dengan gerakan mobil menjauhi teman Anda itu.
- Apakah Anda bergerak? Ya, bila acuannya teman Anda atau pepohonan di pinggir jalan. Anda diam bila acuan yang diambil adalah mobil yang Anda tumpangi. Mengapa? Sebab selama perjalanan posisi Anda dan mobil tidak berubah.

- Gerak berarti perubahan posisi benda.
- Suatu benda dikatakan bergerak bila posisinya setiap saat berubah terhadap suatu acuan tertentu.
- Suatu benda dapat bergerak sekaligus diam tergantung acuan yang kita ambil. Dalam Fisika gerak bersifat relatif, bergantung pada acuan yang dipilih.

POSISI (*POSITION*)

SATU SUMBU KOORDINAT

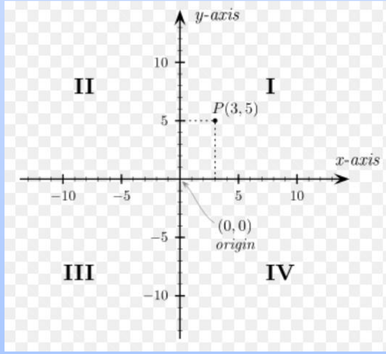
- Benda hanya bergerak pada lintasan berupa garis lurus
- Ex: Gerak mobil saat dijalur lurus jalan tol; gerak kereta api pada jalur rel yang lurus



GERAK 1 DIMENSI

DUA SUMBU KOORDINAT

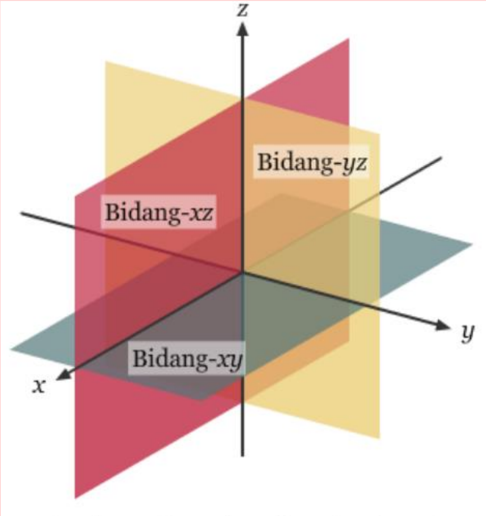
- Benda bergerak pada bidang datar
- Biasanya sumbu koordinat dipilih saling tegak lurus
- Ex: gerak perluru gerak kapal di atas laut, gerak pembalap di sirkuit.



GERAK 2 DIMENSI

TIGA SUMBU KOORDINAT

- Gerak benda dalam ruang



Gambar 1 Sistem koordinat tiga dimensi

GERAK 3 DIMENSI

KINEMATIKA 1
Gerak Satu Dimensi

PERPINDAHAN (*DISPLACEMENT*) DAN JARAK TEMPUH (*DISTANCE*)

- Perpindahan diartikan sebagai perubahan posisi benda dari keadaan awal ke keadaan akhirnya.
- Perpindahan tidak mempersoalkan bagaimana lintasan suatu benda yang bergerak. Perpindahan hanya mempersoalkan kedudukan, awal dan akhir benda itu
- Perpindahan merupakan besaran vektor.
- Persamaan perpindahan benda:

$$\Delta x = x_f - x_i \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Xi = initial position
Xf = final position

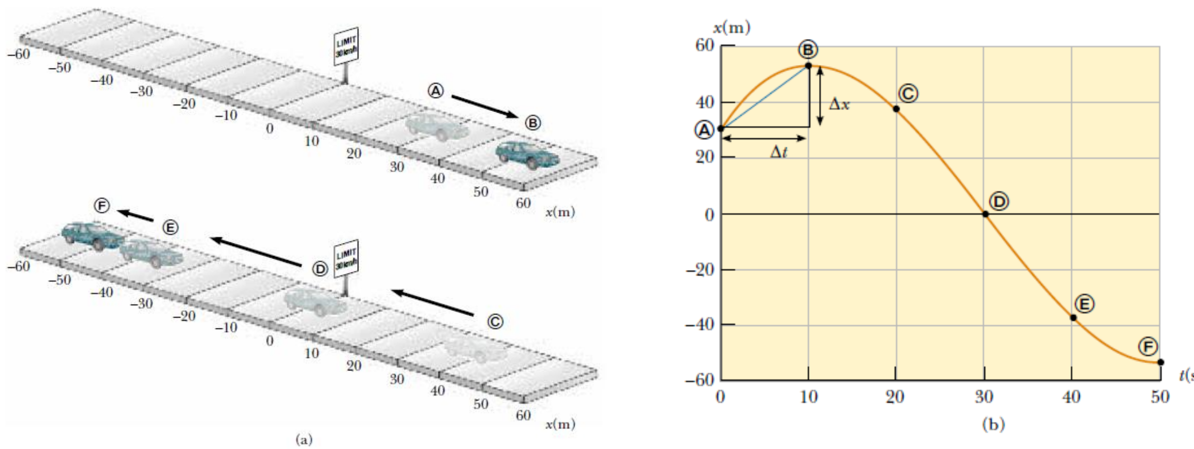
- **Jarak tempuh Bandung-Jakarta melalui lintasan (1), (2), dan (3) berbeda.**
- **Perpindahan dari Bandung ke Jakarta tetap sama, tidak bergantung pada lintasan yang diambil.**

- Panjang lintasan yang ditempuh disebut jarak.
- Jarak tidak mempersoalkan ke arah mana benda bergerak.
- Jarak merupakan besaran skalar.

CONTOH SOAL
PERPINDAHAN DAN JARAK TEMPUH

TABLE 2.1
Position of the Car at Various Times

Position	t(s)	x(m)
Ⓐ	0	30
Ⓑ	10	52
Ⓒ	20	38
Ⓓ	30	0
Ⓔ	40	−37
Ⓕ	50	−53



Tentukan besarnya perpindahan dan jarak tempuh dari A ke F:

1. **Besar perpindahan A ke F = $\Delta x = x_F - x_A$ = -53 – 30 = -83m** **(*This result means that the car ends up 83 m in the negative direction (to the left, in this case) from where it started*).**

2. **Besar jarak tempuh A ke F = 22m + 52m + 53m = 127m**

KECEPATAN (*VELOCITY*) DAN LAJU (*SPEED*)

KECEPATAN

- Kecepatan adalah vektor.
- Kecepatan adalah perpindahan suatu benda dibagi selang waktu untuk menempuhnya.
- Kecepatan rata-rata suatu benda/partikel (*average velocity*, $\overline{V}_x$):

$$\overline{v}_x \equiv \frac{\Delta x}{\Delta t} \qquad \text{........................ (2)}$$

- x mengindikasikan gerak pada sumbu x
- Dari definisi dapat diketahui satuan dari kecepatan rata-rata adalah adalah panjang/waktu (L/T) – m/s (dalam satuan SI)

LAJU

- Kelajuan merupakan besaran skalar
- Kelajuan adalah jarak yang ditempuh suatu benda dibagi selang waktu atau waktu untuk menempuh jarak itu.
- Laju rata-rata suatu benda/partikel (*average speed*) :

$$Laju\ rata-rata = \frac{total\ jarak\ tempuh}{waktu\ tempuh}$$

- Unit satuan laju rata-rata = kecepatan rata-rata = m/s

CONTOH SOAL
KECEPATAN (*VELOCITY*) DAN LAJU (*SPEED*)

TENTUKAN NILAI KECEPATAN RATA-RATA DAN LAJU RATA-RATA DARI SOAL SEBELUMNYA (PERPINDAHAN DAN JARAK TEMPUH)?

Kecepatan rata-rata:

$$\bar{v}_x = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i} = \frac{x_{\mathsf{F}} - x_{\mathsf{A}}}{t_{\mathsf{F}} - t_{\mathsf{A}}}$$

$$= \frac{-53\ \mathrm{m} - 30\ \mathrm{m}}{50\ \mathrm{s} - 0\ \mathrm{s}} = \frac{-83\ \mathrm{m}}{50\ \mathrm{s}} = \boxed{-1.7\ \mathrm{m/s}}$$

Laju rata-rata:

$$\text{Average speed} = \frac{22\ \mathrm{m} + 52\ \mathrm{m} + 53\ \mathrm{m}}{50\ \mathrm{s}} = \boxed{2.5\ \mathrm{m/s}}$$

KECEPATAN SESAAT (*INSTANTANEOUS VELOCITY*)

- **Kecepatan rata-rata tidak memberikan informasi gerak benda tiap saat → Apakah suatu saat kecepatan benda membesar, mengecil, atau bahkan berhenti (HAL INI TIDAK TERKANDUNG DALAM KECEPATAN RATA-RATA).**
- **Kecepatan benda pada berbagai waktu tertuang dalam besaran gerak yang bernama KECEPATAN SESAAT.**
- **Kecepatan sesaat diperoleh dari KECEPATAN RATA-RATA dengan mengambil selang waktu yang sangat kecil, yaitu mendekati nol:**

$$v_x = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} \quad \text{.........................(3)}$$

$$v_x \equiv \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt} \quad \text{.........................(4)}$$

- **Karena kecepatan sesaat merupakan kecepatan pada berbagai waktu maka nilai kecepatan sesaat harus diberikan pada berbagai nilai waktu → dengan demikian kalau ditabelkan maka tabel kecepatan sesaat sangat panjang tergantung dari selang waktu yang dipilih → makin kecil selang waktu yang dipilih untuk mendeskripsikan kecepatan maka jumlah data kecepatan rata-rata menjadi sangat panjang.**

LAJU SESAAT (*INSTANTANEOUS SPEED*)

- Besar kecepatan sesaat adalah definisi LAJU SESAAT.
- Terdapat 2 cara mendapatkan nilai laju sesaat, yaitu:
  1. Ditentukan berdasarkan jarak tempuh dalam waktu yang mendekati nol
  2. Mengambil nilai skalar dari kecepatan sesaat.
- Pada kendaraan, laju sesaat ditunjukkan oleh angka speedometer.

CONTOH SOAL
KECEPATAN RATA-RATA DAN KECEPATAN SESAAT (1)

A particle moves along the x axis. Its x coordinate varies with time according to the expression $x = -4t + 2t^2$, where x is in meters and t is in seconds.[3] The position–time graph for this motion is shown in Figure 2.4. Note that the particle moves in the negative x direction for the first second of motion, is at rest at the moment $t = 1$ s, and moves in the positive x direction for $t > 1$ s. (a) Determine the displacement of the particle in the time intervals $t = 0$ to $t = 1$ s and $t = 1$ s to $t = 3$ s.

Solution During the first time interval, we have a negative slope and hence a negative velocity. Thus, we know that the displacement between Ⓐ and Ⓑ must be a negative number having units of meters. Similarly, we expect the displacement between Ⓑ and Ⓓ to be positive.

In the first time interval, we set $t_i = t_A = 0$ and $t_f = t_B = 1$ s. Using Equation 2.1, with $x = -4t + 2t^2$, we obtain for the first displacement

$$\Delta x_{A \to B} = x_f - x_i = x_B - x_A$$
$$= [-4(1) + 2(1)^2] - [-4(0) + 2(0)^2]$$
$$= -2 \text{ m}$$

To calculate the displacement during the second time interval, we set $t_i = t_B = 1$ s and $t_f = t_D = 3$ s:

$$\Delta x_{B \to D} = x_f - x_i = x_D - x_B$$

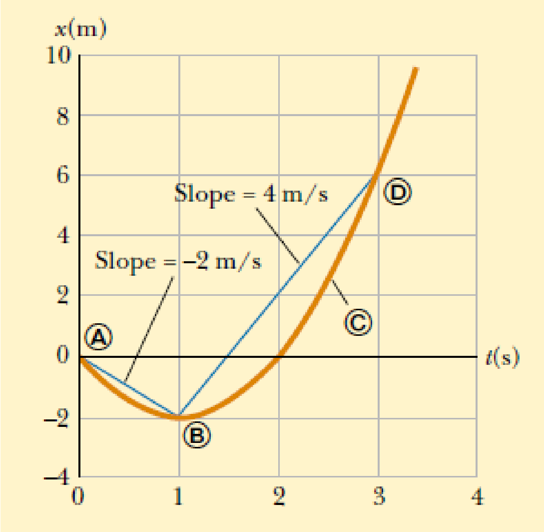


Figure 2.4 Position–time graph for a particle having an x coordinate that varies in time according to the expression $x = -4t + 2t^2$.

$$= [-4(3) + 2(3)^2] - [-4(1) + 2(1)^2]$$
$$= +8 \text{ m}$$

These displacements can also be read directly from the position–time graph.

CONTOH SOAL
KECEPATAN RATA-RATA DAN KECEPATAN SESAAT (2)

(b) Calculate the average velocity during these two time intervals.

Solution In the first time interval, $\Delta t = t_f - t_i = t_B - t_A = 1$ s. Therefore, using Equation 2.2 and the displacement calculated in (a), we find that

$$\overline{v}_{x(A\rightarrow B)} = \frac{\Delta x_{A\rightarrow B}}{\Delta t} = \frac{-2\text{ m}}{1\text{ s}} = \boxed{-2\text{ m/s}}$$

In the second time interval, $\Delta t = 2$ s; therefore,

$$\overline{v}_{x(B\rightarrow D)} = \frac{\Delta x_{B\rightarrow D}}{\Delta t} = \frac{8\text{ m}}{2\text{ s}} = \boxed{+4\text{ m/s}}$$

These values agree with the slopes of the lines joining these points in Figure 2.4.

(c) Find the instantaneous velocity of the particle at $t = 2.5$ s.

Solution Certainly we can guess that this instantaneous velocity must be of the same order of magnitude as our previous results, that is, around 4 m/s. Examining the graph, we see that the slope of the tangent at position Ⓒ is greater than the slope of the blue line connecting points Ⓑ and Ⓓ. Thus, we expect the answer to be greater than 4 m/s. By measuring the slope of the position–time graph at $t = 2.5$ s, we find that

$$v_x = \boxed{+6\text{ m/s}}$$

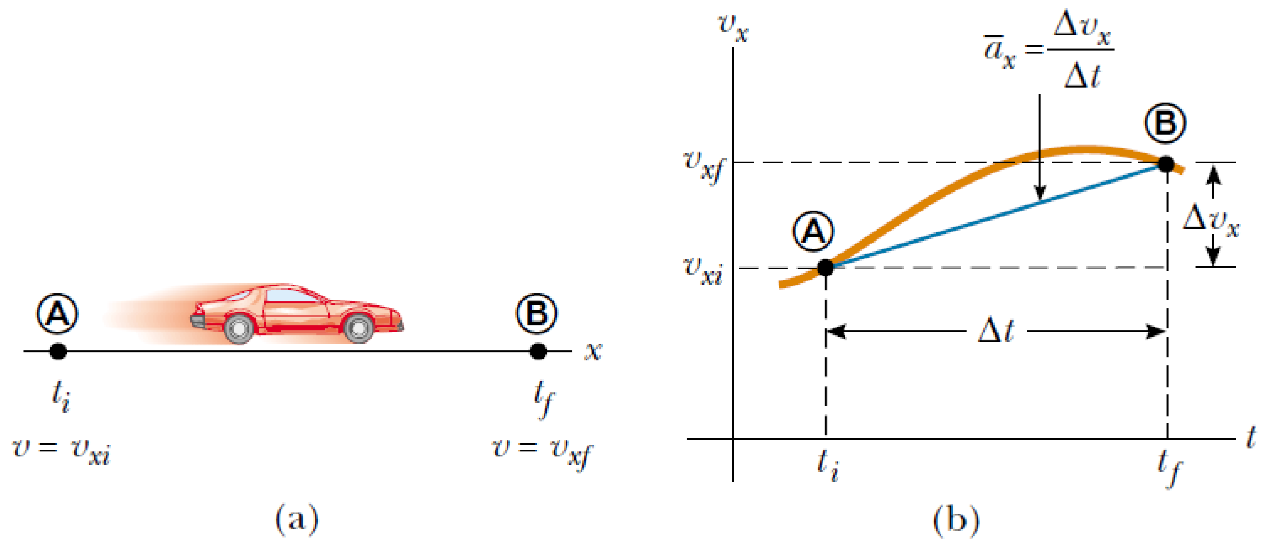
PERCEPATAN (*ACCELERATION*) (1)

- Selama gerakan, kadang kecepatan benda berubah. Perubahan tersebut bisa berupa perubahan nilai saja, perubahan arah saja, atau perubahan nilai dan arah.
- Perubahan tersebut ada yang CEPAT dan ada yang LAMBAT.
- Besaran yang mengukur berapa cepat kecepatan berubah dinamakan PERCEPATAN.
- Percepatan ratrata merupakan besaran vektor.
- PERCEPATAN RATA-RATA didefinisikan sebagai perbandingan antara perubahan kecepatan benda dengan lama kecepatan tersebut berubah:

$$\overline{a}_x \equiv \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xi}}{t_f - t_i} \qquad \text{.........................(5)}$$

- Pada perhitungan percepatan rata-rata kita tidak memperdulikan nilai kecepatan pada berbagai waktu, yang dibutuhkan adalann KECEPATAN PADA SAAT AWAL DAN SAAT AKHIR.
- Satuan besaran percepatan rata-rata adalah : m/s^2

PERCEPATAN (ACCELERATION) (2)



(a) A "particle" moving along the x axis from Ⓐ to Ⓑ has velocity v_{xi} at $t = t_i$ and velocity v_{xf} at $t = t_f$. (b) Velocity–time graph for the particle moving in a straight line. The slope of the blue straight line connecting Ⓐ and Ⓑ is the average acceleration in the time interval $\Delta t = t_f - t_i$.

PERCEPTAN SESAAT (1)

❖ Jika selang waktu yang kita ambil dalam menghitung percepatan rata-rata mendekati nol, maka percepatan rata-rata tersebut berubah menjadi PERCEPATAN SESAAT.

$$a_x \equiv \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt} \quad \text{.......................(6)}$$

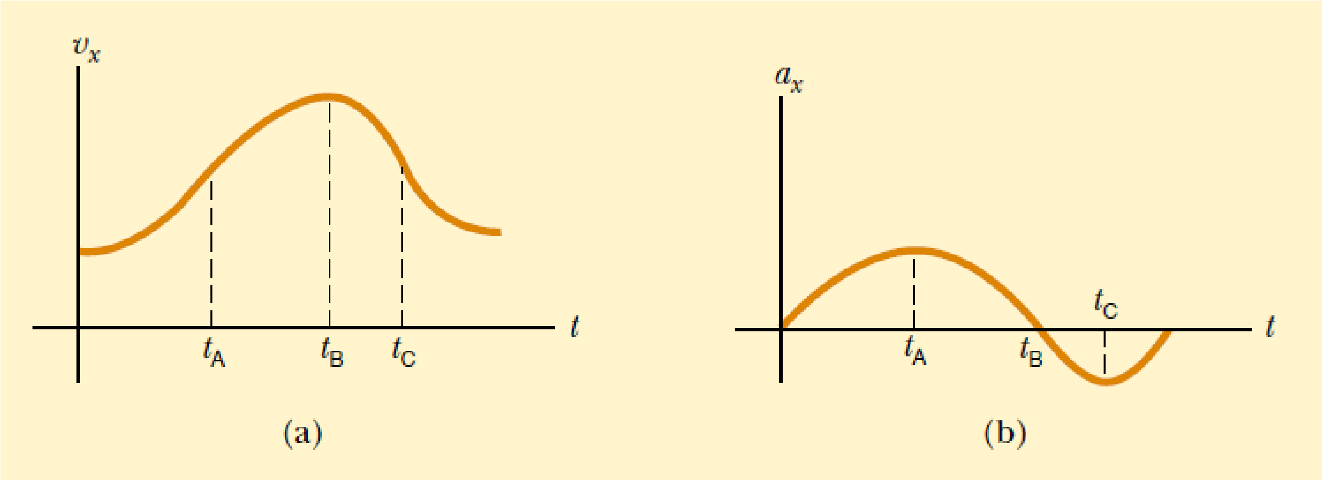
❖ Karena $v_x = d_x/d_t$, percepatan rata-rata dapat dituliskan sebagai berikut:

$$a_x = \frac{dv_x}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2} \quad \text{.......................(7)}$$

Cat: dalam gerak 1 dimensi, percepatan merupakan turunan kedua dari x terhadap waktu.

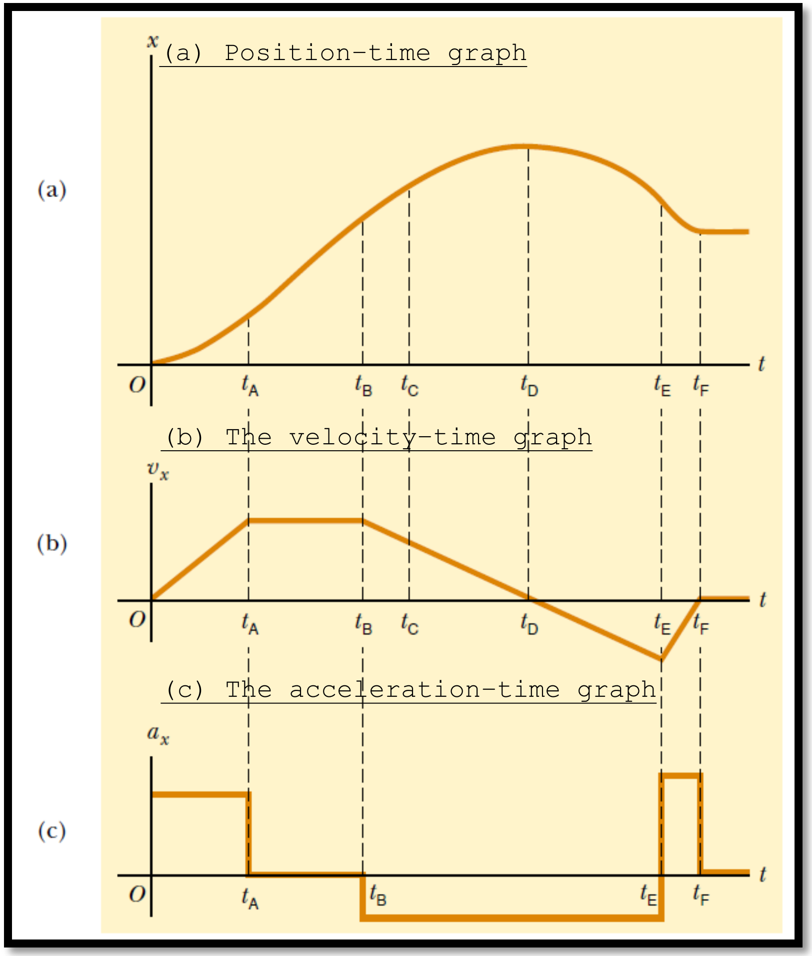
PERCEPATAN SESAAT (2)

- Figure illustrates how an acceleration–time graph is related to a velocity–time graph. The acceleration at any time is the SLOPE of the velocity–time graph at that time.
- Positive values of acceleration correspond to those points in Figure (a) where the velocity is increasing in the positive x direction. The acceleration reaches a maximum at time t_A, when the slope of the velocity–time graph is a maximum. The acceleration then goes to zero at time t_B, when the velocity is a maximum (that is, when the slope of the vx-t graph is zero). The acceleration is negative when the velocity is decreasing in the positive x direction, and it reaches its most negative value at time t_C.



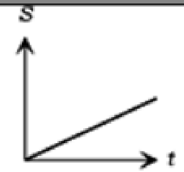
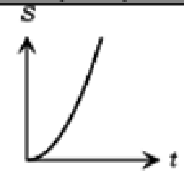
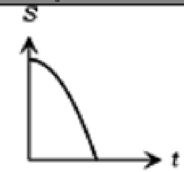
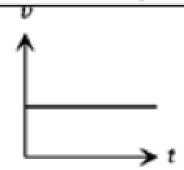
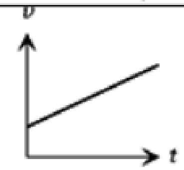
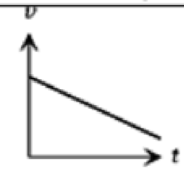
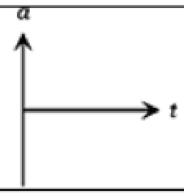
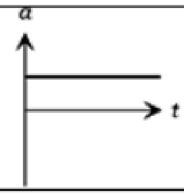
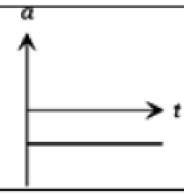
GRAPICAL RELATIONSHIP BETWEEN X, V_X, AND A_X (1)

- The velocity at any instant is the slope of the tangent to the *x*-*t* graph at that instant.
- Between t=0 and t=tA, the slope of the *x*-*t* graph increases uniformly, and so the velocity increases linearly.
- Between *t*A and *t*B, the slope of the *x*-*t* graph is constant, and so the velocity remains constant.
- At *t*D, the slope of the *x*-*t* graph is zero, so the velocity is zero at that instant. Between *t*D and *t*E, the slope of the *x*-*t* graph and thus the velocity are negative and decrease uniformly in this interval.
- In the interval *t*E to *t*F , the slope of the *x*-*t* graph is still negative, and at *t* F it goes to zero. Finally, after *t* F , the slope of the *x*-*t* graph is zero, meaning that the object is at rest for
- The acceleration at any instant is the slope of the tangent to the *vx* -*t* graph at that instant. The acceleration is constant and positive between 0 and *t*A, where the slope of the *vx* -*t* graph is positive. It is zero between *t*A and *t*B and for because the slope of the *vx* -*t* graph is zero at these times. It is negative between *t*B and *t*E because the slope of the *vx* -*t* graph is negative during this interval.



GRAPICAL RELATIONSHIP BETWEEN X, V_X, AND A_X (2)

❑ Grafik

besaran	GLB	GLBB	
		dipercepat	diperlambat
Perpindahan			
Kecepatan			
Percepatan			

- ☆ *Gradien* grafik S-t menyatakan kecepatan
- ☆ *Gradien* grafik v-t menyatakan percepatan
- ☆ Luas daerah di bawah grafik v-t menyatakan perpindahan
- ☆ Luas daerah di bawah grafik a-t menyatakan kecepatan

CONTOH SOAL PERCEPATAN RATA-RATA DAN PERCEPATAN SESAAT

The velocity of a particle moving along the x axis varies in time according to the expression $v_x = (40 - 5t^2)$ m/s, where t is in seconds. (a) Find the average acceleration in the time interval $t = 0$ to $t = 2.0$ s.

Solution Figure 2.8 is a v_x-t graph that was created from the velocity versus time expression given in the problem statement. Because the slope of the entire v_x-t curve is negative, we expect the acceleration to be negative.

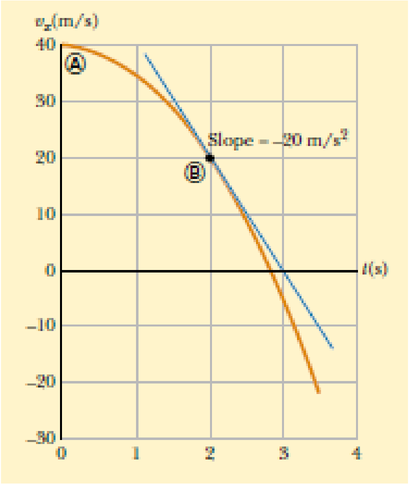


Figure 2.8 The velocity–time graph for a particle moving along the x axis according to the expression $v_x = (40 - 5t^2)$ m/s. The acceleration at $t = 2$ s is equal to the slope of the blue tangent line at that time.

We find the velocities at $t_i = t_A = 0$ and $t_f = t_B = 2.0$ s by substituting these values of t into the expression for the velocity:

$$v_{xA} = (40 - 5t_A^2)\text{ m/s} = [40 - 5(0)^2]\text{ m/s} = +40\text{ m/s}$$

$$v_{xB} = (40 - 5t_B^2)\text{ m/s} = [40 - 5(2.0)^2]\text{ m/s} = +20\text{ m/s}$$

Therefore, the average acceleration in the specified time interval $\Delta t = t_B - t_A = 2.0$ s is

$$\bar{a}_x = \frac{v_{xf} - v_{xi}}{t_f - t_i} = \frac{v_{xB} - v_{xA}}{t_B - t_A} = \frac{(20 - 40)\text{ m/s}}{(2.0 - 0)\text{ s}}$$

$$= -10\text{ m/s}^2$$

The negative sign is consistent with our expectations—namely, that the average acceleration, which is represented by the slope of the line (not shown) joining the initial and final points on the velocity–time graph, is negative.

(b) Determine the acceleration at $t = 2.0$ s.

Solution The velocity at any time t is $v_{xi} = (40 - 5t^2)$ m/s, and the velocity at any later time $t + \Delta t$ is

$$v_{xf} = 40 - 5(t + \Delta t)^2 = 40 - 5t^2 - 10t\,\Delta t - 5(\Delta t)^2$$

Therefore, the change in velocity over the time interval Δt is

$$\Delta v_x = v_{xf} - v_{xi} = [-10t\,\Delta t - 5(\Delta t)^2]\text{ m/s}$$

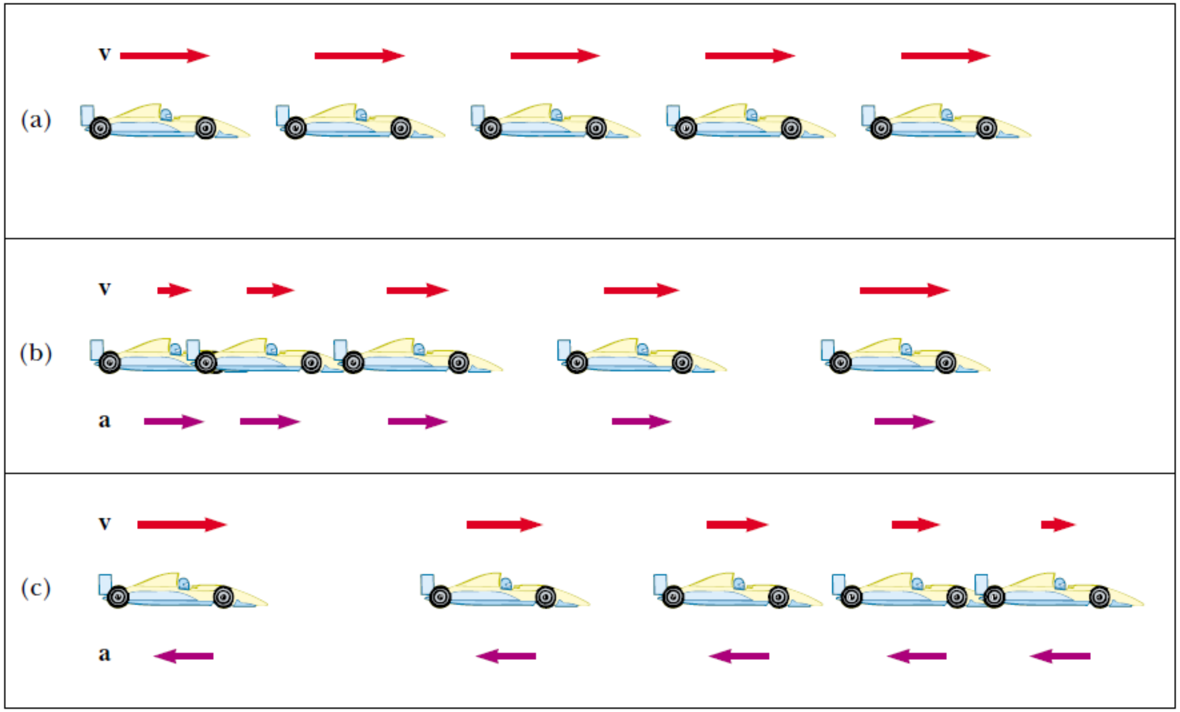
Dividing this expression by Δt and taking the limit of the result as Δt approaches zero gives the acceleration at *any* time t:

$$a_x = \lim_{\Delta t \to 0} \frac{\Delta v_x}{\Delta t} = \lim_{\Delta t \to 0} (-10t - 5\Delta t) = -10t\text{ m/s}^2$$

Therefore, at $t = 2.0$ s,

$$a_x = (-10)(2.0)\text{ m/s}^2 = -20\text{ m/s}^2$$

MOTION DIAGRAMS



Ket: *red for velocity vectors and violet for acceleration vectors*

Sumber: Walker Jearl, Fundamental of Physic, 8^{th} edition

(a) Motion diagram for a car moving at **constant velocity** (**zero acceleration**).

(b) Motion diagram for a car whose constant acceleration is in the direction of its velocity. The velocity vector at each instant is indicated by a red arrow, and the constant acceleration by a violet arrow.

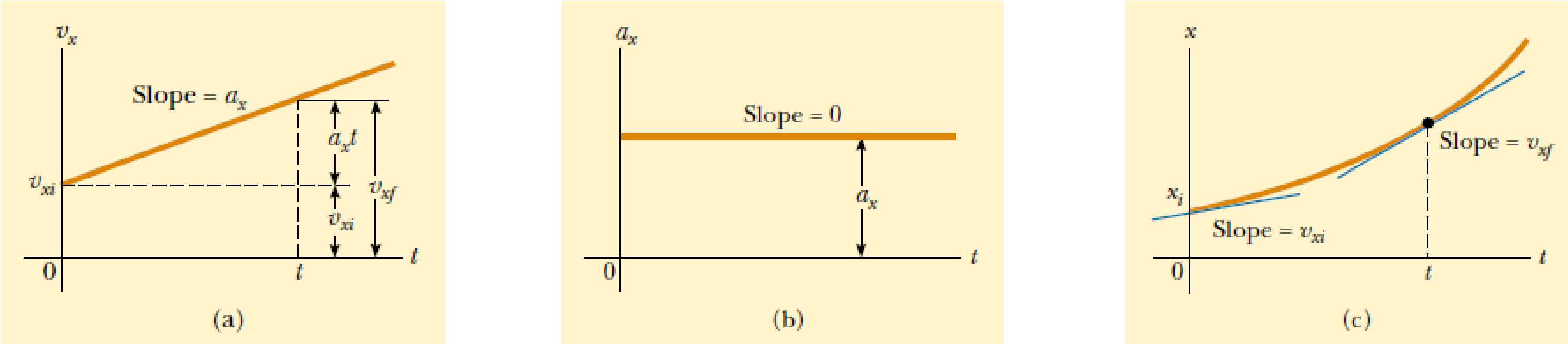
(c) Motion diagram for a car whose constant acceleration is in the direction *opposite* the velocity at each instant.

ONE-DIMENSIONAL MOTION WITH CONSTANT ACCELERATION (1)

- Suatu partikel dikatakan mengalami gerak dengan percepatan konstan manakala partikel tersebut mengalami perubahan kecepatan yang tetap tiap satuan waktu
- Jika percepatan memiliki nilai konstan:

$$a_x = \frac{v_{xf} - v_{xi}}{t}$$ **atau** $$v_{xf} = v_{xi} + a_x t$$ **(for constant a_x)** ....(8)

An object moving along the *x* axis with constant acceleration a_x



The velocity-time graph **The acceleration-time graph.** **The position-time graph**

Note that the slope is positive; this indicates a positive acceleration. If the acceleration were negative, then the slope of the line in **Figure a** would be negative.

ONE-DIMENSIONAL MOTION WITH CONSTANT ACCELERATION (2)

Because velocity at constant acceleration varies linearly in time according to **Equation 8**, we can express the average velocity in any time interval as the arithmetic mean of the initial velocity v_{xi} and the final velocity v_{xf} :

$$\overline{v}_x = \frac{v_{xi} + v_{xf}}{2} \qquad \text{(for constant } a_x\text{)} \qquad \text{..........................(9)}$$

We can now use Equations 1, 2, and 9 to obtain the displacement of any object as a function of time. Recalling that Δx in Equation 2 represents $x_f - x_i$, and now using t in place of Δt (because we take $t_i = 0$), we can say

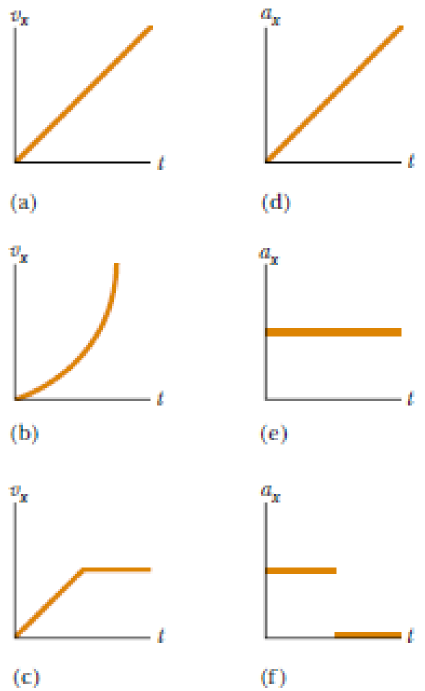
$$x_f - x_i = \overline{v}_x t = \tfrac{1}{2}(v_{xi} + v_{xf})t \qquad \text{(for constant } a_x\text{)} \qquad \text{..........................(10)}$$

We can obtain another useful expression for displacement at constant acceleration by substituting Equation 8 into Equation 10:

$$x_f - x_i = \tfrac{1}{2}(v_{xi} + v_{xi} + a_x t)t$$

$$x_f - x_i = v_{xi}t + \tfrac{1}{2}a_x t^2 \qquad \text{..........................(11)}$$

ONE-DIMENSIONAL MOTION WITH CONSTANT ACCELERATION (3)



Parts (a), (b), and (c) are v_x-t graphs of objects in one-dimensional motion. The possible accelerations of each object as a function of time are shown in scrambled order in (d), (e), and (f).

- The position-time graph for motion at constant (positive) acceleration shown in **Figure (c)** is obtained from Equation 11. Note that the curve is a parabola. The slope of the tangent line to this curve at equals the initial velocity *vxi* , and the slope of the tangent line at any later timeequals the velocity at that time, *vxf* .
- We can check the validity of Equation 11 by moving the *xi* term to the righthand side of the equation and differentiating the equation with respect to time:

$$v_{xf} = \frac{dx_f}{dt} = \frac{d}{dt}\left(x_i + v_{xi}t + \frac{1}{2}a_x t^2\right) = v_{xi} + a_x t$$

ONE-DIMENSIONAL MOTION WITH CONSTANT ACCELERATION (4)

Finally, we can obtain an expression for the final velocity that does not contain a time interval by substituting the value of *t* from Equation 8 into Equation 10:

$$x_f - x_i = \frac{1}{2}(v_{xi} + v_{xf})\left(\frac{v_{xf} - v_{xi}}{a_x}\right) = \frac{{v_{xf}}^2 - {v_{xi}}^2}{2a_x}$$

$${v_{xf}}^2 = {v_{xi}}^2 + 2a_x(x_f - x_i) \qquad \text{(for constant } a_x\text{)} \qquad \text{.........................} \textbf{(12)}$$

For motion at *zero* acceleration, we see from Equations 8 and 11 that:

$$\left.\begin{aligned} v_{xf} = v_{xi} &= v_x \\ x_f - x_i &= v_x t \end{aligned}\right\} \quad \text{when } a_x = 0$$

That is, when acceleration is zero, velocity is constant and displacement changes linearly with time.

KINEMATIC EQUATIONS FOR MOTION IN A STRAIGHT LINE UNDER CONSTANT ACCELERATION

Dari pembahasan sebelumnya kita dapat menghubungkan keempat variabel dalam kinematika, yaitu posisi, kecepatan, percepatan dan waktu dalam 4 persamaan sebagai berikut:

TABLE 2.2 Kinematic Equations for Motion in a Straight Line Under Constant Acceleration

Equation	Information Given by Equation
$v_{xf} = v_{xi} + a_x t$	Velocity as a function of time
$x_f - x_i = \frac{1}{2}(v_{xi} + v_{xf})t$	Displacement as a function of velocity and time
$x_f - x_i = v_{xi}t + \frac{1}{2}a_x t^2$	Displacement as a function of time
${v_{xf}}^2 = {v_{xi}}^2 + 2a_x(x_f - x_i)$	Velocity as a function of displacement

Note: Motion is along the x axis.

Sumber: Walker Jearl, Fundamental of Physic, 8^{th} edition

CONTOH SOAL GERAK 1 DIMENSI DENGAN PERCEPATAN KONSTAN

CONCEPTUAL EXAMPLE 2.5 **The Velocity of Different Objects**

Consider the following one-dimensional motions: (a) A ball thrown directly upward rises to a highest point and falls back into the thrower's hand. (b) A race car starts from rest and speeds up to 100 m/s. (c) A spacecraft drifts through space at constant velocity. Are there any points in the motion of these objects at which the instantaneous velocity is the same as the average velocity over the entire motion? If so, identify the point(s).

Solution (a) The average velocity for the thrown ball is zero because the ball returns to the starting point; thus its displacement is zero. (Remember that average velocity is defined as $\Delta x/\Delta t$.) There is one point at which the instantaneous velocity is zero—at the top of the motion.

(b) The car's average velocity cannot be evaluated unambiguously with the information given, but it must be some value between 0 and 100 m/s. Because the car will have every instantaneous velocity between 0 and 100 m/s at some time during the interval, there must be some instant at which the instantaneous velocity is equal to the average velocity.

(c) Because the spacecraft's instantaneous velocity is constant, its instantaneous velocity at *any* time and its average velocity over *any* time interval are the same.

EXAMPLE 2.7 **Carrier Landing**

A jet lands on an aircraft carrier at 140 mi/h ($\approx$ 63 m/s). (a) What is its acceleration if it stops in 2.0 s?

Solution We define our *x* axis as the direction of motion of the jet. A careful reading of the problem reveals that in addition to being given the initial speed of 63 m/s, we also know that the final speed is zero. We also note that we are not given the displacement of the jet while it is slowing down. Equation 2.8 is the only equation in Table 2.2 that does not involve displacement, and so we use it to find the acceleration:

$$a_x = \frac{v_{xf} - v_{xi}}{t} \approx \frac{0 - 63 \text{ m/s}}{2.0 \text{ s}} = \boxed{-31 \text{ m/s}^2}$$

(b) What is the displacement of the plane while it is stopping?

Solution We can now use any of the other three equations in Table 2.2 to solve for the displacement. Let us choose Equation 2.10:

$$x_f - x_i = \tfrac{1}{2}(v_{xi} + v_{xf})t = \tfrac{1}{2}(63 \text{ m/s} + 0)(2.0 \text{ s}) = \boxed{63 \text{ m}}$$

If the plane travels much farther than this, it might fall into the ocean. Although the idea of using arresting cables to enable planes to land safely on ships originated at about the time of the First World War, the cables are still a vital part of the operation of modern aircraft carriers.

GERAK JATUH BEBAS
(*FREELY FALLING OBJECTS*)

- Gerak jatuh bebas adalah kondisi khusus dari gerak dalam arah sumbu y.
- Suatu partikel dikatakan mengalami Gerak Jatuh Bebas ketika partikel tersebut jatuh dari ketinggian tertentu (y_o) dengan kecepatan awal v_o = 0 dan dipercepat ke bawah oleh percepatan gravitasi bumi (*g*).
- Nilai dari g = 9,8 m/s^2
- Dengan kata lain, pada Gerak Jatuh Bebas diberlakukan $v_o = 0$, $y_o = 0$ dan $a_y = -g = -9{,}8\ m/s^2$

CONTOH SOAL GERAK JATUH BEBAS (1)

CONCEPTUAL EXAMPLE 2.9 **The Daring Sky Divers**

A sky diver jumps out of a hovering helicopter. A few seconds later, another sky diver jumps out, and they both fall along the same vertical line. Ignore air resistance, so that both sky divers fall with the same acceleration. Does the difference in their speeds stay the same throughout the fall? Does the vertical distance between them stay the same throughout the fall? If the two divers were connected by a long bungee cord, would the tension in the cord increase, lessen, or stay the same during the fall?

Solution At any given instant, the speeds of the divers are different because one had a head start. In any time interval Δt after this instant, however, the two divers increase their speeds by the same amount because they have the same acceleration. Thus, the difference in their speeds remains the same throughout the fall.

The first jumper always has a greater speed than the second. Thus, in a given time interval, the first diver covers a greater distance than the second. Thus, the separation distance between them increases.

Once the distance between the divers reaches the length of the bungee cord, the tension in the cord begins to increase. As the tension increases, the distance between the divers becomes greater and greater.

EXAMPLE 2.10 **Describing the Motion of a Tossed Ball**

A ball is tossed straight up at 25 m/s. Estimate its velocity at 1-s intervals.

Solution Let us choose the upward direction to be positive. Regardless of whether the ball is moving upward or downward, its vertical velocity changes by approximately -10 m/s for every second it remains in the air. It starts out at 25 m/s. After 1 s has elapsed, it is still moving upward but at 15 m/s because its acceleration is downward (downward acceleration causes its velocity to decrease). After another second, its upward velocity has dropped to 5 m/s. Now comes the tricky part—after another half second, its velocity is zero. The ball has gone as high as it will go. After the last half of this 1-s interval, the ball is moving at -5 m/s. (The minus sign tells us that the ball is now moving in the negative direction, that is, *downward*. Its velocity has changed from $+5$ m/s to -5 m/s during that 1-s interval. The change in velocity is still $-5 - [+5] = -10$ m/s in that second.) It continues downward, and after another 1 s has elapsed, it is falling at a velocity of -15 m/s. Finally, after another 1 s, it has reached its original starting point and is moving downward at -25 m/s. If the ball had been tossed vertically off a cliff so that it could continue downward, its velocity would continue to change by about -10 m/s every second.

CONTOH SOAL GERAK JATUH BEBAS (2)

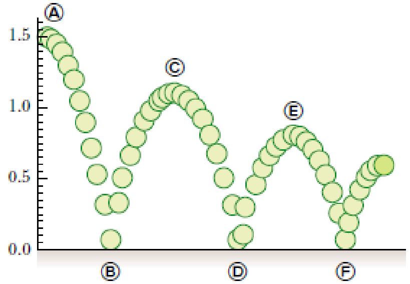
CONCEPTUAL EXAMPLE 2.11 **Follow the Bouncing Ball**

A tennis ball is dropped from shoulder height (about 1.5 m) and bounces three times before it is caught. Sketch graphs of its position, velocity, and acceleration as functions of time, with the $+y$ direction defined as upward.

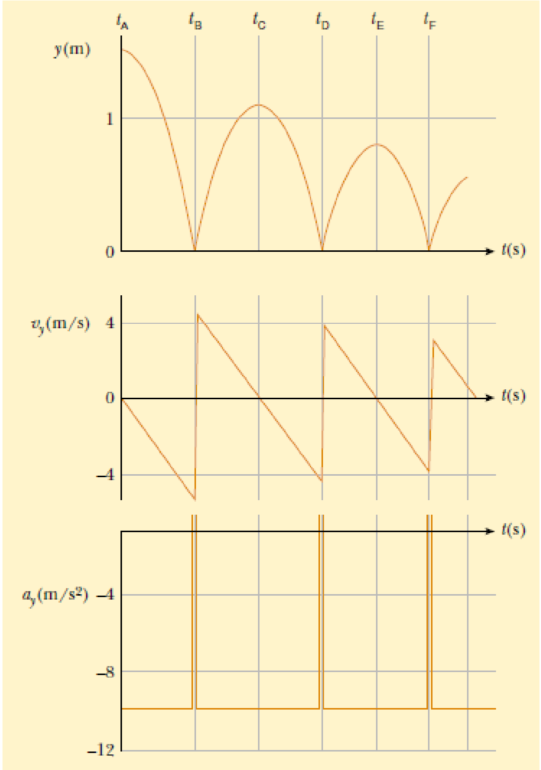
Solution For our sketch let us stretch things out horizontally so that we can see what is going on. (Even if the ball were moving horizontally, this motion would not affect its vertical motion.)

From Figure 2.13 we see that the ball is in contact with the floor at points Ⓑ, Ⓓ, and Ⓕ. Because the velocity of the ball changes from negative to positive three times during these bounces, the slope of the position–time graph must change in the same way. Note that the time interval between bounces decreases. Why is that?

During the rest of the ball's motion, the slope of the velocity–time graph should be $-9.80\ \text{m/s}^2$. The acceleration–time graph is a horizontal line at these times because the acceleration does not change when the ball is in free fall. When the ball is in contact with the floor, the velocity changes substantially during a very short time interval, and so the acceleration must be quite great. This corresponds to the very steep upward lines on the velocity–time graph and to the spikes on the acceleration–time graph.



(a)



(b)

Figure 2.13 (a) A ball is dropped from a height of 1.5 m and bounces from the floor. (The horizontal motion is not considered here because it does not affect the vertical motion.) (b) Graphs of position, velocity, and acceleration versus time.

CONTOH SOAL GERAK JATUH BEBAS (3)

EXAMPLE 2.12 **Not a Bad Throw for a Rookie!**

A stone thrown from the top of a building is given an initial velocity of 20.0 m/s straight upward. The building is 50.0 m high, and the stone just misses the edge of the roof on its way down, as shown in Figure 2.14. Using $t_A = 0$ as the time the stone leaves the thrower's hand at position Ⓐ, determine (a) the time at which the stone reaches its maximum height, (b) the maximum height, (c) the time at which the stone returns to the height from which it was thrown, (d) the velocity of the stone at this instant, and (e) the velocity and position of the stone at $t = 5.00$ s.

Solution (a) As the stone travels from Ⓐ to Ⓑ, its velocity must change by 20 m/s because it stops at Ⓑ. Because gravity causes vertical velocities to change by about 10 m/s for every second of free fall, it should take the stone about 2 s to go from Ⓐ to Ⓑ in our drawing. (In a problem like this, a sketch definitely helps you organize your thoughts.) To calculate the time t_B at which the stone reaches maximum height, we use Equation 2.8, $v_{yB} = v_{yA} + a_y t$, noting that $v_{yB} = 0$ and setting the start of our clock readings at $t_A \equiv 0$:

$$20.0\ \text{m/s} + (-9.80\ \text{m/s}^2)t = 0$$

$$t = t_B = \frac{20.0\ \text{m/s}}{9.80\ \text{m/s}^2} = \boxed{2.04\ \text{s}}$$

Our estimate was pretty close.

(b) Because the average velocity for this first interval is 10 m/s (the average of 20 m/s and 0 m/s) and because it travels for about 2 s, we expect the stone to travel about 20 m. By substituting our time interval into Equation 2.11, we can find the maximum height as measured from the position of the thrower, where we set $y_i = y_A = 0$:

$$y_{max} = y_B = v_{yA}\,t + \tfrac{1}{2}a_y t^2$$

$$y_B = (20.0\ \text{m/s})(2.04\ \text{s}) + \tfrac{1}{2}(-9.80\ \text{m/s}^2)(2.04\ \text{s})^2$$

$$= \boxed{20.4\ \text{m}}$$

Our free-fall estimates are very accurate.

(c) There is no reason to believe that the stone's motion from Ⓑ to Ⓒ is anything other than the reverse of its motion

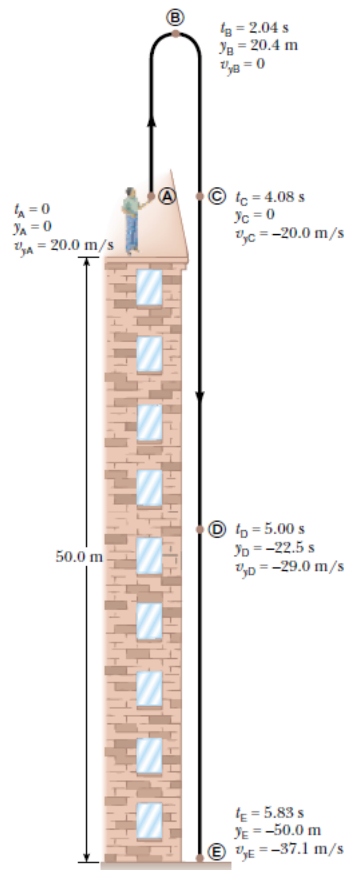


Figure 2.14 Position and velocity versus time for a freely falling stone thrown initially upward with a velocity v_{yi} = 20.0 m/s.

CONTOH SOAL GERAK JATUH BEBAS (4)

from Ⓐ to Ⓑ. Thus, the time needed for it to go from Ⓐ to Ⓒ should be twice the time needed for it to go from Ⓐ to Ⓑ. When the stone is back at the height from which it was thrown (position Ⓒ), the y coordinate is again zero. Using Equation 2.11, with $y_f = y_C = 0$ and $y_i = y_A = 0$, we obtain

$$y_C - y_A = v_{yA}\, t + \tfrac{1}{2}a_y t^2$$
$$0 = 20.0t - 4.90t^2$$

This is a quadratic equation and so has two solutions for $t = t_C$. The equation can be factored to give

$$t(20.0 - 4.90t) = 0$$

One solution is $t = 0$, corresponding to the time the stone starts its motion. The other solution is $t = 4.08$ s, which is the solution we are after. Notice that it is double the value we calculated for t_B.

(d) Again, we expect everything at Ⓒ to be the same as it is at Ⓐ, except that the velocity is now in the opposite direction. The value for t found in (c) can be inserted into Equation 2.8 to give

$$v_{yC} = v_{yA} + a_y t = 20.0\ \text{m/s} + (-9.80\ \text{m/s}^2)(4.08\ \text{s})$$
$$= -20.0\ \text{m/s}$$

The velocity of the stone when it arrives back at its original height is equal in magnitude to its initial velocity but opposite in direction. This indicates that the motion is symmetric.

(e) For this part we consider what happens as the stone falls from position Ⓑ, where it had zero vertical velocity, to position Ⓓ. Because the elapsed time for this part of the motion is about 3 s, we estimate that the acceleration due to gravity will have changed the speed by about 30 m/s. We can calculate this from Equation 2.8, where we take $t = t_D - t_B$:

$$v_{yD} = v_{yB} + a_y t = 0\ \text{m/s} + (-9.80\ \text{m/s}^2)(5.00\ \text{s} - 2.04\ \text{s})$$
$$= -29.0\ \text{m/s}$$

We could just as easily have made our calculation between positions Ⓐ and Ⓓ by making sure we use the correct time interval, $t = t_D - t_A = 5.00$ s:

$$v_{yD} = v_{yA} + a_y t = 20.0\ \text{m/s} + (-9.80\ \text{m/s}^2)(5.00\ \text{s})$$
$$= -29.0\ \text{m/s}$$

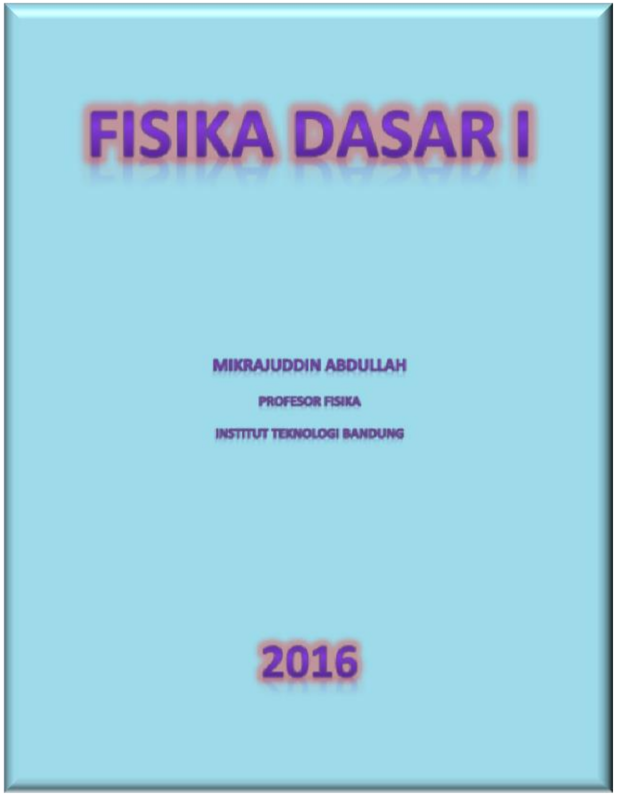
To demonstrate the power of our kinematic equations, we can use Equation 2.11 to find the position of the stone at $t_D = 5.00$ s by considering the change in position between a different pair of positions, Ⓒ and Ⓓ. In this case, the time is $t_D - t_C$:

$$y_D = y_C + v_{yC}t + \tfrac{1}{2}a_y t^2$$
$$= 0\ \text{m} + (-20.0\ \text{m/s})(5.00\ \text{s} - 4.08\ \text{s}) + \tfrac{1}{2}(-9.80\ \text{m/s}^2)(5.00\ \text{s} - 4.08\ \text{s})^2$$
$$= -22.5\ \text{m}$$

Exercise Find (a) the velocity of the stone just before it hits the ground at Ⓔ and (b) the total time the stone is in the air.

Answer (a) -37.1 m/s (b) 5.83 s

REFERENSI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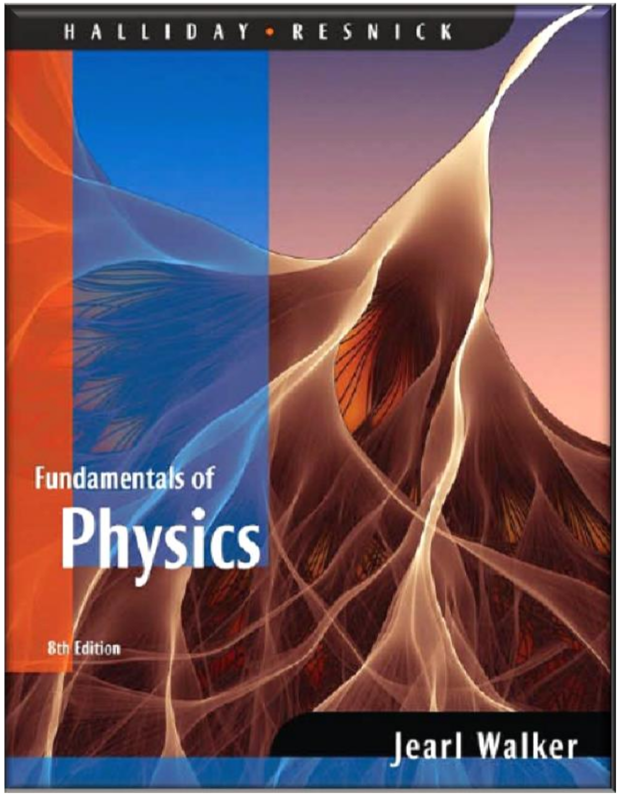
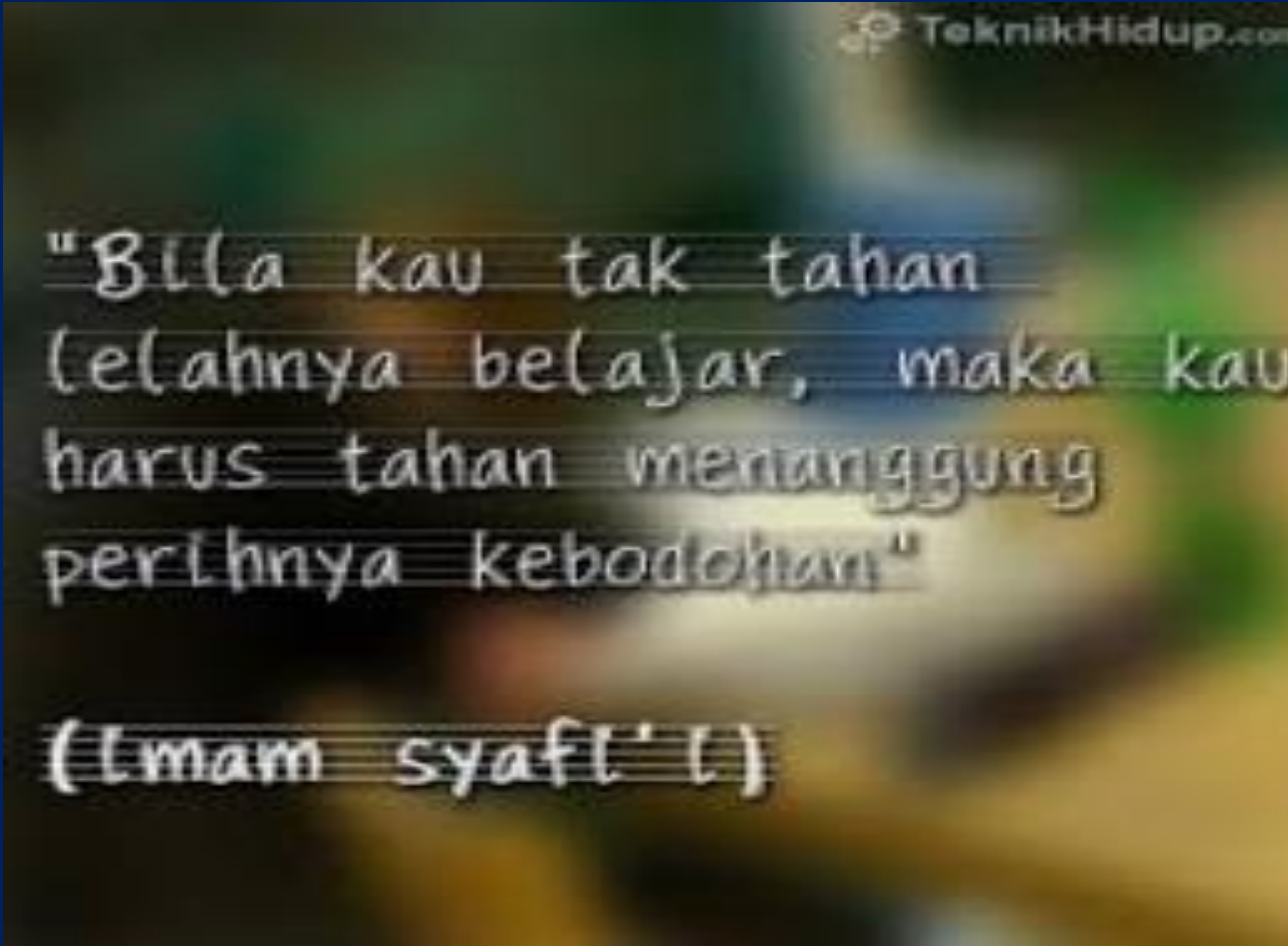

HALLIDAY • RESNICK
Fundamentals of
Physics
8th Edition
Jearl Walker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(Imam syafi'i)