Physics 231: non-calculus introductory physics I

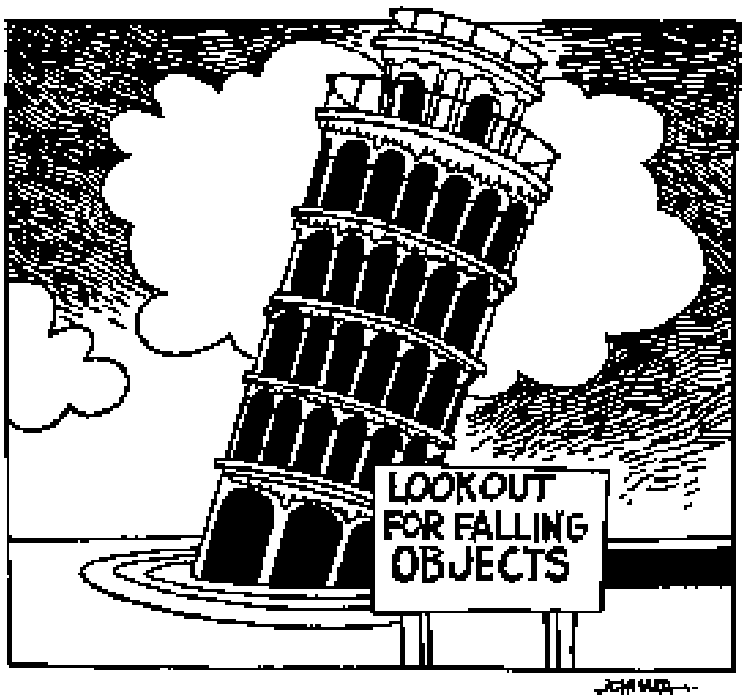
Section 003

http://www.pa.msu.edu/people/yuan/classes.htm

Honors option:

- Serve two hours a week in the helproom (BPS 1248)
- must score 3.5 and above in all midterms

PHYSICS 231
Lecture 3: Motion in 1-D, part II



"You go ahead of me. I think you're faster."

Previously…

VECTORS
- Displacement
- Average Velocity
- Instantaneous velocity
- Average acceleration
- Instantaneous acceleration

SCALARS
- Distance
- Average speed
- Instantaneous speed

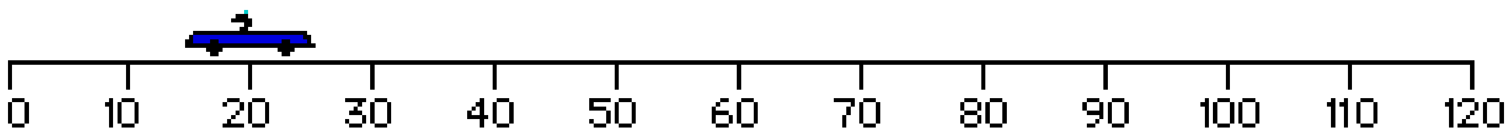
MOTION DIAGRAMS

Speed versus velocity

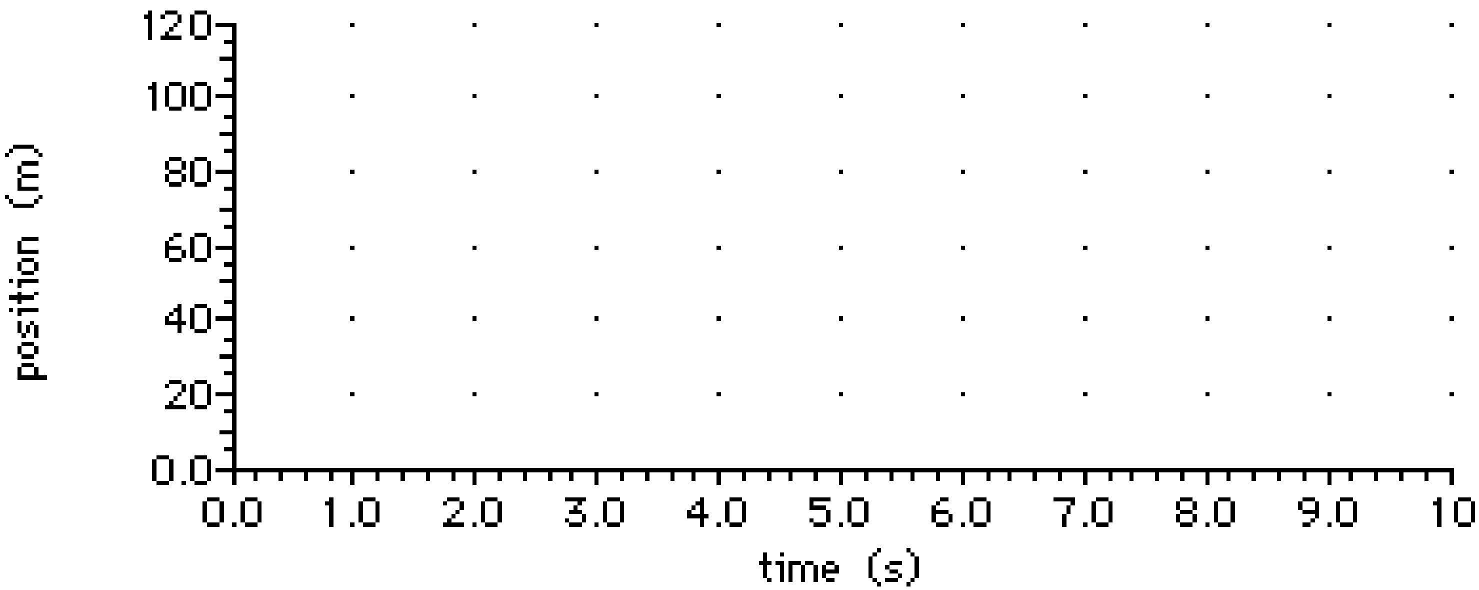
A car travels from East Lansing to Okemos (3 km). The trip takes 10 minutes (1/6 hour). He then turns around and travels back. It takes him 20 minutes (1/3 hour) What was his average speed and average velocity over The whole trip?

a) Average speed: 13.5 km/h Average velocity 12 km/h
b) Average speed: 12 km/h Average velocity 0 km/h
c) Average speed: 13.5 km/h Average velocity 0 km/h
d) Average speed: 0 km/h Average velocity 13.5 km/h
e) Don't know

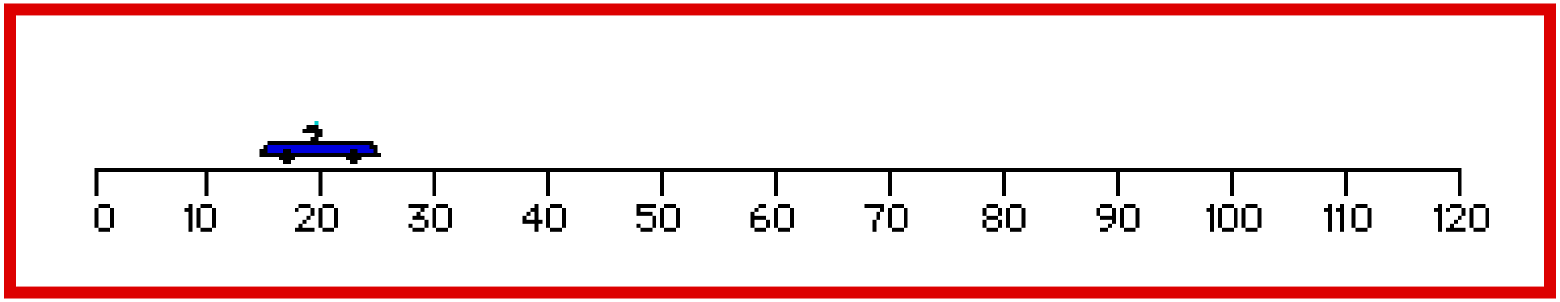
Average velocity = (displacement/time)=$(x_f-x_i)/\Delta t$
Average speed=(distance/time)
Hence, 6/(1/6 + 1/3) = 12 Note: $x_f=x_i$

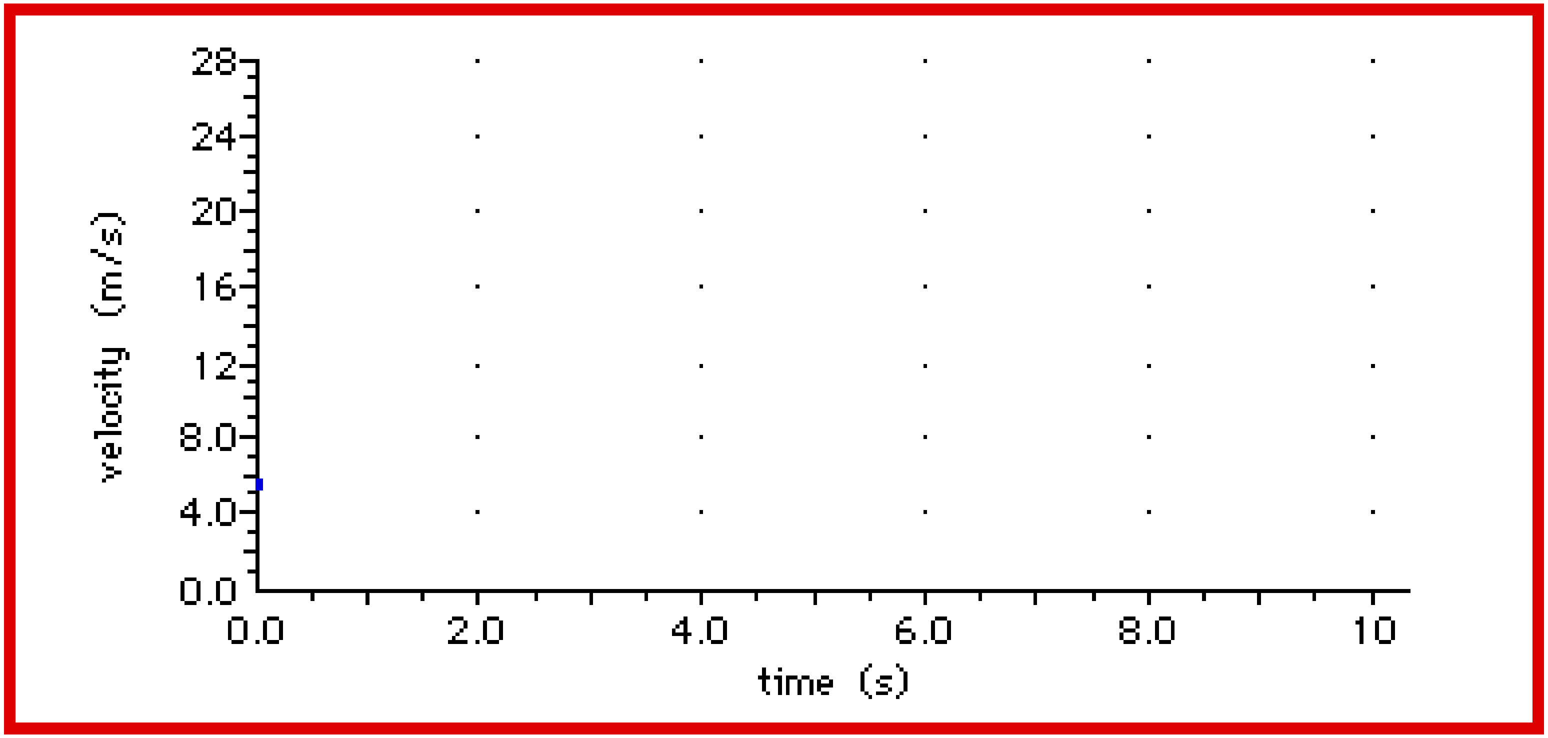


0
10
20
30
40
50
60
70
80
90
100
110
120



position (m)
120
100
80
60
40
20
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10
time (s)


0
10
20
30
40
50
60
70
80
90
100
110
120

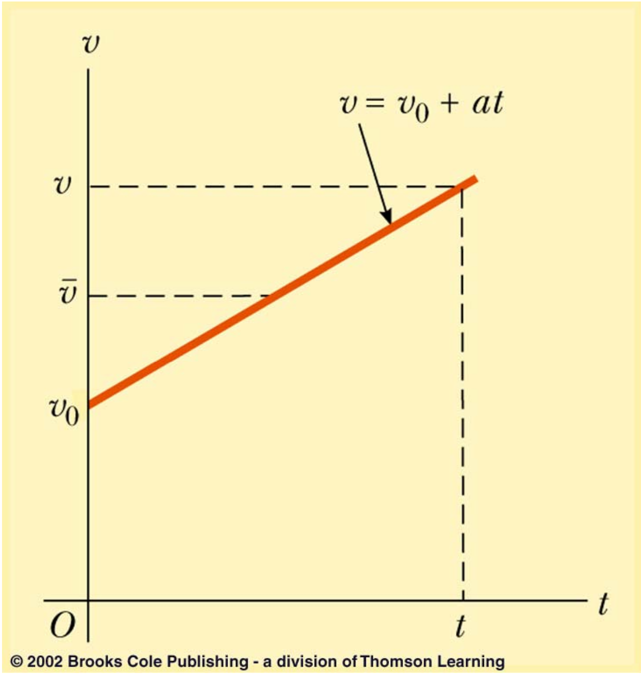

28
24
20
16
12
8.0
4.0
0.0
velocity (m/s)
0.0
2.0
4.0
6.0
8.0
10
time (s)

Constant acceleration

$$v(t) = v_0 + at$$

Velocity at t=t equals…

Velocity at t=0…



Plus the gain in velocity per second
Multiplied by the time span
(every second, the velocity increases
With *a* m/s)

Constant acceleration II

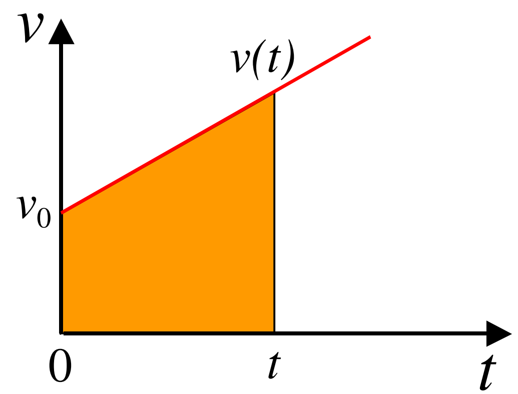
$$x(t) = x_o + \bar{v}t = x_o + \frac{(v_0 + v_t)}{2}t = x_o + v_o t + \tfrac{1}{2}at^2$$

Start position plus average velocity multiplied by time

Substitute $\bar{v} = \dfrac{v_0 + v_t}{2}$

Substitute $v(t) = v_0 + at$

Constant Acceleration



- V(t) is a straight line.
- The area under the line in time interval t is

$$\Delta x = \left(\frac{v_0 + v_t}{2}\right)(t - 0) = \left(\frac{v_0 + v_t}{2}\right)\Delta t$$

- The average velocity in defined as $\bar{v} = \dfrac{\Delta x}{\Delta t}$

Hence, $\bar{v} = \dfrac{v_0 + v_t}{2}$

Review of Velocity:

Definitions

Displacement: distance travelled, *and direction*:

$$\Delta x = x_f - x_i$$

Average velocity: rate of change of position: $\bar{v} = \frac{\Delta x}{\Delta t}$

Instantaneous velocity: $$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

Motion with constant velocity: $(a = 0)$

$$v = constant$$

displacement : $x - x_o = v\, t$

Review of Acceleration:

Acceleration: rate of change of velocity:

$$\bar{a} = \frac{\Delta v}{\Delta t} \quad ; \quad a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t}$$

Motion with constant acceleration: $(a \neq 0)$

$$a = constant$$

change in velocity : $v - v_o = a\,t$

average velocity : $\bar{v} = \frac{1}{2}(v_o + v) = v_o + \frac{1}{2}\,a\,t$

displacement : $x - x_o = \bar{v}t = v_o\,t + \frac{1}{2}\,a\,t^2$

change in velocity : $v^2 - v_0^2 = 2\,a\,(x - x_0) = 2\,a\,s$

Derivation

$$t = \frac{v - v_0}{a}$$

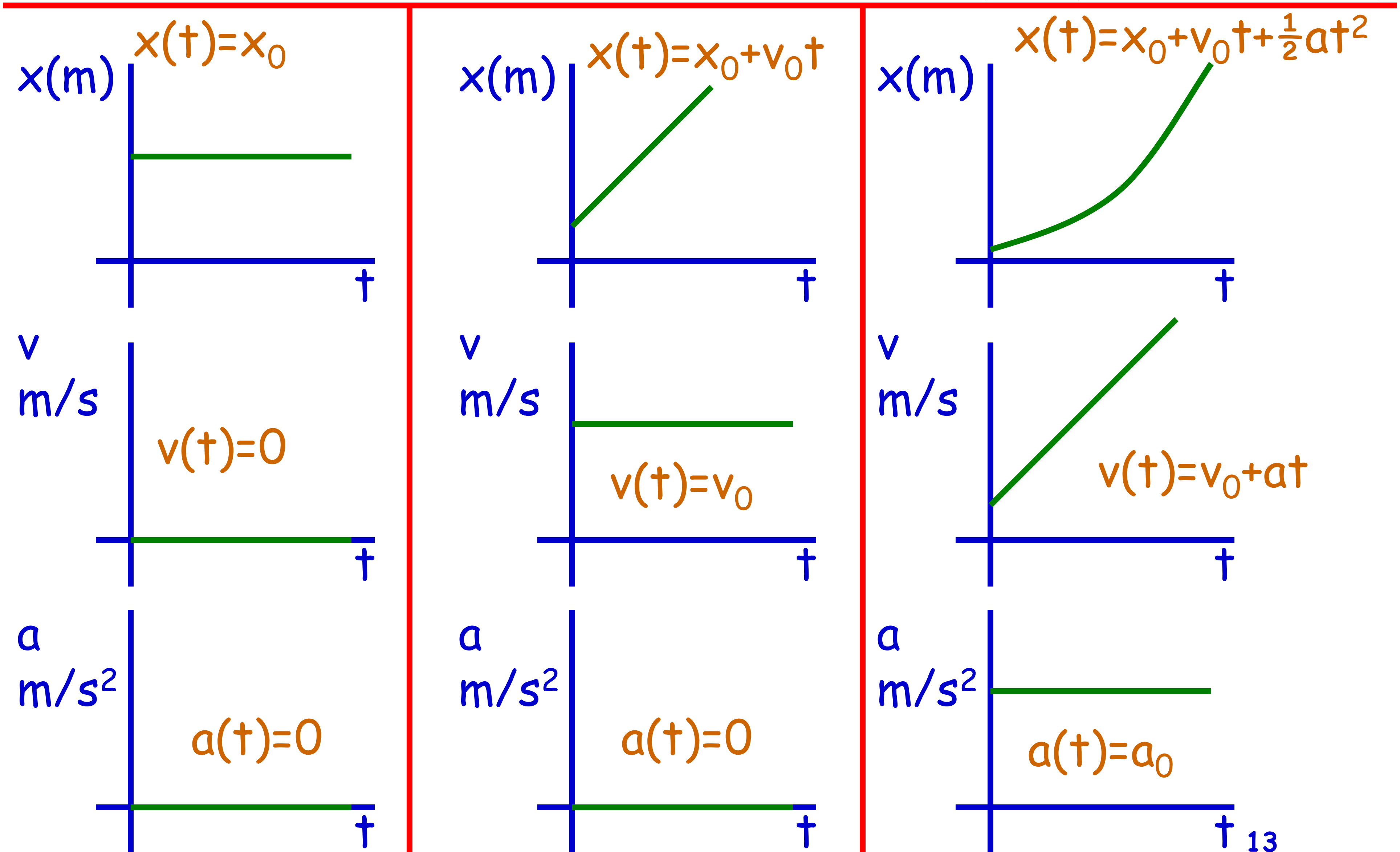
$$x - x_0 = \bar{v}t = \frac{v + v_0}{2}\frac{v - v_0}{a} = \frac{v^2 - v_0^2}{2a}$$

$$\Rightarrow$$

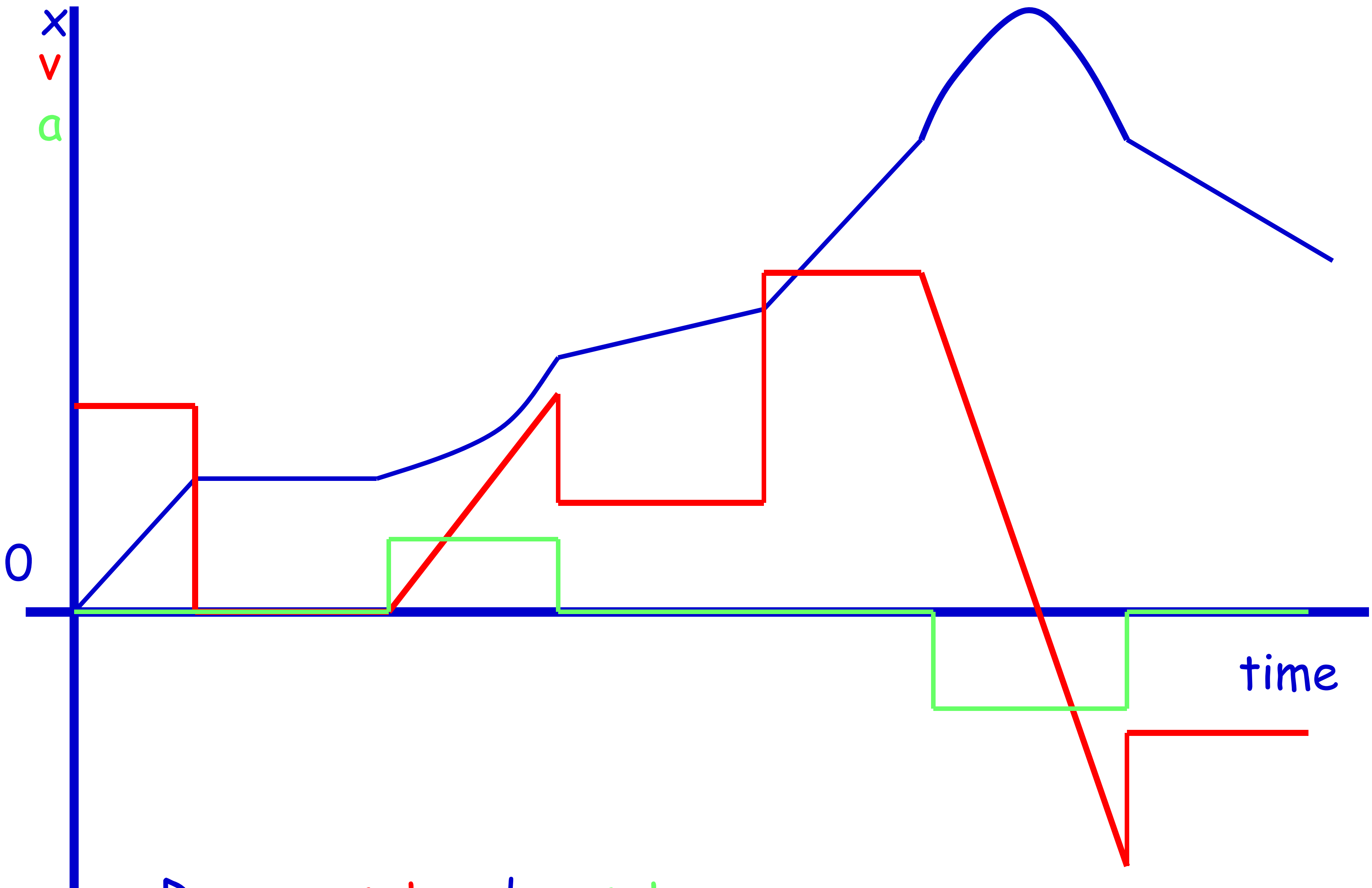
$$v^2 - v_0^2 = 2a\left(x - x_0\right)$$

Important things!

Constant motion | Constant velocity | Constant acceleration

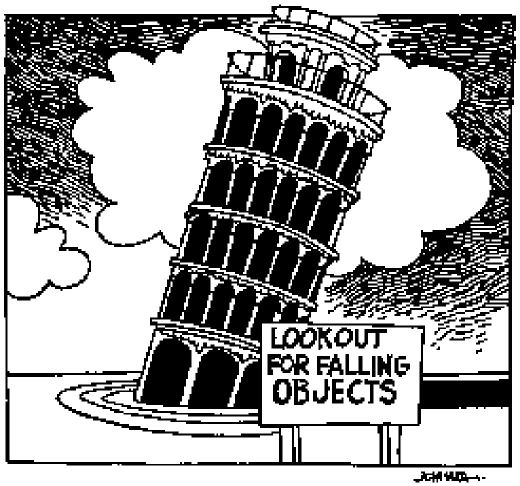


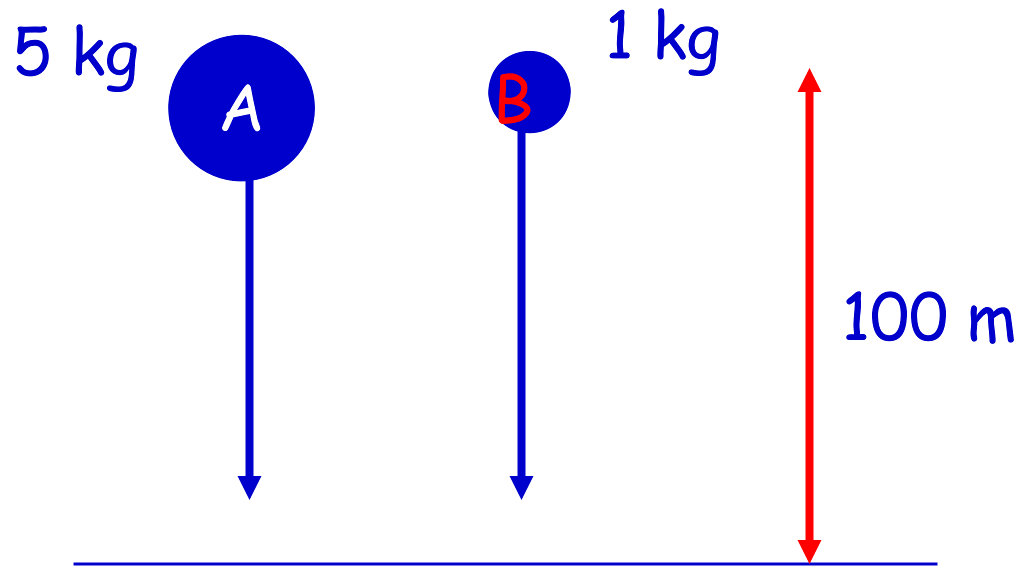
example



Draw v vs. t and a vs. t

Free fall



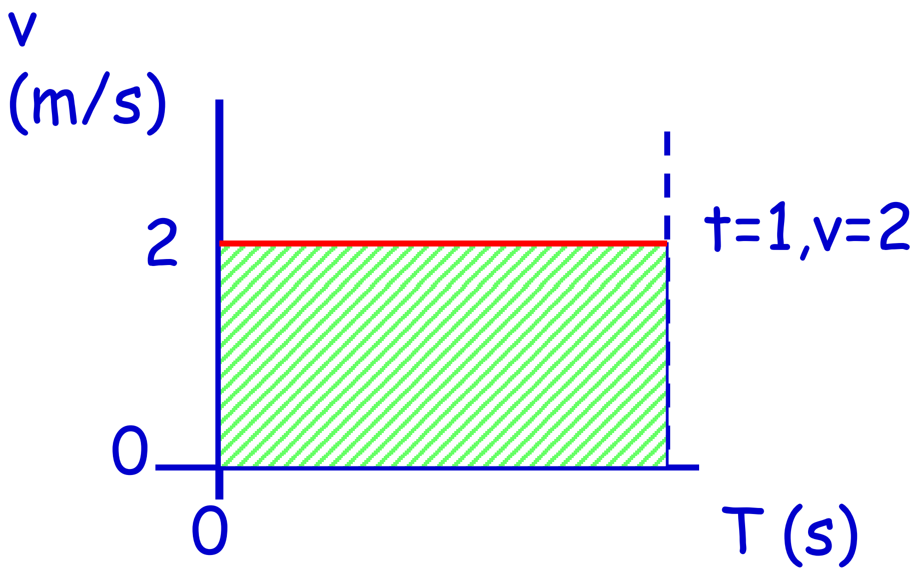


$$x(t) = x_o + v_o t + \tfrac{1}{2} a t^2$$

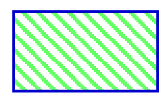
$$v(t) = v_0 + at$$

a is the the acceleration felt due to gravitation (commonly called g=-9.8 m/s^2)

Why no mass dependence???

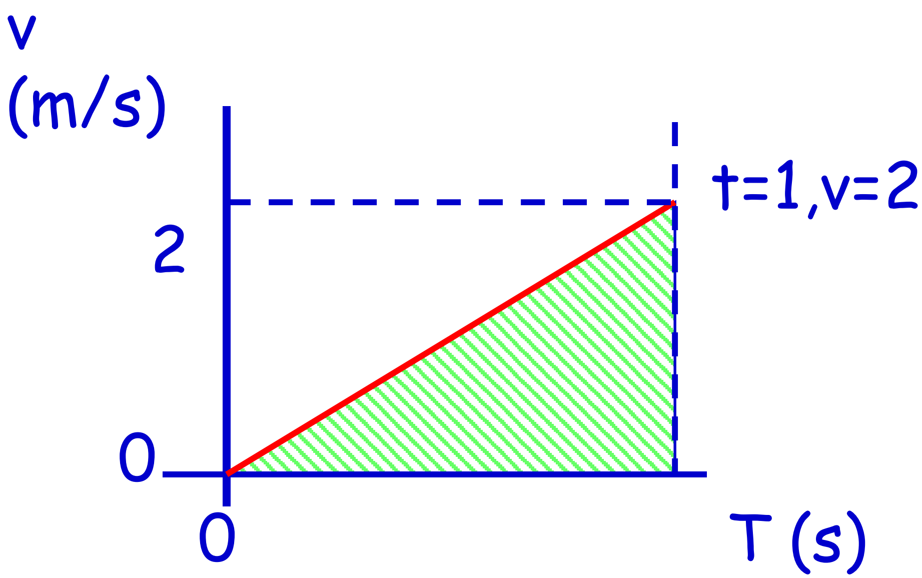


1)What is the distance covered in 1 second?

2)What is the area indicated by  ?

Q:	1)	2)
a)	1.	1.
b)	1.	2.
c)	2.	1.
d)	2.	2.

The area under the v-t curve is equal to the displacement of the object!



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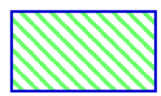
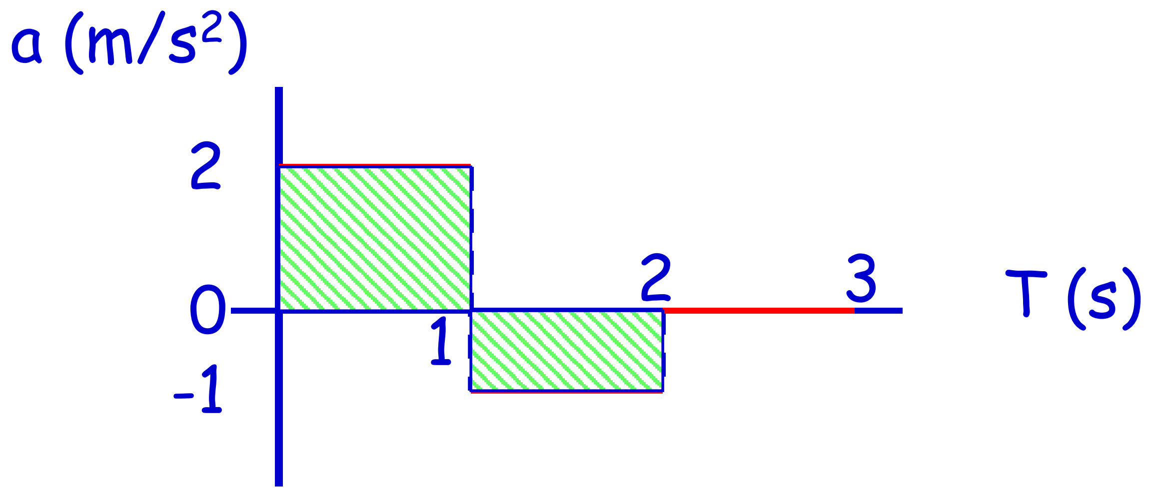
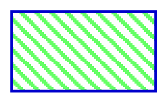
2)What is the area indicated by  ?

The area under the v-t curve is equal to the displacement of the object!

Q:	1)	2)
a)	1.	1.
b)	1.	2.
c)	2.	1.
d)	2.	2.

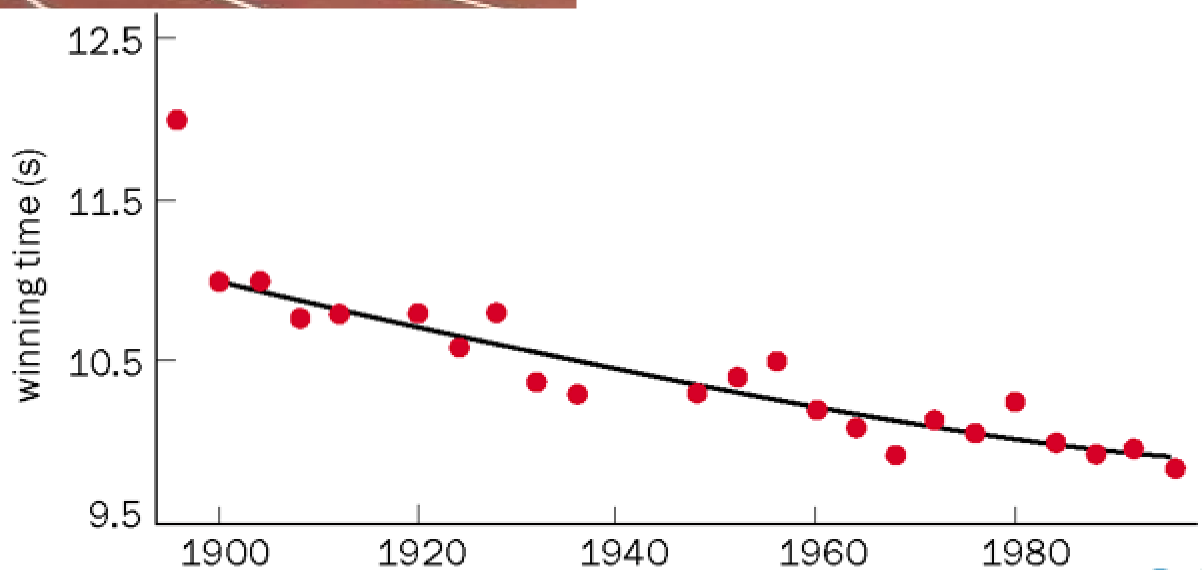


If the initial velocity (at T=0) is 4 m/s,

1)What is the velocity at T=2 second?
2)What is the area indicated by  ?

Q:	1)	2)
a)	5.	1.
b)	7.	3.
c)	1.	1.
d)	3.	3.

Kinematics in sports



100 m dash: what is the best strategy?

After long training Ben Lewis can accelerate with $a=3.00\ m/s^2$ over a distance of 20.0 m. Over the remaining 80.0 m, he can maintain this top-speed.

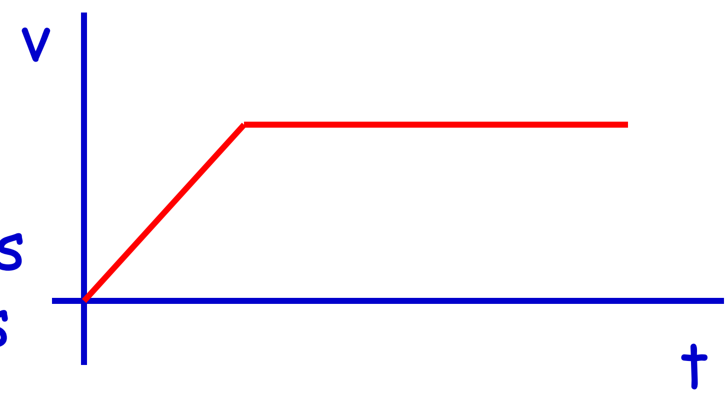
A) After how many seconds Ben reaches his top-speed?

B) What is his speed at that time?

C) In how much time does he cross the finish line?

A) $20.0\ m = 1/2*3.00*t^2$ $t=3.65\ s$

B) $v(t=3.65)=3.00*t=10.95\ m/s$



C) last 80 m: $t=80/10.95=7.30\ s$

total time: $3.65+7.30=10.95\ s$

After a lot of training...

Ben manages to accelerate the first 3.65 s with $a=4.00\ m/s^2$. After reaching his top-speed, he cannot maintain it however, and slowly de-accelerates ($a=-0.4\ m/s^2$). Did his total time improve over 100 m?

A) What distance does Ben cover while accelerating?

B) What is his speed at that time?

C) How long does is take to cover to remaining distance and what is his total time?

A) $x=1/2*4.00*3.65^2=26.6$ m

B) $v(t=3.65\ s)=4.00*3.65=14.6$ m/s

C) $100=26.6+14.6*t-1/2*0.4*t^2$

$t^2-73*t+372=0$, so $t=5.51$ or $t=67.5$

total time: $3.65+5.51=9.16$