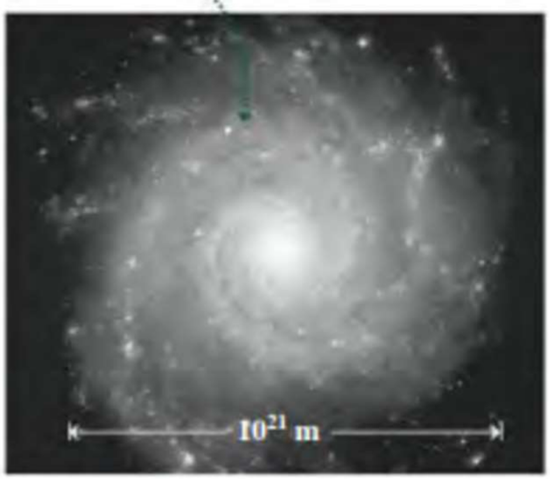
1.2 Measurements and Units

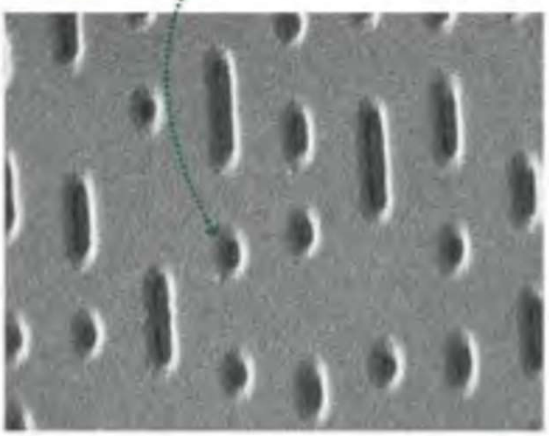
Table 1.2 Distances, Times, and Masses (rounded to one significant figure)

Radius of observable universe	1×10^{26} m
Earth's radius	6×10^{6} m
Tallest mountain	9×10^{3} m
Height of person	2 m
Diameter of red blood cell	1×10^{-5} m
Size of proton	1×10^{-15} m
Age of universe	4×10^{17} s
Earth's orbital period (1 year)	3×10^{7} s
Human heartbeat	1 s
Wave period, microwave oven	5×10^{-10} s
Time for light to cross a proton	3×10^{-24} s
Mass of Milky Way galaxy	1×10^{42} kg
Mass of mountain	1×10^{18} kg
Mass of human	70 kg
Mass of red blood cell	1×10^{-13} kg
Mass of uranium atom	4×10^{-25} kg
Mass of electron	1×10^{-30} kg

This galaxy is 10^{21} m across and has a mass of $\sim 10^{42}$ kg.



Your movie is stored on a DVD in "pits" only 4×10^{-7} m in size.



Speed of light c = 3.00×10^8 m/s

- $3.00 \times 10^2 \times 10^6$

M = 1,000,000,000 = 10^6
M = 1,000,000 = 10^6
K = 1,000 = 10^3
1,000 x 1,000 = $10^{3+3} = 10^6$
$10^{10} = 10^{1+9} = 10^{4+6} = 10^{7+3}$

10^{10} m $= 10^{1+9} = 10^1 \times 10^9$ = 10 Gm
1010m $= 10^{4+6} = 10^4 \times 10^6$ = 10 Mm

$0.001 = 1 / 1000 = 1 / 10^3 = 10^{-3}$

POWER	PREFIX	SYMBOL
10^{24}	yotta	Y
10^{21}	zetta	Z
10^{18}	exa	E
10^{15}	peta	P
10^{12}	tera	T
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^2	hecto	h
10^1	deca	da
10^0	—	—
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p
10^{-15}	femto	f
10^{-18}	atto	a
10^{-21}	zepto	z
10^{-24}	yocto	y

Unit Conversions

The following unit abbreviations can be prefixed to any metric "from unit" or "to unit" to automatically convert the units.

	A	B	C	D	E	F
1						
2		**Prefix**	**Abbreviation**	**Value**	**Multiplier**	
3		exa	E	1000000000000000000	1.00E+18	
4		peta	P	1000000000000000	1.00E+15	
5		tara	T	1000000000000	1.00E+12	
6		giga	G	1000000000	1.00E+09	
7		mega	M	1000000	1.00E+06	
8		kilo	k	1000	1.00E+03	
9		hecto	h	100	1.00E+02	
10		deka	e	10	1.00E+01	
11		deci	d	0.1	1.00E-01	
12		centi	c	0.01	1.00E-02	
13		milli	m	0.001	1.00E-03	
14		micro	u	0.000001	1.00E-06	
15		nano	n	0.000000001	1.00E-09	
16		pico	p	0.000000000001	1.00E-12	
17		femto	f	0.000000000000001	1.00E-15	
18		atto	a	0.000000000000000001	1.00E-18	
19						
20		1 mile in metres	1609.34	=CONVERT(1,"mi","m")		
21		1 mile in kilometres	1.61	=CONVERT(1,"mi","km")		
22		1 mile in centimetres	160934.40	=CONVERT(1,"mi","cm")		
23		1 mile in millimetres	1609344.00	=CONVERT(1,"mi","mm")		
24						

PHYSICAL CONSTANTS

CONSTANT	SYMBOL	THREE-FIGURE VALUE	BEST KNOWN VALUE*
Speed of light	c	3.00×10^{8} m/s	299,792,458 m/s (exact)
Elementary charge	e	1.60×10^{-19} C	$1.602\,176\,634 \times 10^{-19}$ C (exact)
Electron mass	m_e	9.11×10^{-31} kg	$9.109\,383\,56(11) \times 10^{-31}$ kg
Proton mass	m_p	1.67×10^{-27} kg	$1.672\,621\,898(21) \times 10^{-27}$ kg
Gravitational constant	G	6.67×10^{-11} N·m²/kg²	$6.67408(31) \times 10^{-11}$ N·m²/kg²
Permeability constant	μ_0	1.26×10^{-6} N/A² (H/m)	$12.566\,370\,616\,9(29) \times 10^{-7}$ N/A²
Permittivity constant	ϵ_0	8.85×10^{-12} C²/N·m² (F/m)	$8.854\,187\,815\,8(20) \times 10^{-7}$ C²/ N·m²
Boltzmann's constant	k	1.38×10^{-23} J/K	$1.380\,649 \times 10^{-23}$ J/K (exact)
Universal gas constant	R	8.31 J/K·mol	$N_A k$ (exact)
Stefan–Boltzmann constant	σ	5.67×10^{-8} W/m²·K⁴	$5.670\,367(13) \times 10^{-8}$ W/m²·K⁴
Planck's constant	$h (= 2\pi\hbar)$	6.63×10^{-34} J·s	$6.626\,070\,15 \times 10^{-34}$ J·s (exact)
Avogadro's number	N_A	6.02×10^{23} mol^{-1}	$6.022\,140\,76 \times 10^{23}$ mol^{-1} (exact)
Bohr radius	a_0	5.29×10^{-11} m	$5.291\,772\,085\,9(36) \times 10^{-11}$ m

Speed of light c = 3.00×10^{8} m/s

Changing Units

$$(2722\ \text{ft})\left(\frac{0.3048\ \text{m}}{1\ \text{ft}}\right) = 829.7\ \text{m}$$

GOT IT?

1.1 A Canadian speed limit of 50 km/h is closest to which U.S. limit expressed in miles per hour? (a) 60 mi/h; (b) 45 mi/h; (c) 30 mi/h

FIGURE 1.3 Dubai's Burj Khalifa is the world's tallest structure.

Conversion Factors (more conversion factors in Appendix C)

Length

1 in = 2.54 cm
1 mi = 1.609 km
1 ft = 0.3048 m
1 light year = 9.46×10^{15} m

Velocity

1 mi/h = 0.447 m/s
1 m/s = 2.24 mi/h = 3.28 ft/s

Mass, energy, force

1 u = 1.661×10^{-27} kg
1 cal = 4.184 J
1 Btu = 1.054 kJ
1 kWh = 3.6 MJ
1 eV = 1.602×10^{-19} J
1 pound (lb) = 4.448 N
= weight of 0.454 kg

Time

1 day = 86,400 s
1 year = 3.156×10^{7} s

Pressure

1 atm = 101.3 kPa = 760 mm Hg
1 atm = 14.7 lb/in^2

Rotation and angle

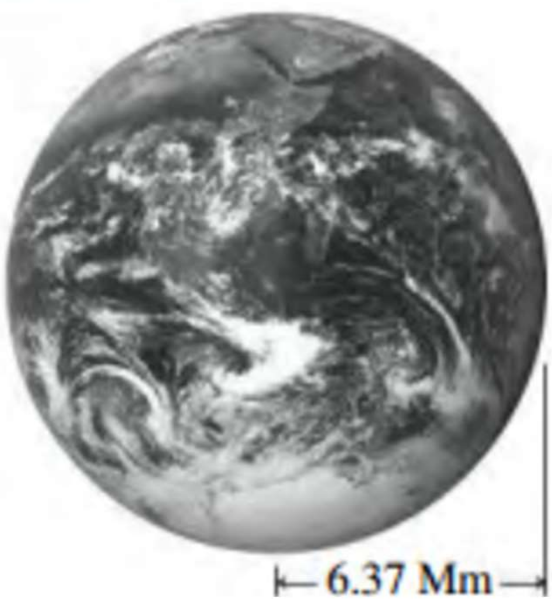
1 rad = $180°/\pi$ = 57.3°
1 rev = 360° = 2π rad
1 rev/s = 60 rpm

Magnetic field

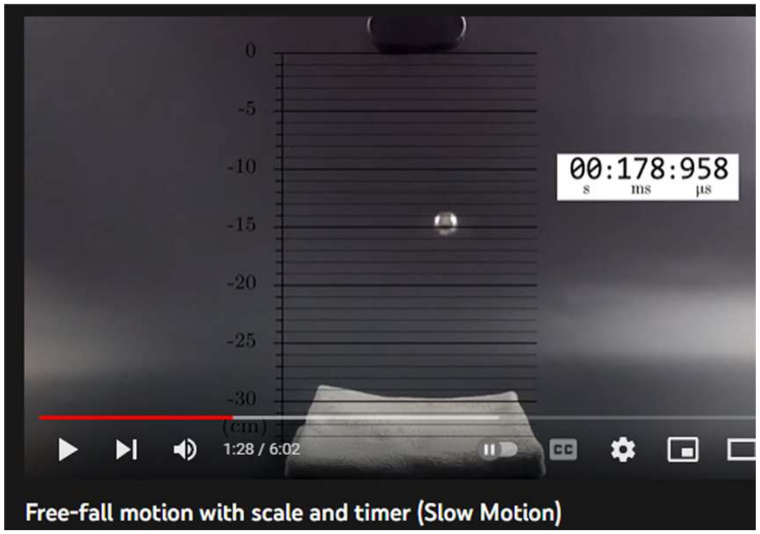
1 gauss = 10^{-4} T

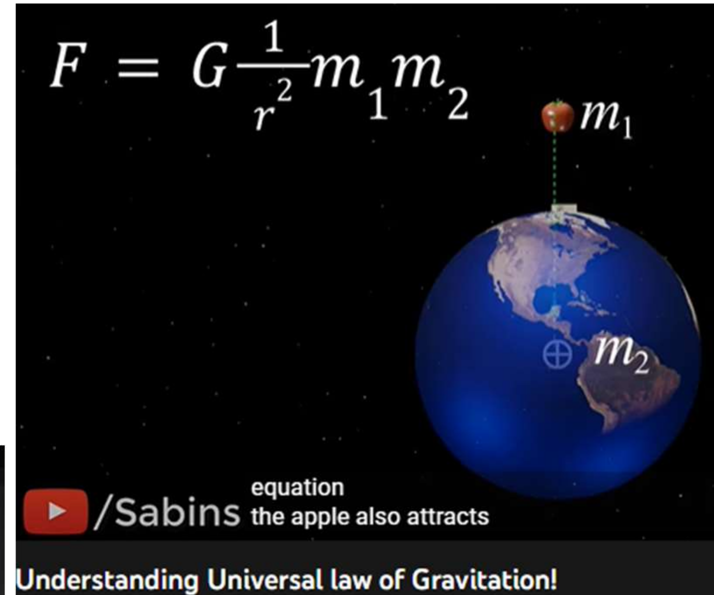
Numbers are often written with prefixes or in scientific notation to express powers of 10. Precision is shown by the number of significant figures:

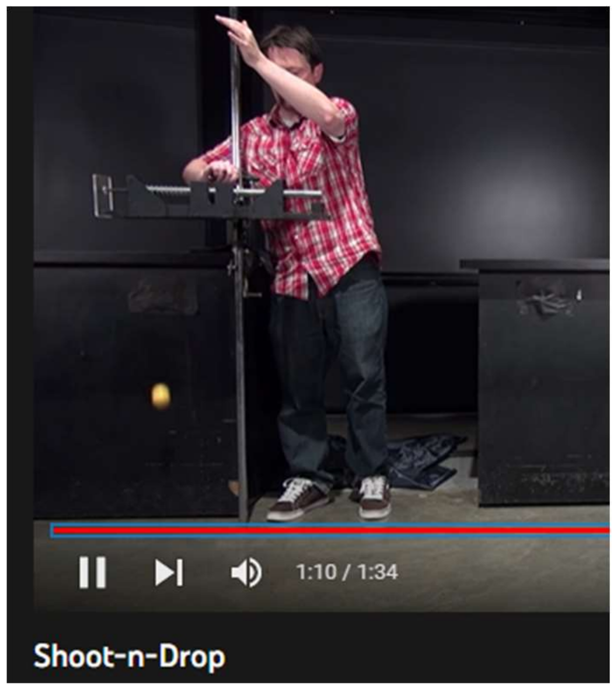
$$\text{Earth's radius}\quad \underbrace{6.37}_{\text{Three significant figures}} \times \overbrace{10^6}^{\text{Power of 10}}\ \text{m} = 6.37\ \underbrace{\text{M}}_{\text{SI prefix for } \times 10^6}\text{m}$$

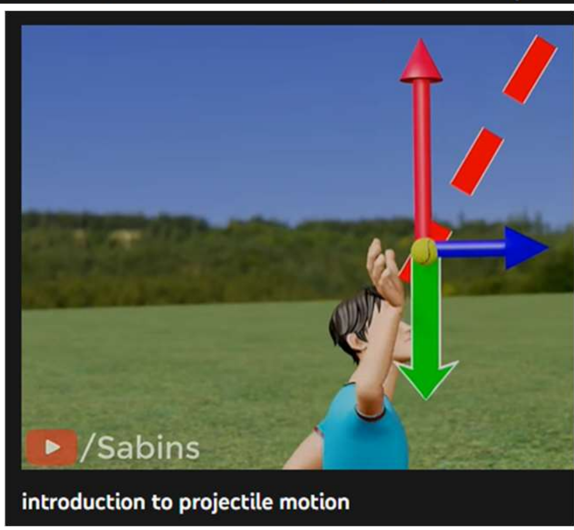


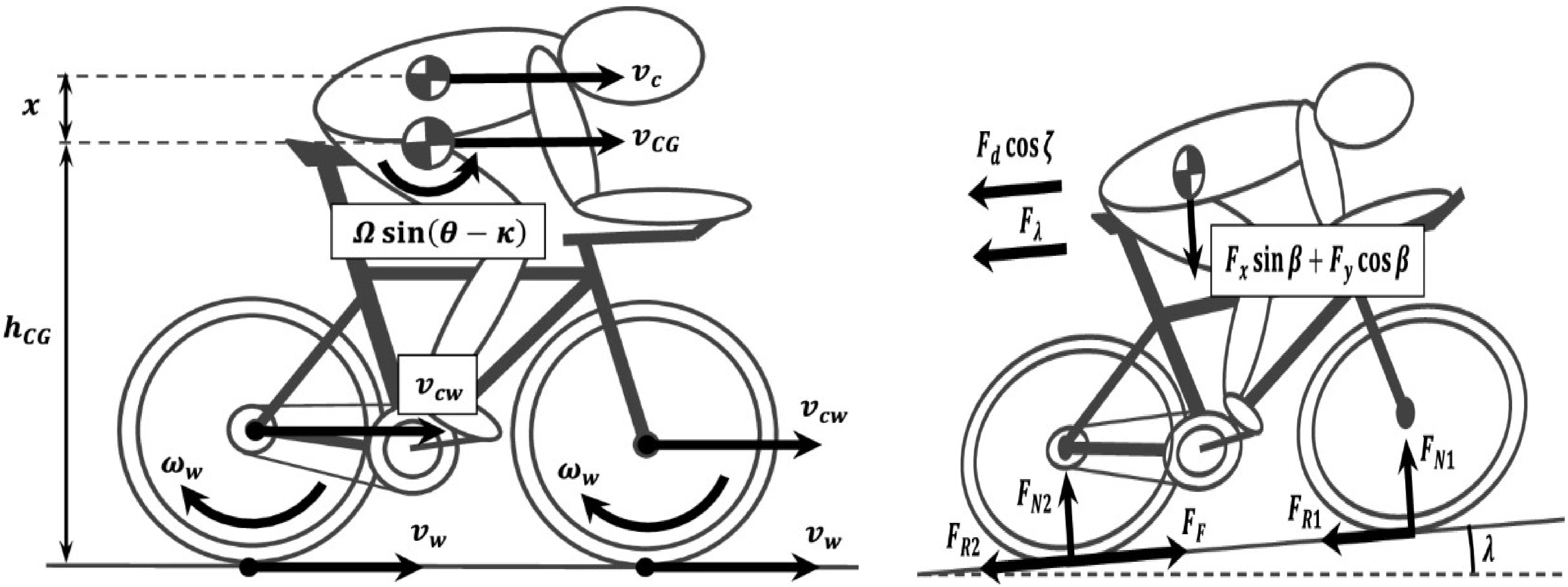
https://www.youtube.com/watch?v=FCMgAmDLOis











x
h_{CG}
v_c
v_{CG}
$\Omega \sin(\theta - \kappa)$
v_{cw}
v_{cw}
ω_w
ω_w
v_w
v_w
$F_d \cos\zeta$
F_λ
$F_x \sin\beta + F_y \cos\beta$
F_{N1}
F_{N2}
F_{R1}
F_{R2}
F_F
λ

Vectors and scalars are both quantities (amounts of something)

Vectors	Scalars
Have magnitude (size) and direction	Have magnitude (size) and NO direction

Vectors

Have magnitude (size) and direction

Examples:

(magnitude) (Direction)
5 meters east

- Displacement
- Force
- Velocity
- Acceleration
- Momentum

Scalars

Have magnitude (size) and NO direction

Examples:

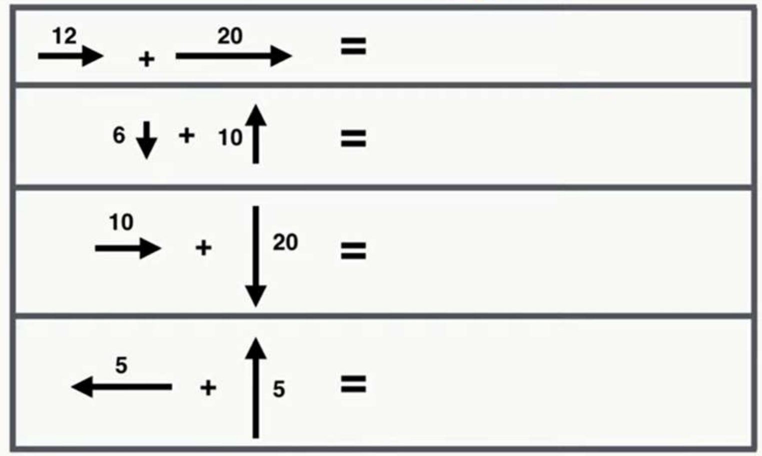
(magnitude)
5 meters

- Length
- Area
- Temperature
- Mass
- Energy

Drawing a Vector

Vectors are quantities that have both magnitude (size) and direction. To show their magnitude and direction, we draw vectors as arrows.

Adding Vectors:



Check for understanding

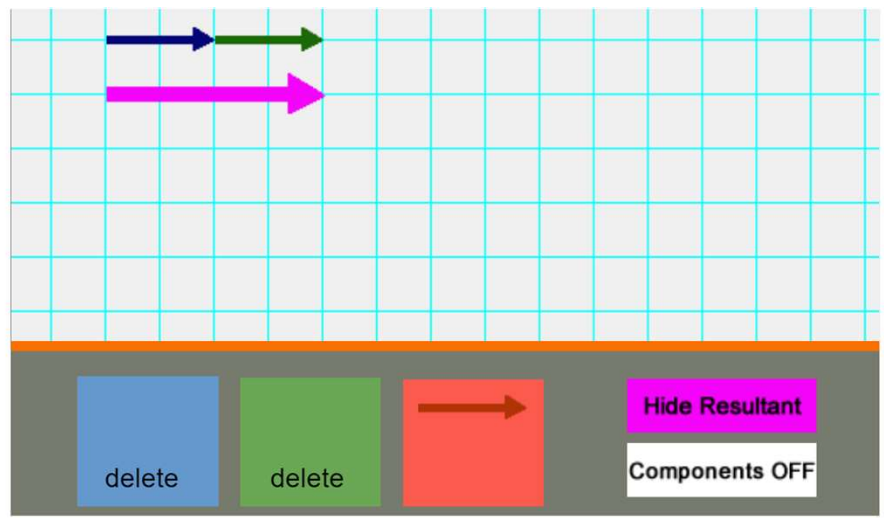
Labeling Vectors

The symbol we use for labeling vectors is a letter with an arrow above it.

$\vec{E}$ = 10 meters

The same letter without an arrow above it means the scalar magnitude of that vector

E = 10 meters

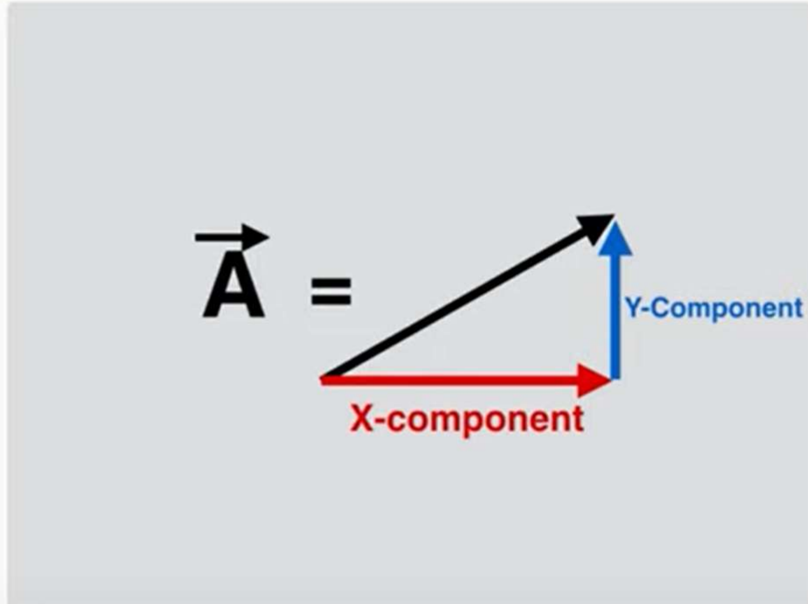


X and Y Components:

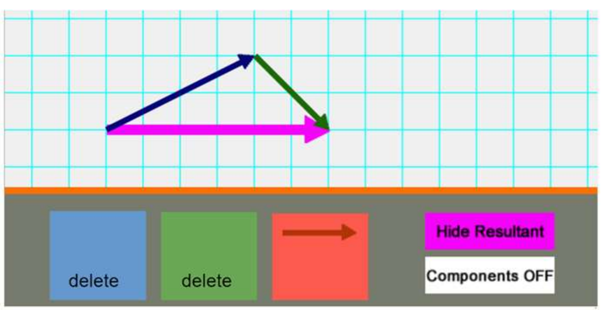
All vectors have an x-component and a y-component

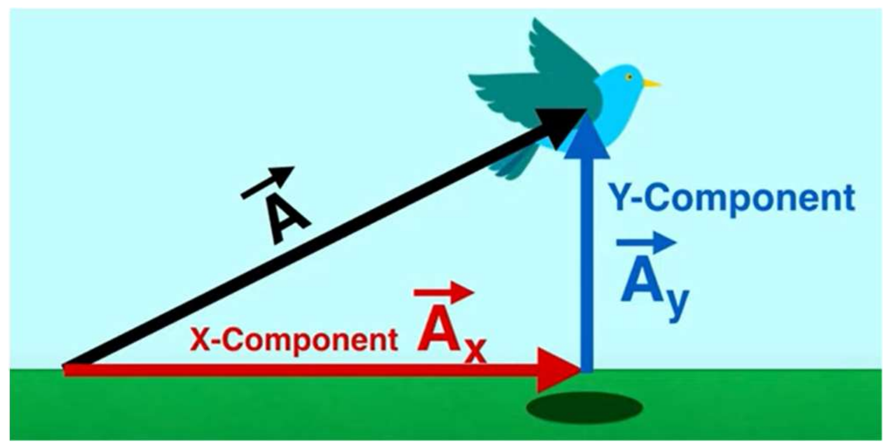
X-component: how far in the horizontal direction the vector travels

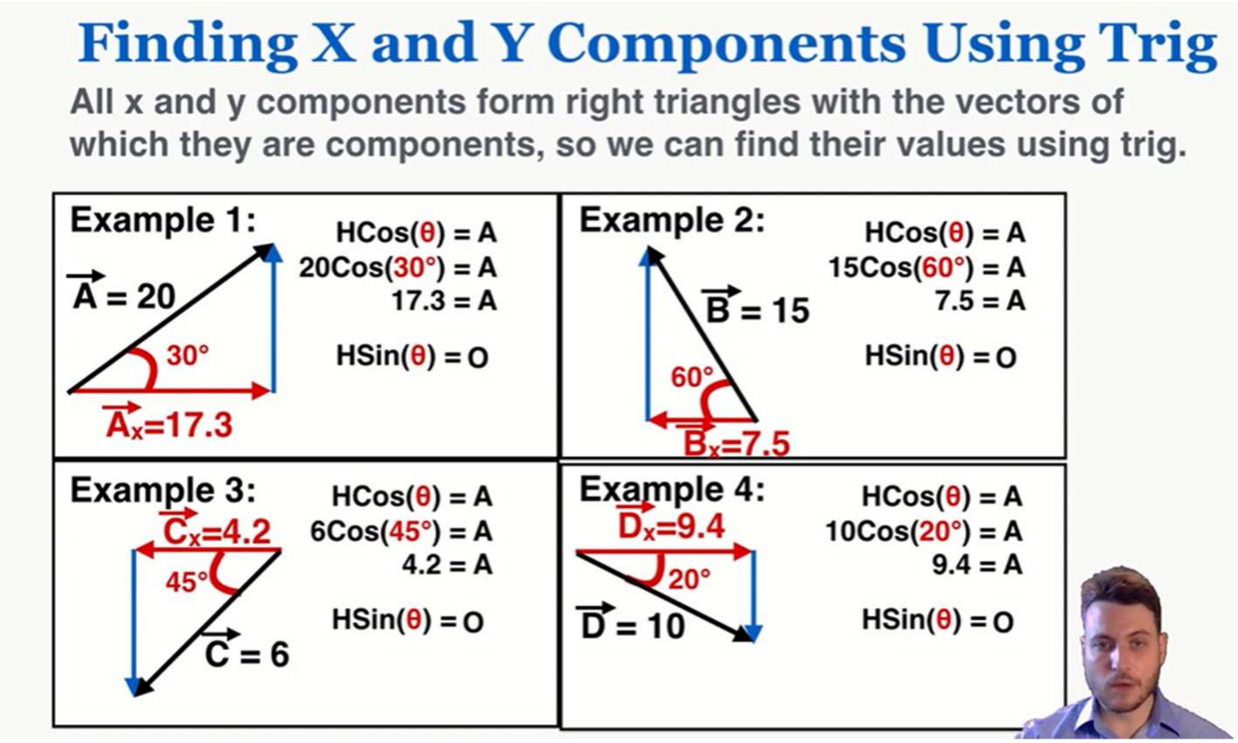
Y-Component: how far in the vertical direction the vector travels



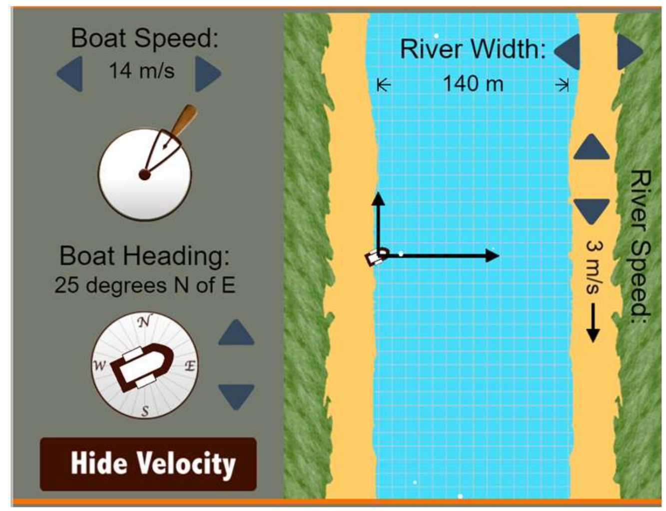
https://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Vector-Addition/Vector-Addition-Interactive







https://www.youtube.com/watch?v=GjgHAff_Oio&list=PLeveVE-rwOyLM5yS2-uMLPxKBIffiG8MS&index=6



https://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Riverboat-Simulator/Riverboat-Simulator-Interactive

Finding the Angle of a Vector

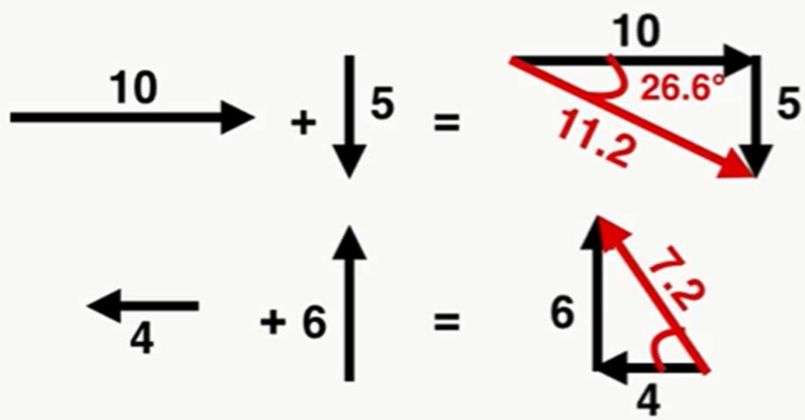
After adding two vectors that point up, down, left, or right together, you need to find the angle. Vectors communicate magnitude AND direction, so the direction of the sum of vectors matters a lot.

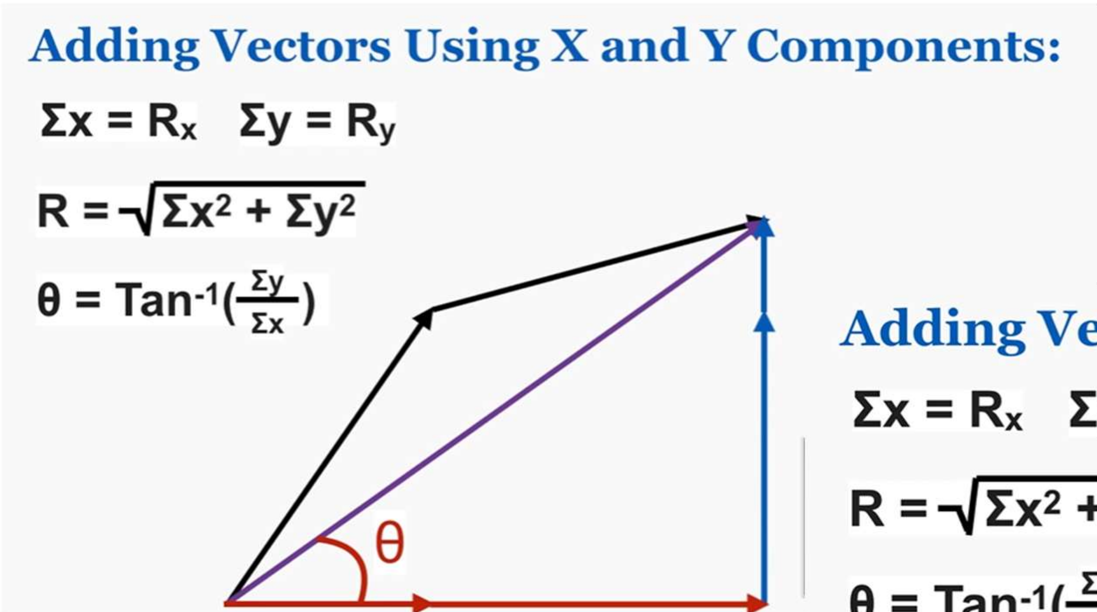
Because the simple vectors we're adding point up, down, left, and right, they form right triangles with their resultants, so we can use trig to find the angles of the vectors.

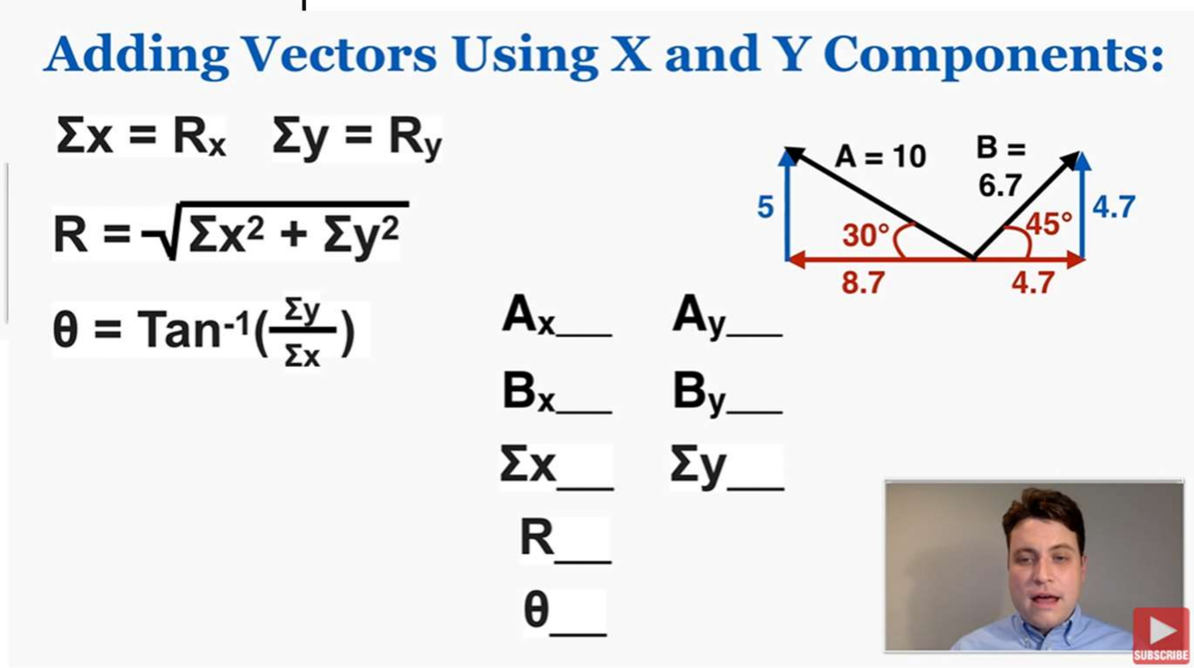
$$\tan^{-1}\left(\frac{\text{Opposite}}{\text{Adjacent}}\right) = \theta$$

$$\tan^{-1}\left(\frac{5}{10}\right) = \theta$$

$$26.6° = \theta$$







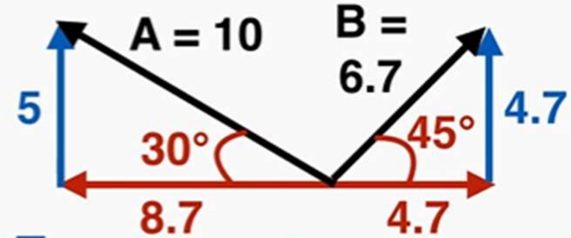
https://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Vector-Guessing-Game/Vector-Guessing-Game-Interactive

Adding Vectors Using X and Y Components:

$\Sigma x = R_x \quad \Sigma y = R_y$

$R = \sqrt{\Sigma x^2 + \Sigma y^2}$

$\theta = Tan^{-1}\left(\frac{\Sigma y}{\Sigma x}\right)$



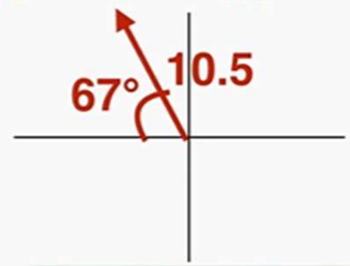
A_x -8.7 $\quad A_y$ 5

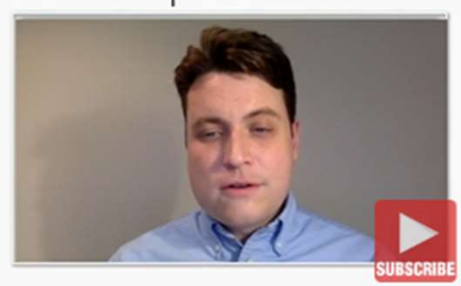
B_x 4.7 $\quad B_y$ 4.7

Σx -4 $\quad \Sigma y$ 9.7

R 10.5

θ 67°





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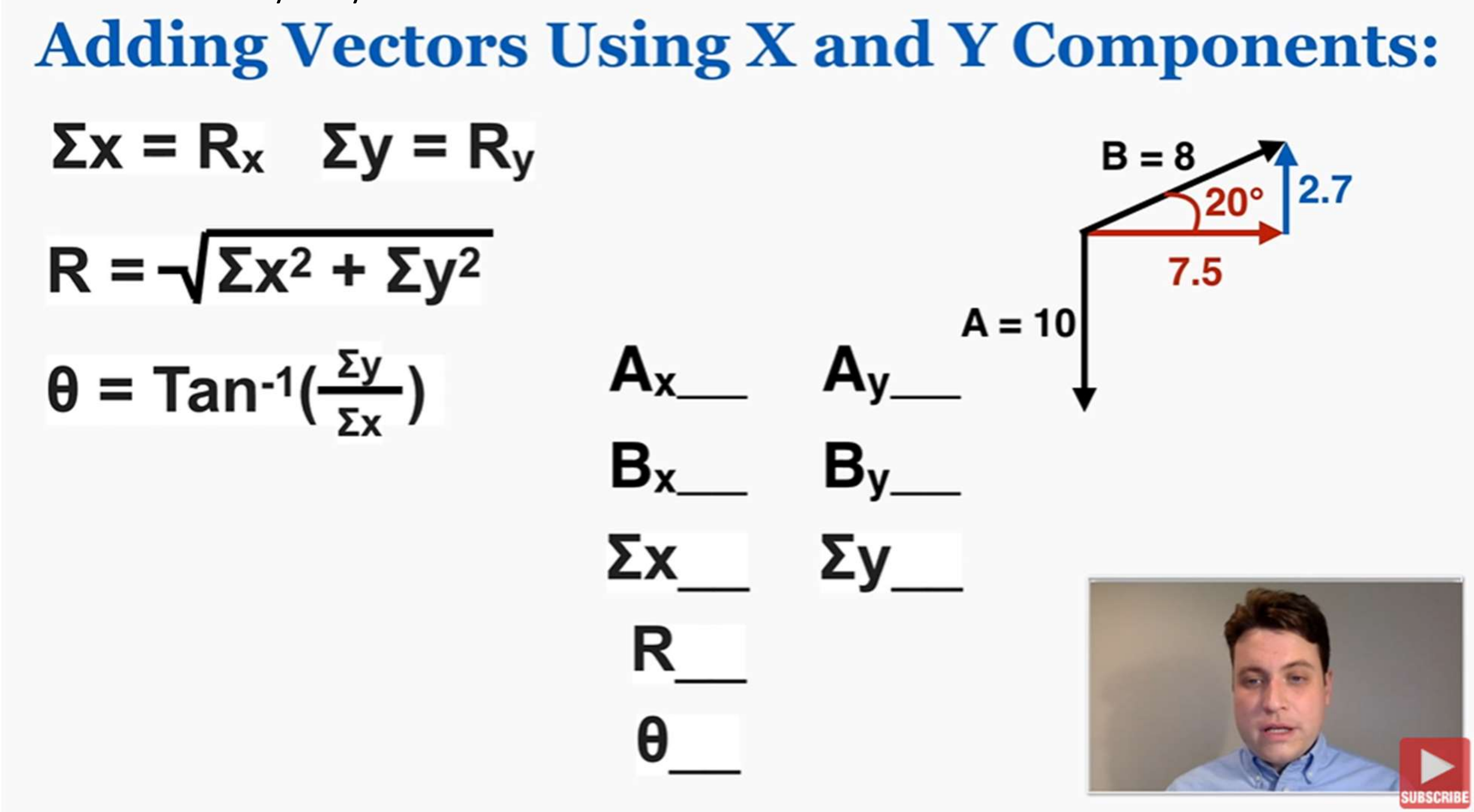
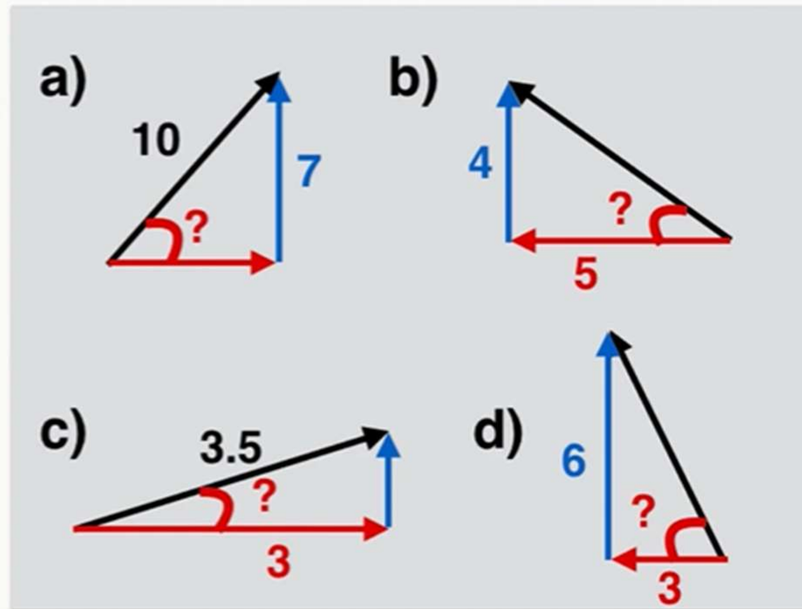


Finding the Angle of a Vector

$$\mathrm{Sin}^{-1}\left(\frac{\text{Length of opposite side}}{\text{Length of hypotenuse}}\right) = \theta$$

$$\mathrm{Cos}^{-1}\left(\frac{\text{Length of adjacent side}}{\text{Length of hypotenuse}}\right) = \theta$$

$$\mathrm{Tan}^{-1}\left(\frac{\text{Length of opposite side}}{\text{Length of adjacent side}}\right) = \theta$$



https://www.youtube.com/watch?v=D_4WG6WO_NE&list=PLeveVE-rwOyLM5yS2-uMLPxKBIffiG8MS&index=4

Fonction trigonométrique	สูตร **Excel** Fonction Excel
Sin(x)	**=SIN(radians)**
Cos(x)	**=COS(radians)**
Tan(x)	**=TAN(radians)**
ArcSin(x)	**=ASIN(valeur)**
arcCos(x)	**=ACOS(valeur)**
arcTan(x)	**=ATAN(valeur)**

	A	B	C	D	E	F
48	**Angle(rd.)**	**0**	**π/6**	**π/4**	**π/3**	**π/2**
49	Radians	-	0,5236	0,7854	1,0472	1,5708
50	Degrés	-	30,00	45,00	60,00	90,00
51	Sinus	-	0,5000	0,7071	0,8660	1,0000
52		0	1/2	$\sqrt{2}/2$	$\sqrt{3}/2$	1
53	Cosinus	1,0000	0,8660	0,7071	0,5000	0,0000
54		1	$\sqrt{3}/2$	$\sqrt{2}/2$	1/2	0
55	Tangente	-	0,5774	1,0000	1,7321	1,63E+16
56		0	$\sqrt{3}/3$	1	$\sqrt{3}$	∞

= ROUND(1.10789 ,2) = 1.11

= PI() = 3.14159 >> 180 องศา

= RADIANS(30) = PI()/6

= DEGREES(3.14159) = 180 >>

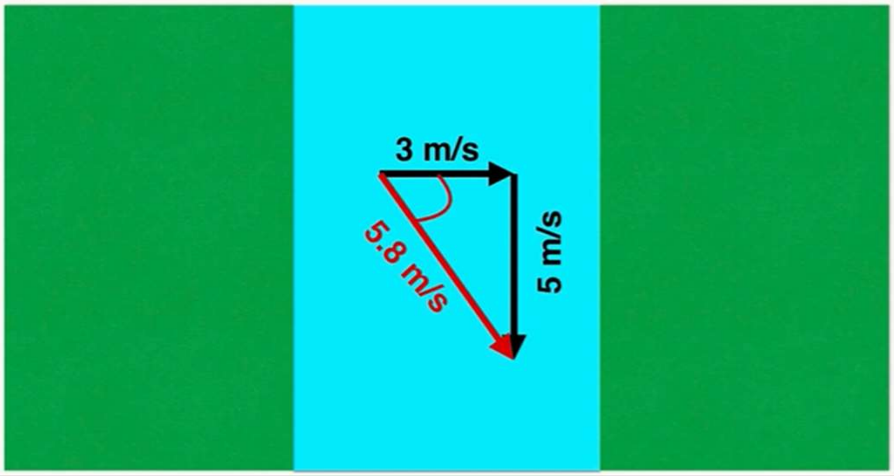
= SIN(RADIANS(30)) >> SIN (30)

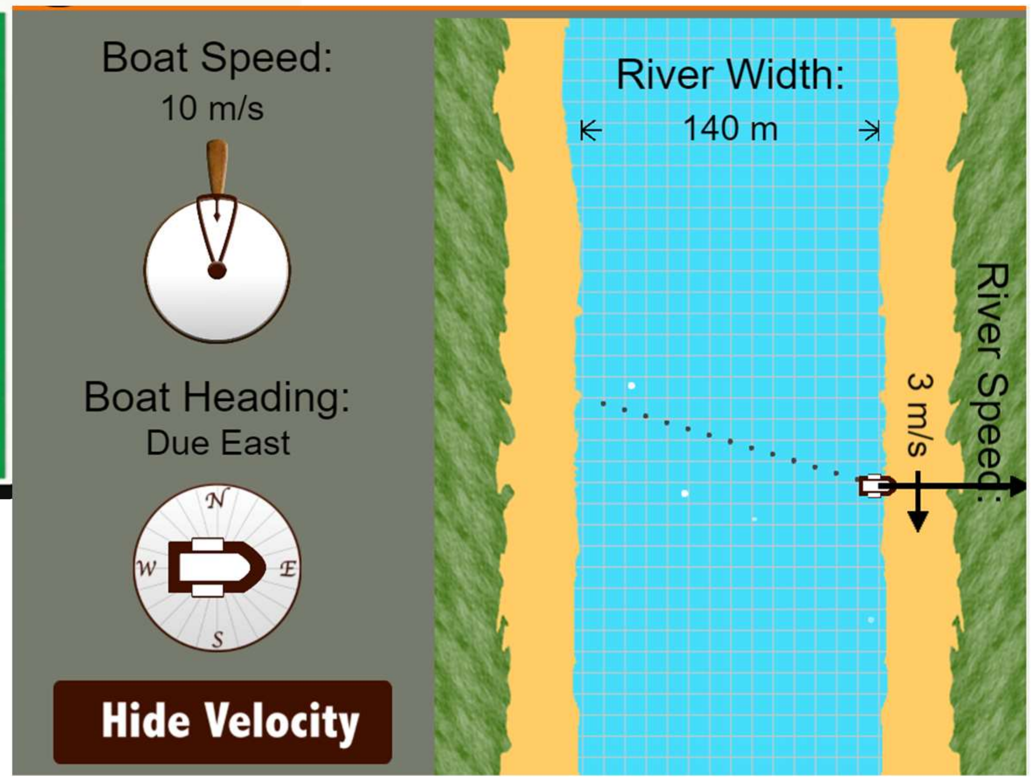
=FORMULATEXT(F7) >> แสดงสูตร

	A	B	C	D	E	F
48	**Angle(rd.)**	**0**	**π/6**	**π/4**	**π/3**	**π/2**
49	Radians	0	=PI()/6	=PI()/4	=PI()/3	=PI()/2
50	Degrés	=DEGRES(B49)	=DEGRES(C49)	=DEGRES(D49)	=DEGRES(E49)	=DEGRES(F49)
51	Sinus	=SIN(B49)	=SIN(C49)	=SIN(D49)	=SIN(E49)	=SIN(F49)
52		0	1/2	$\sqrt{2}/2$	$\sqrt{3}/2$	1
53	Cosinus	=COS(B49)	=COS(C49)	=COS(D49)	=COS(E49)	=COS(F49)
54		1	$\sqrt{3}/2$	$\sqrt{2}/2$	1/2	0
55	Tangente	=TAN(B49)	=TAN(C49)	=TAN(D49)	=TAN(E49)	=TAN(F49)
56		0	$\sqrt{3}/3$	1	$\sqrt{3}$	∞

Finding the Angle of a Vector

Example: You start swimming straight across a river at 3 m/s but the river's current pulls you downstream at 5 m/s. What velocity do you have in total? What direction do you move in?





https://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Riverboat-Simulator/Riverboat-Simulator-Interactive

https://www.physicsclassroom.com

https://www.youtube.com/watch?v=AG0Yy3aRzA0&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=3

Speed

Definition	Variable	Unit
Speed is the distance an object travels divided by the time it takes to travel that distance. It is a scalar.	Speed	ms^{-1}

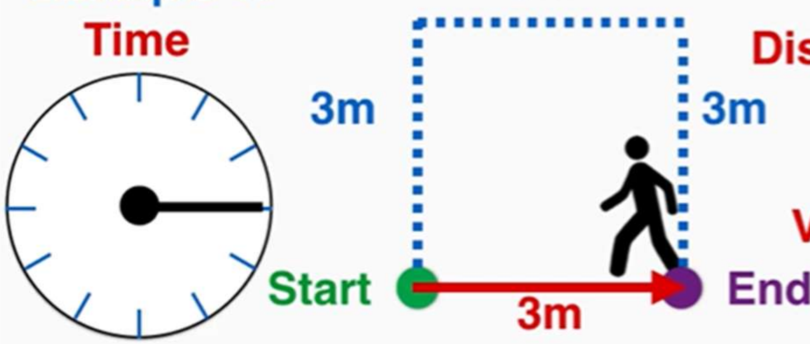
Equation
Speed $= \frac{d}{t}$

Velocity

Definition	Variable	Unit
Velocity is the displacement an object travels divided by the time it takes to travel that displacement. It is a vector.	V	ms^{-1}

Equation
Velocity $= \frac{s}{t}$

Example 1:



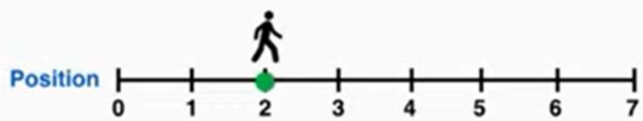
Distance = 9m

Displacement = 3m right

Speed $= \frac{9m}{3s} = 3\ ms^{-1}$

Velocity $= \frac{3m\ right}{3s} =$

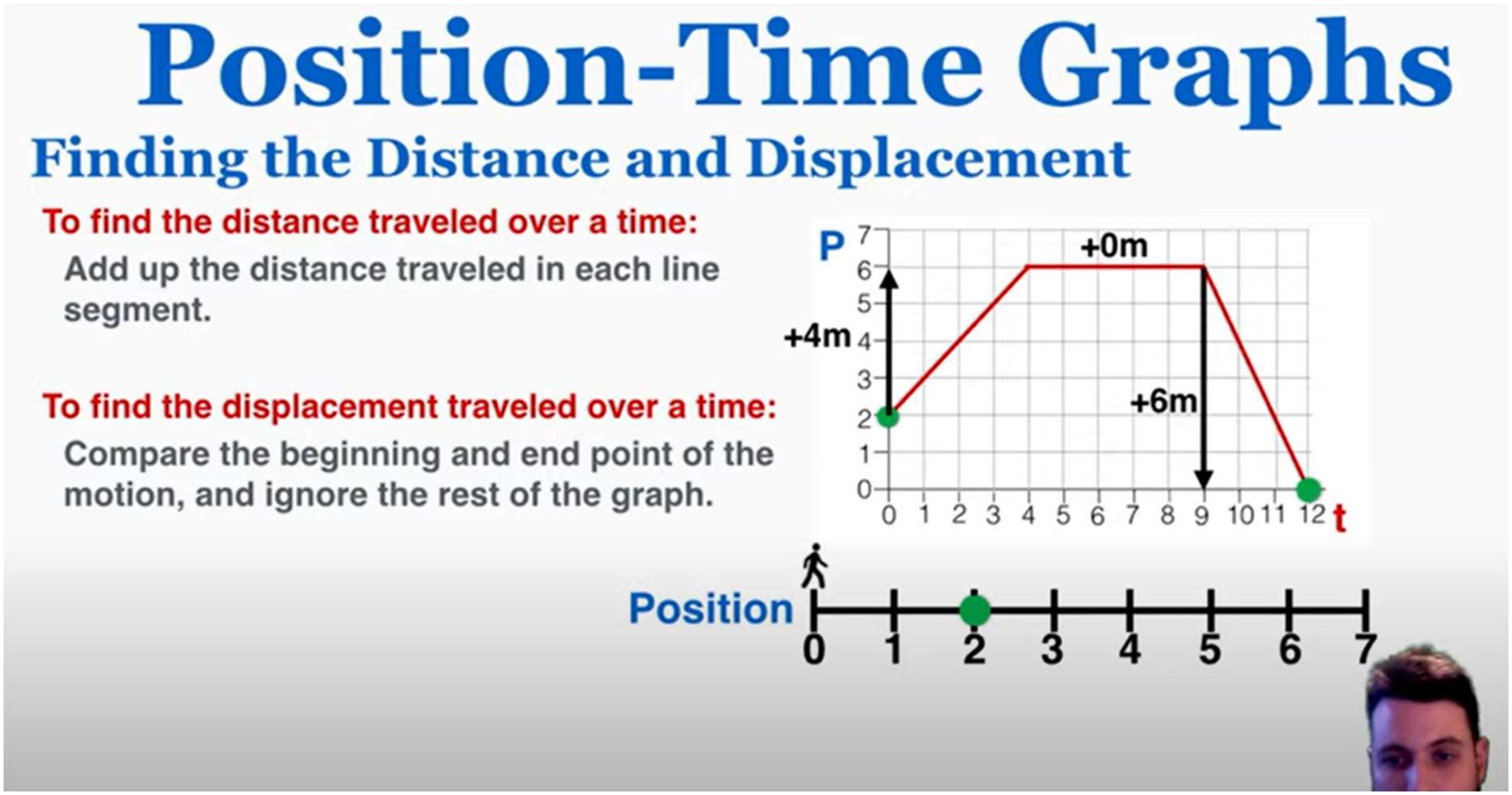
Position-Time Graphs



Patterns in the graph:

The y-intercept of the position-time graph is the starting position of the object.

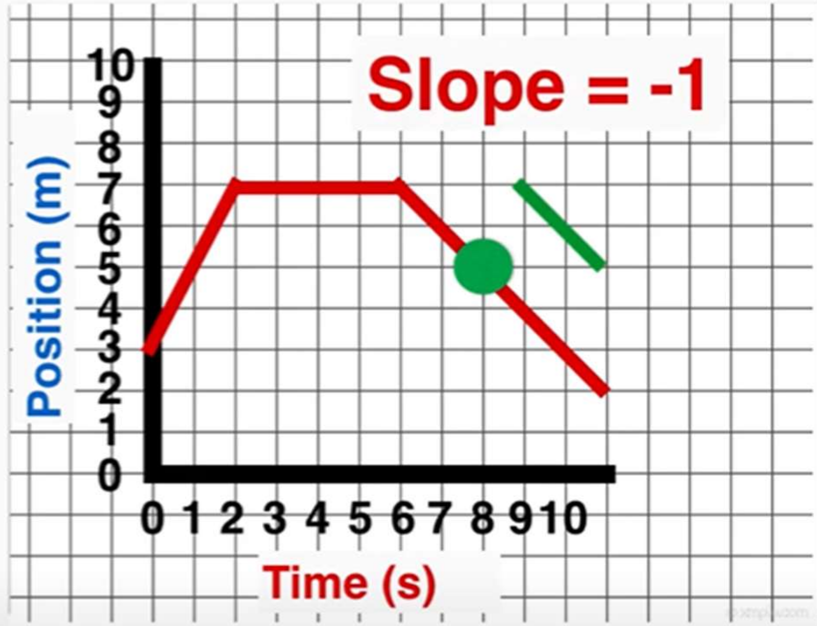
https://www.youtube.com/watch?v=_pDUHbcBlKY&list=PLeve
VE-rwOyLMMeJhlTKn33j4a7pml1ia&index=5

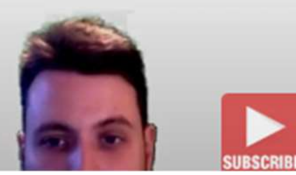


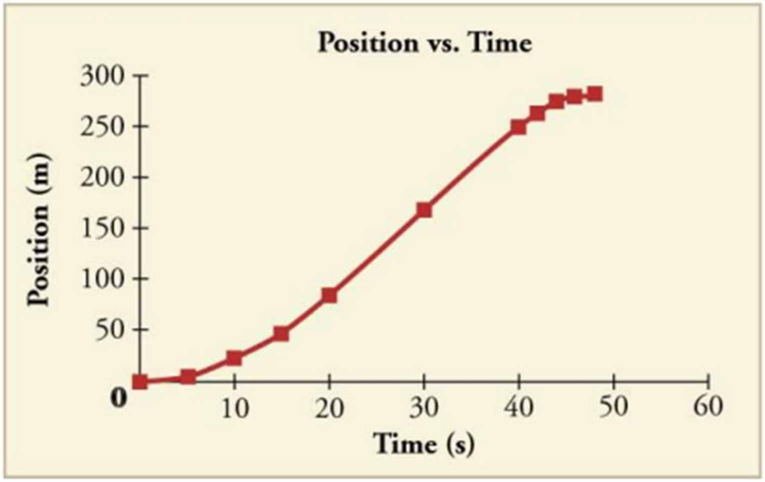
On a P v T graph:

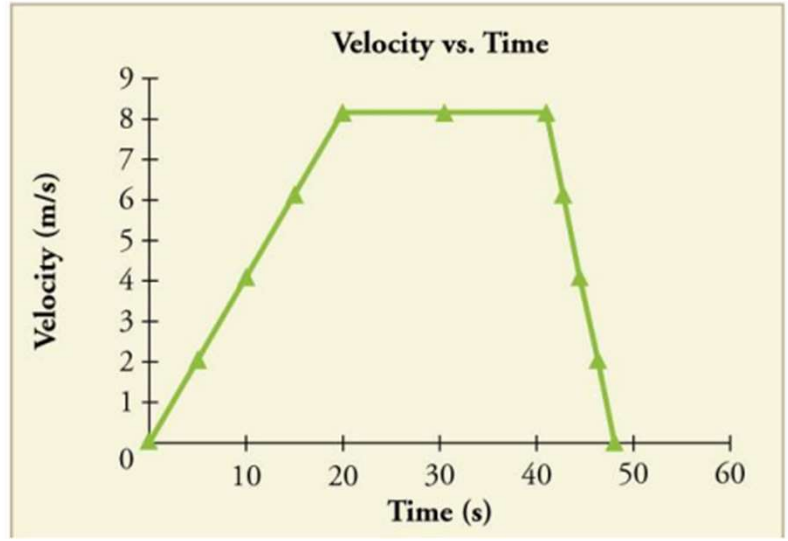
Instantaneous speed and velocity:

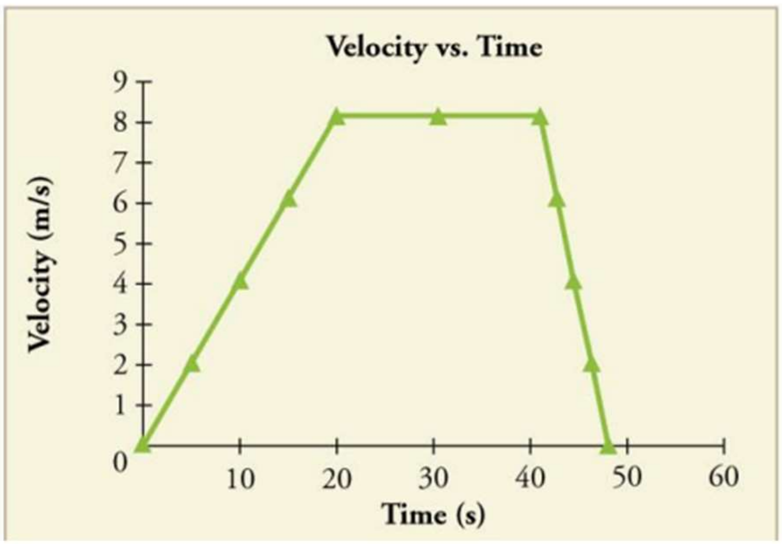
The instantaneous speed and velocity on a P v T graph is the slope at that exact point. The instantaneous speed is always positive.

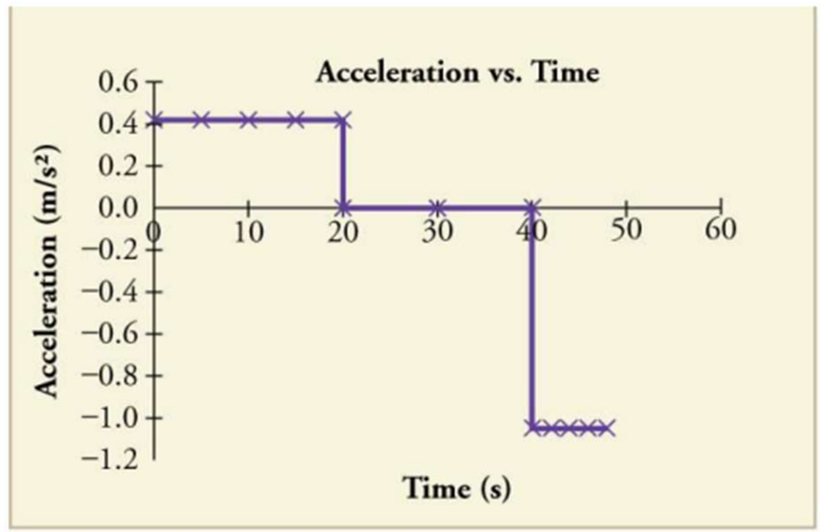


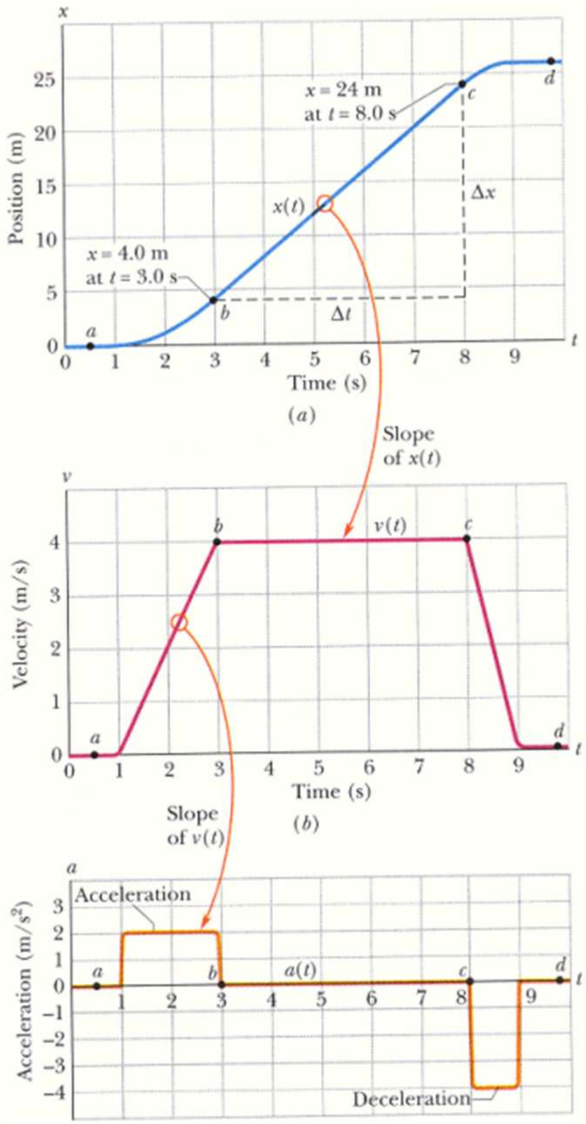


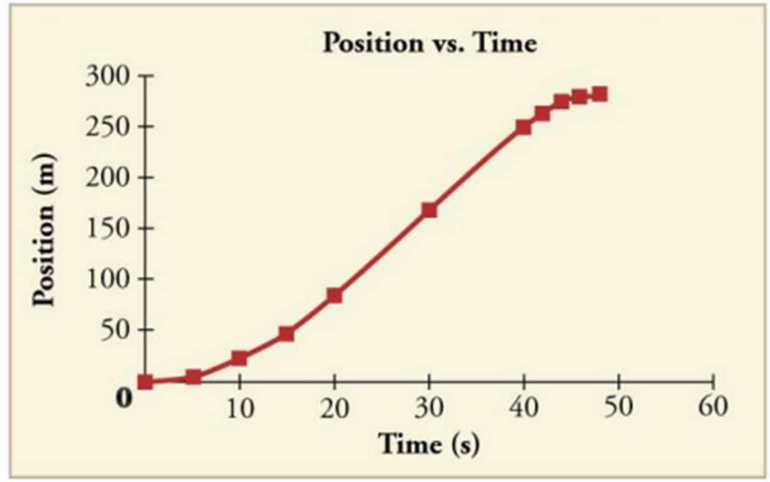

Position vs. Time
Position (m)
300
250
200
150
100
50
0
10
20
30
40
50
60
Time (s)

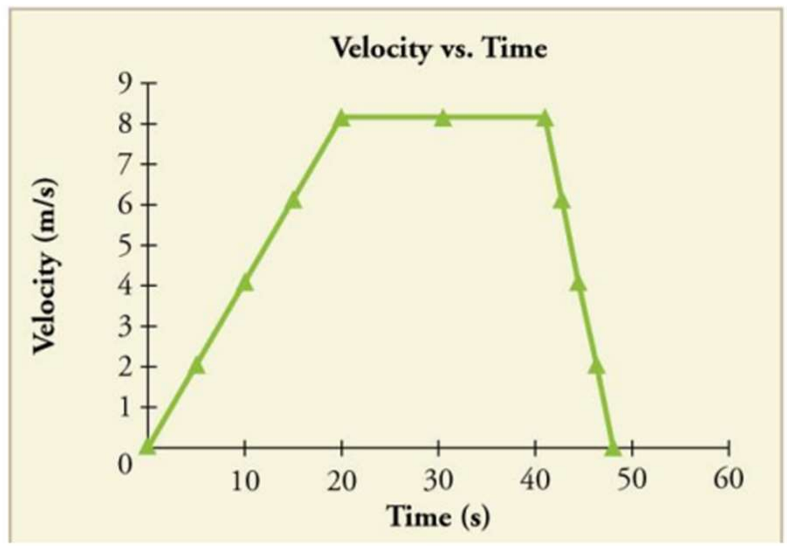

Velocity vs. Time
Velocity (m/s)
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
Time (s)

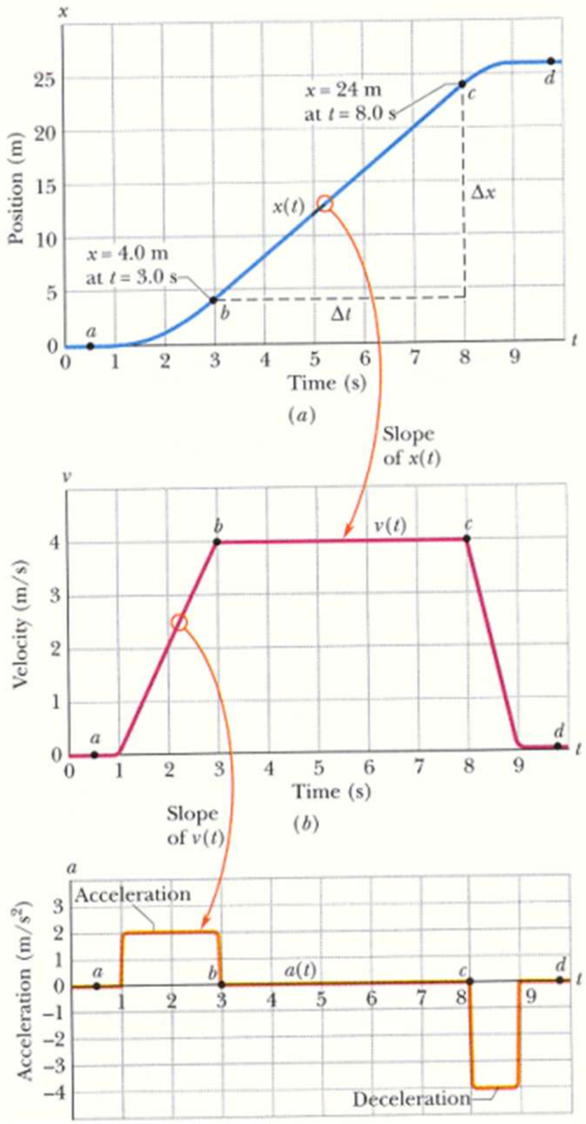

Velocity vs. Time
Velocity (m/s)
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
Time (s)


Acceleration vs. Time
Acceleration (m/s²)
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
−0.8
−1.0
−1.2
0
10
20
30
40
50
60
Time (s)

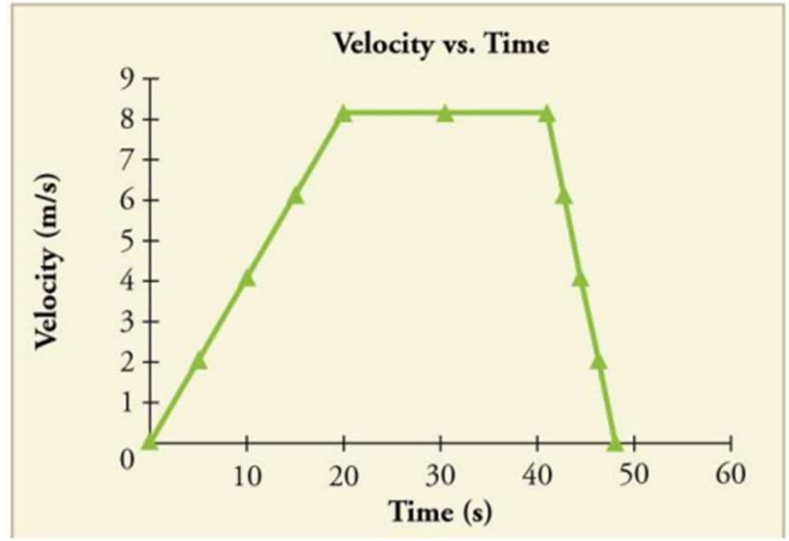

x
Position (m)
x = 24 m
at t = 8.0 s
x = 4.0 m
at t = 3.0 s
x(t)
Δx
Δt
a
b
c
d
t
Time (s)
(a)
Slope
of x(t)
v
Velocity (m/s)
v(t)
Time (s)
(b)
Slope
of v(t)
Acceleration (m/s²)
Acceleration
a(t)
Deceleration


Position vs. Time
Position (m)
Time (s)

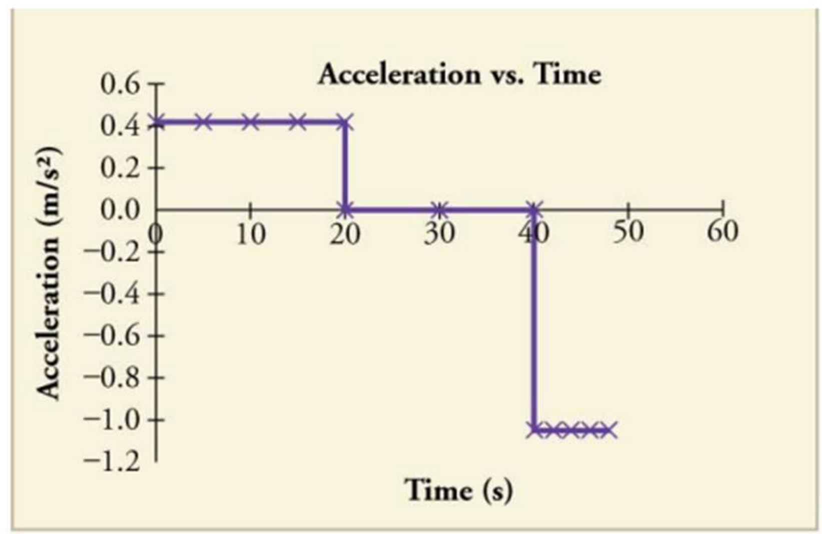

Velocity vs. Time
Velocity (m/s)
Time (s)



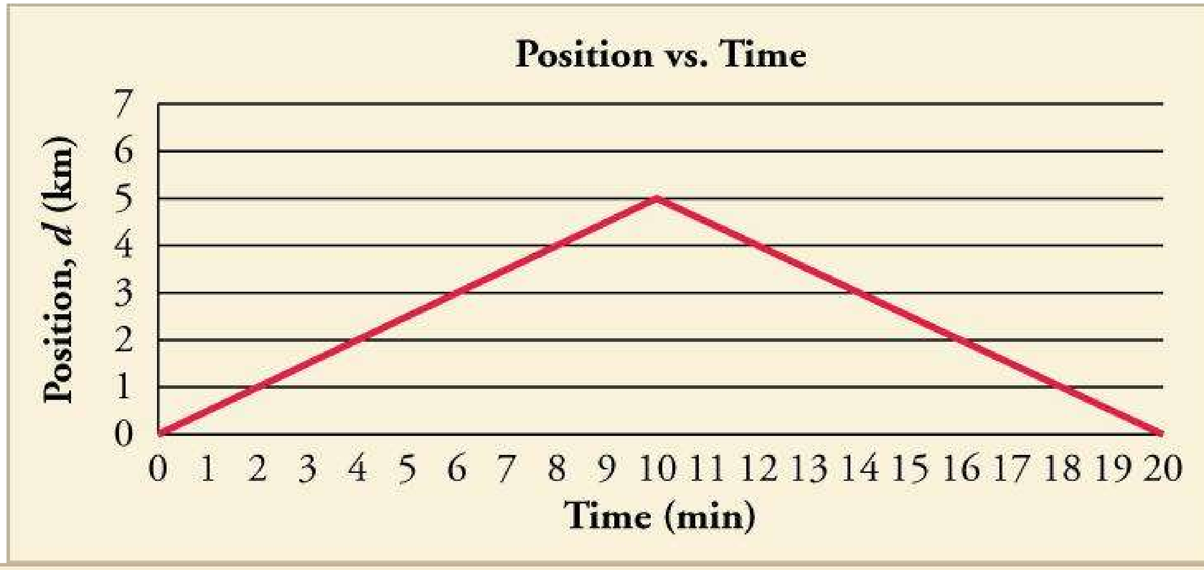
x = 24 m
at t = 8.0 s
x = 4.0 m
at t = 3.0 s
x(t)
Δx
Δt
Position (m)
Time (s)
(a)
Slope
of x(t)
v(t)
Velocity (m/s)
Time (s)
(b)
Slope
of v(t)
Acceleration
a(t)
Acceleration (m/s²)
Deceleration



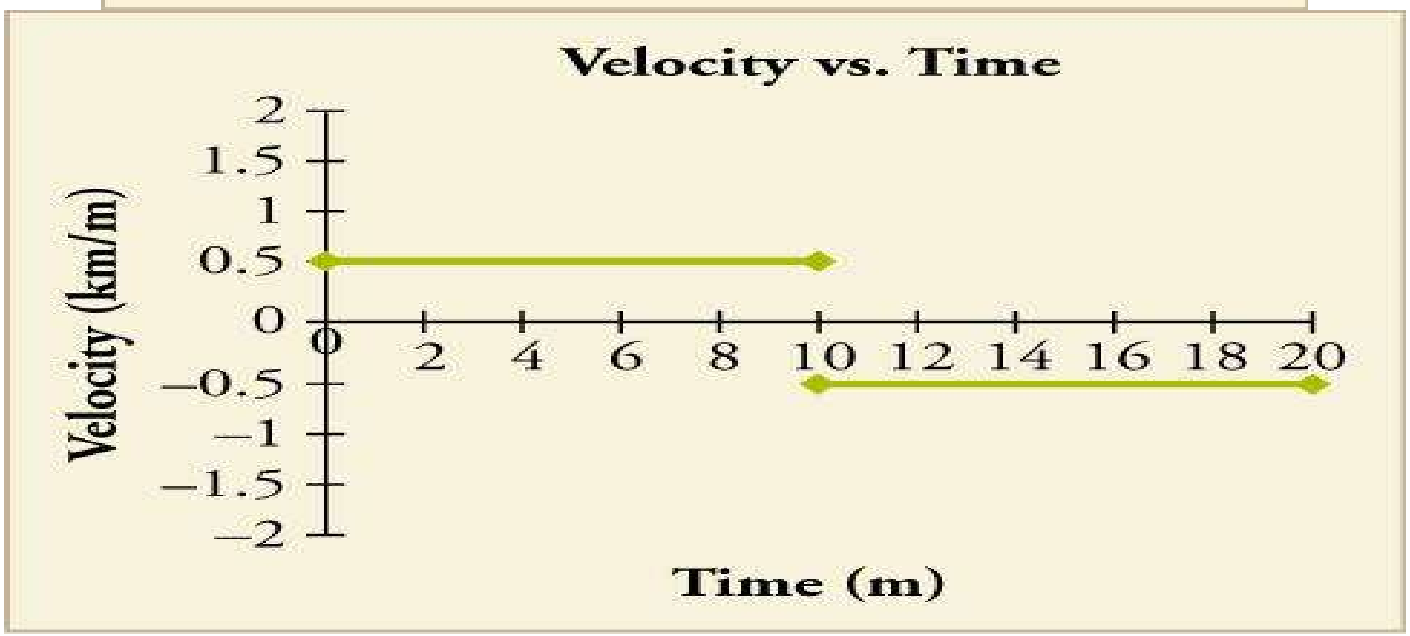
Velocity vs. Time
Velocity (m/s)
Time (s)



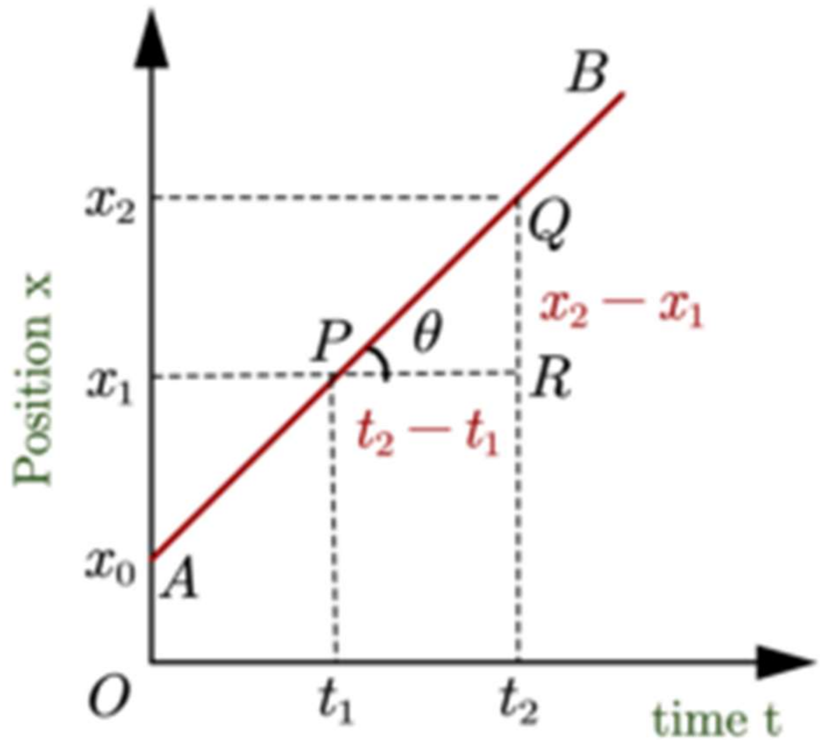
Acceleration vs. Time
Acceleration (m/s²)
Time (s)



Position vs. Time
Position, d (km)
0
1
2
3
4
5
6
7
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Time (min)



Velocity vs. Time
Velocity (km/m)
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
0 2 4 6 8 10 12 14 16 18 20
Time (m)

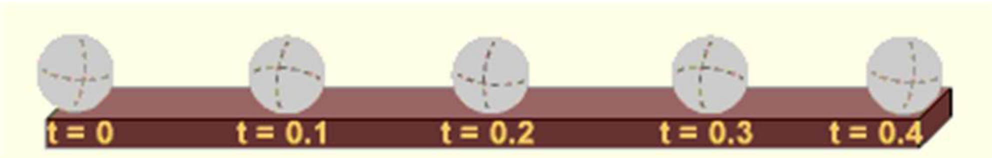


Position time graph for uniform motion

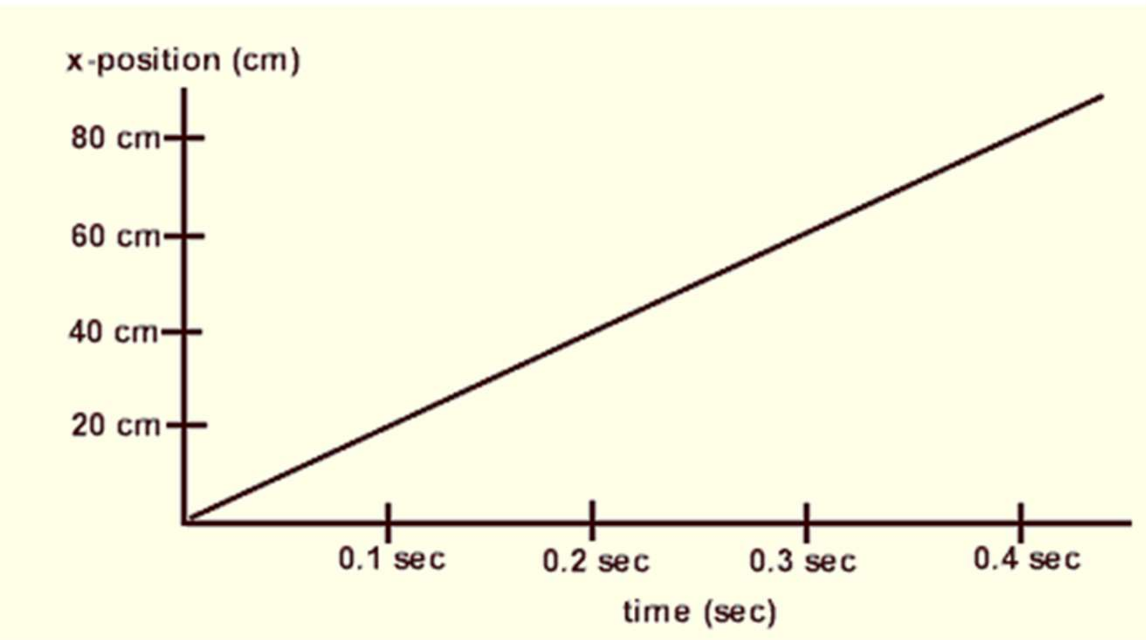
Position vs time graph slope = slope of line AB

$$= \tan\theta = \frac{QR}{PR} = \frac{x_2 - x_1}{t_2 - t_1}$$

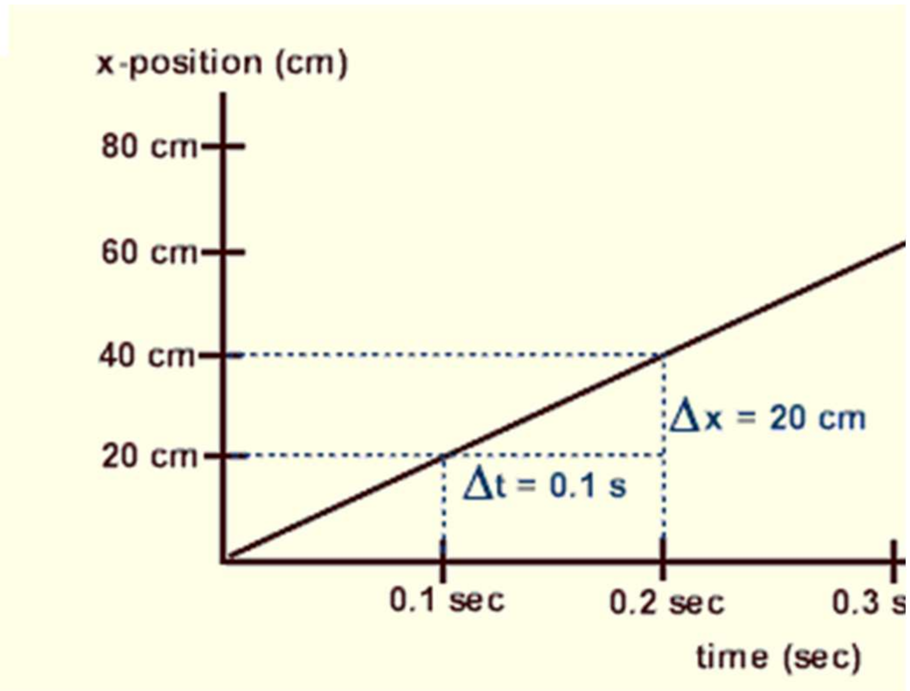
$$= \frac{Displacement}{time} = velocity\ (v)$$



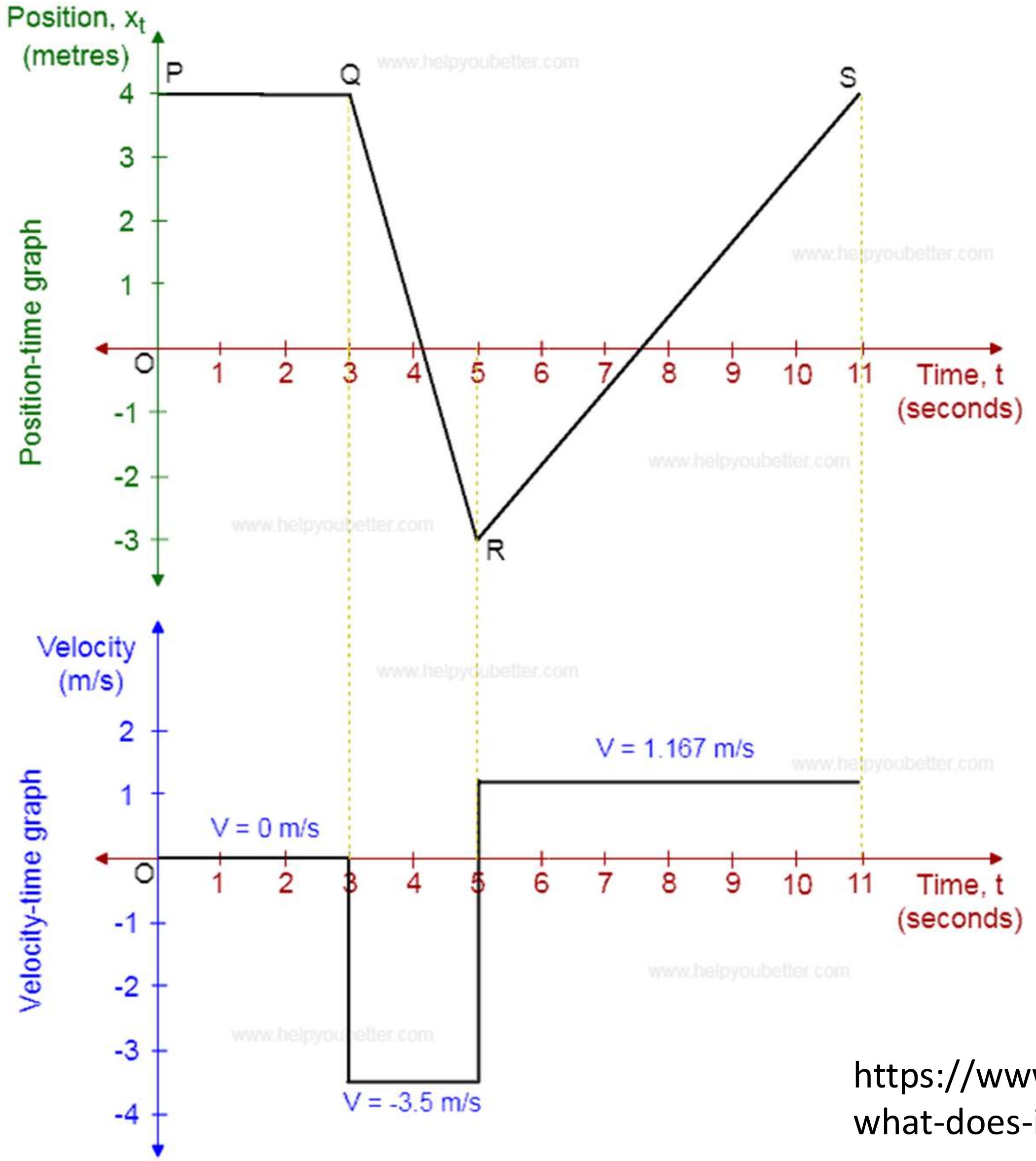
t = 0
t = 0.1
t = 0.2
t = 0.3
t = 0.4

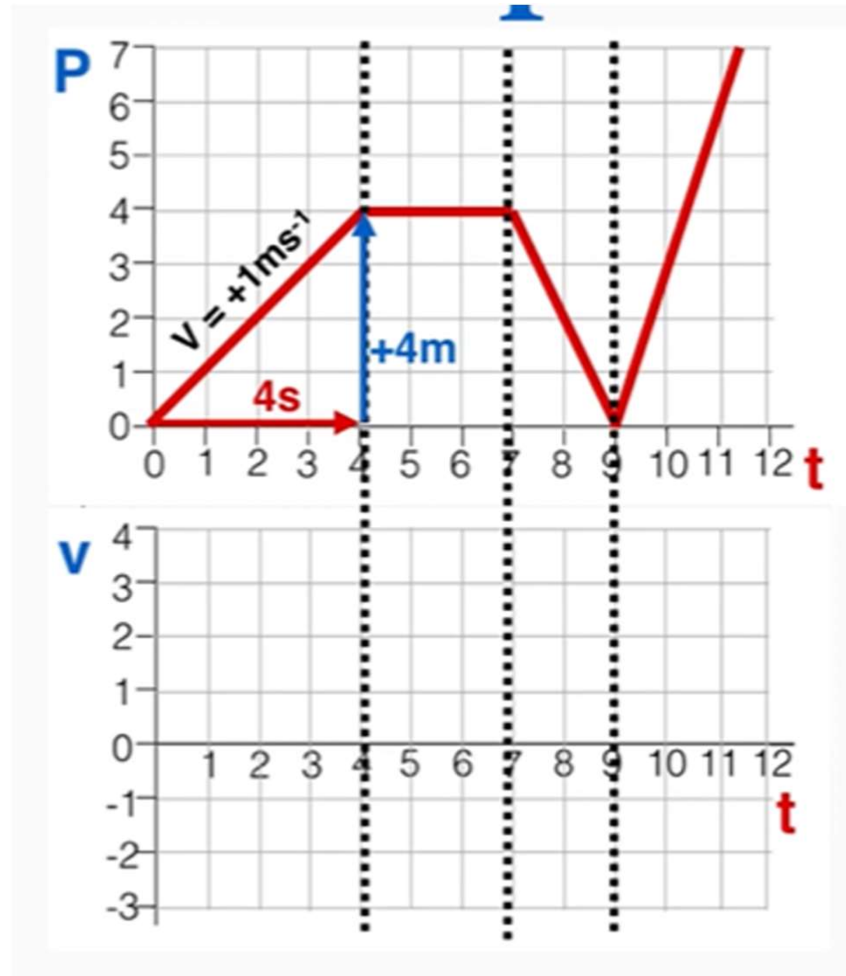


x-position (cm)
80 cm
60 cm
40 cm
20 cm
0.1 sec
0.2 sec
0.3 sec
0.4 sec
time (sec)

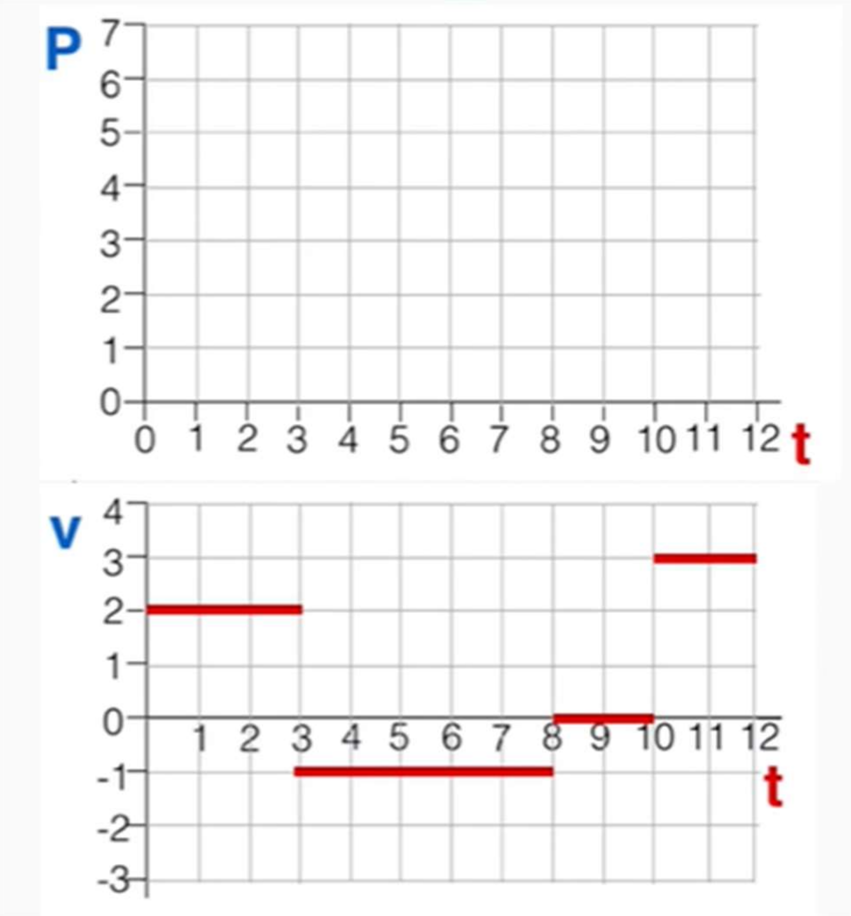


x-position (cm)
80 cm
60 cm
40 cm
20 cm
Δx = 20 cm
Δt = 0.1 s
0.1 sec
0.2 sec
time (sec)

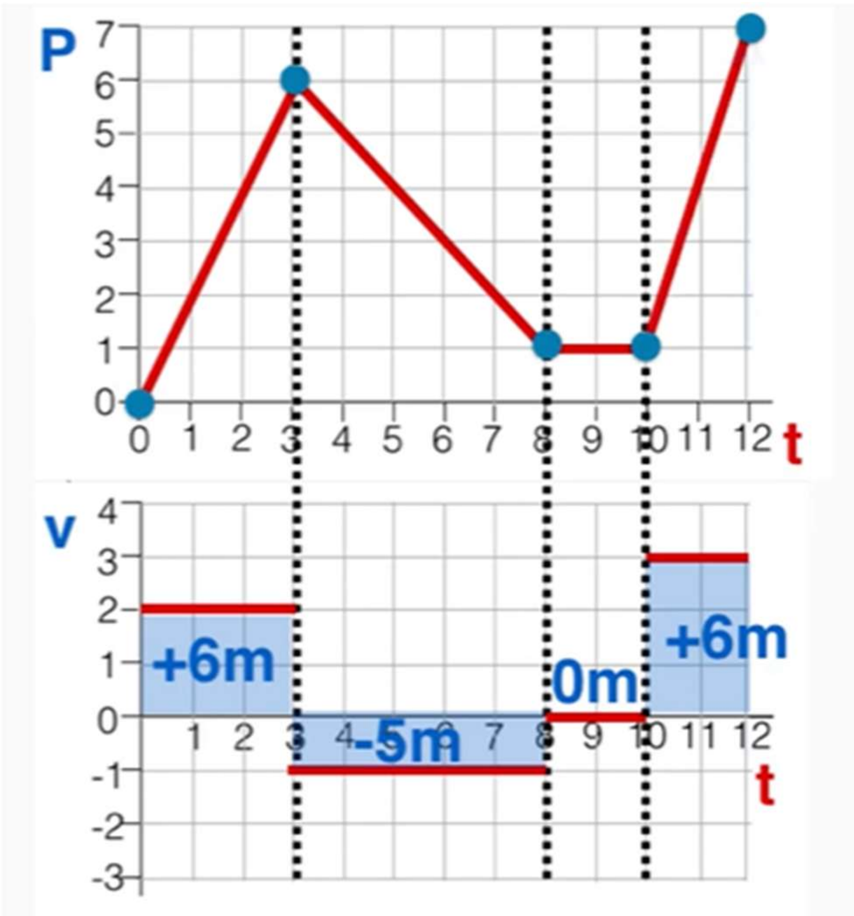




https://www.helpyoubetter.com/position-time-graph-and-what-does-it-tells-you/

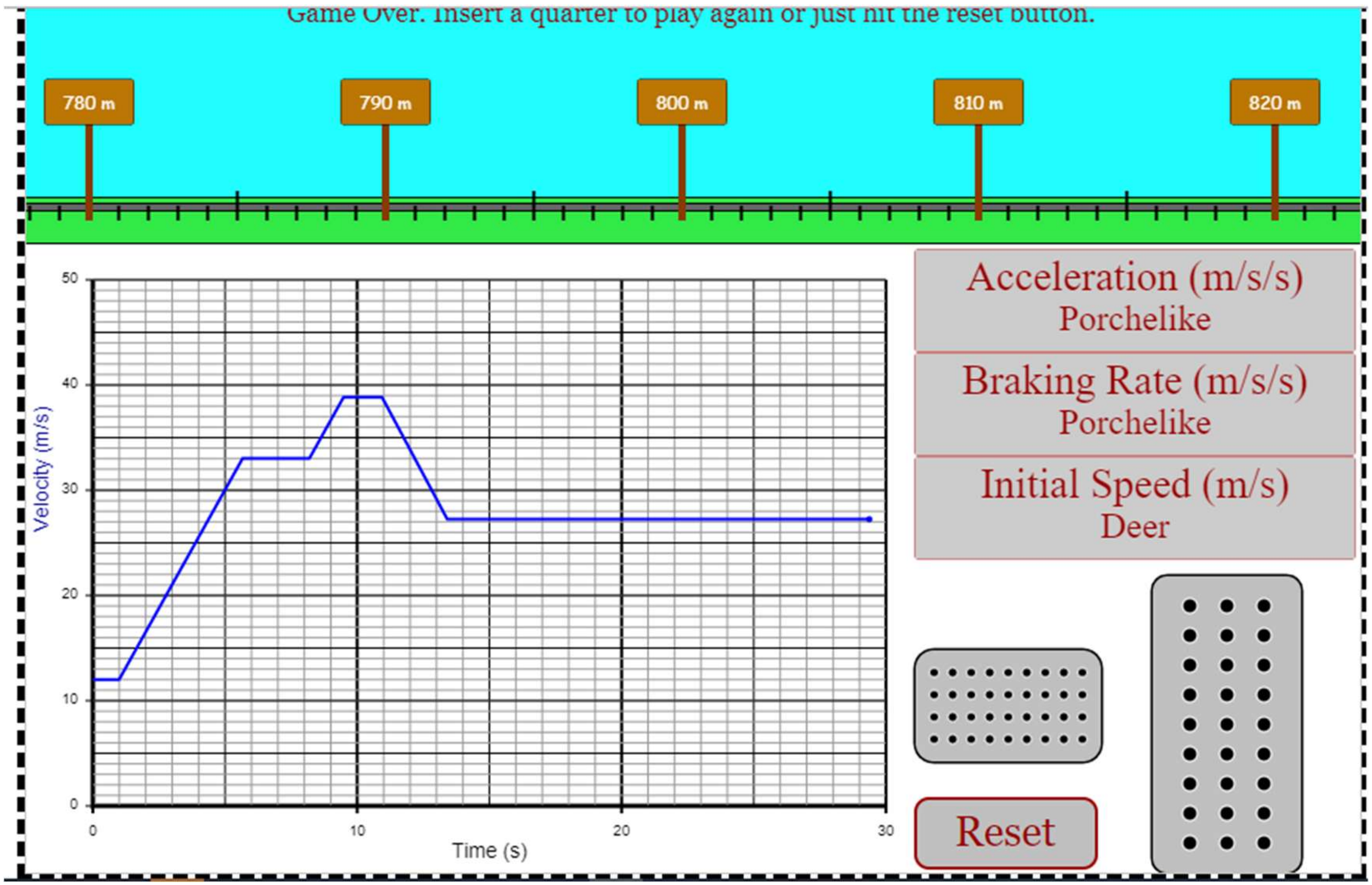


P
v
t

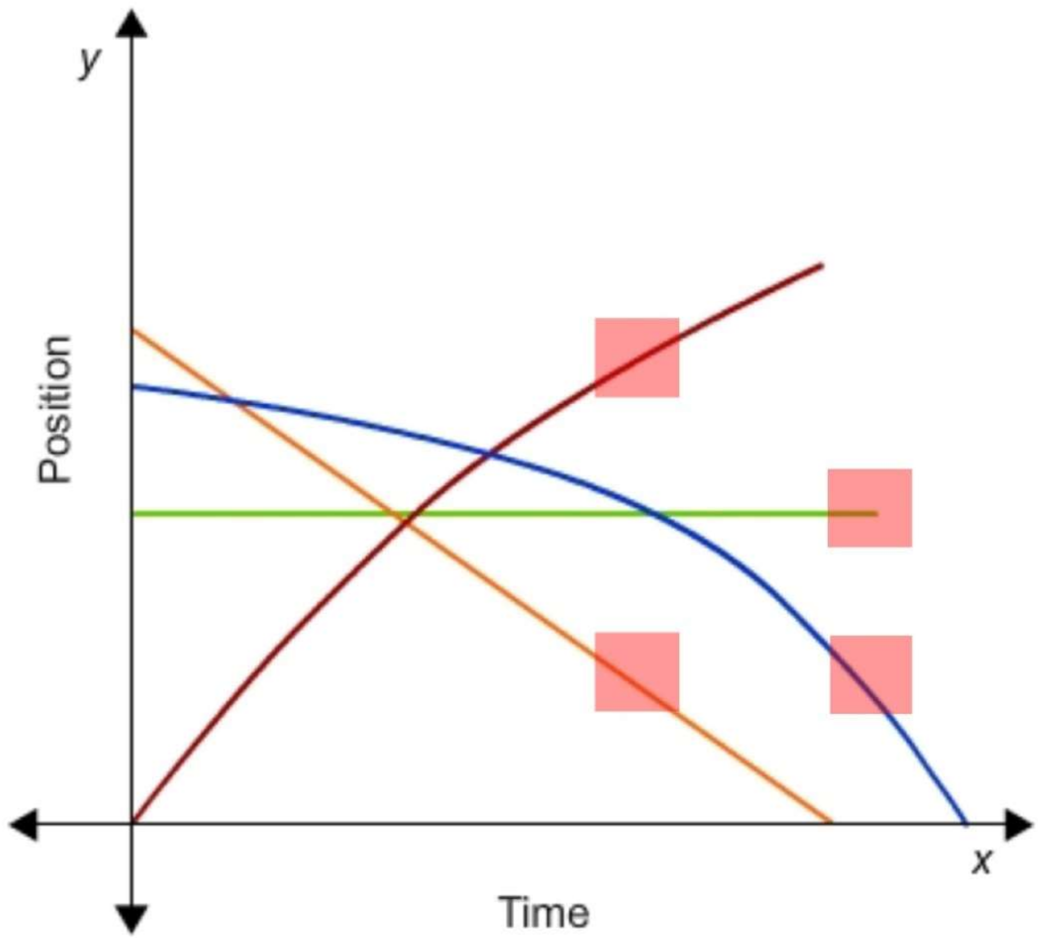


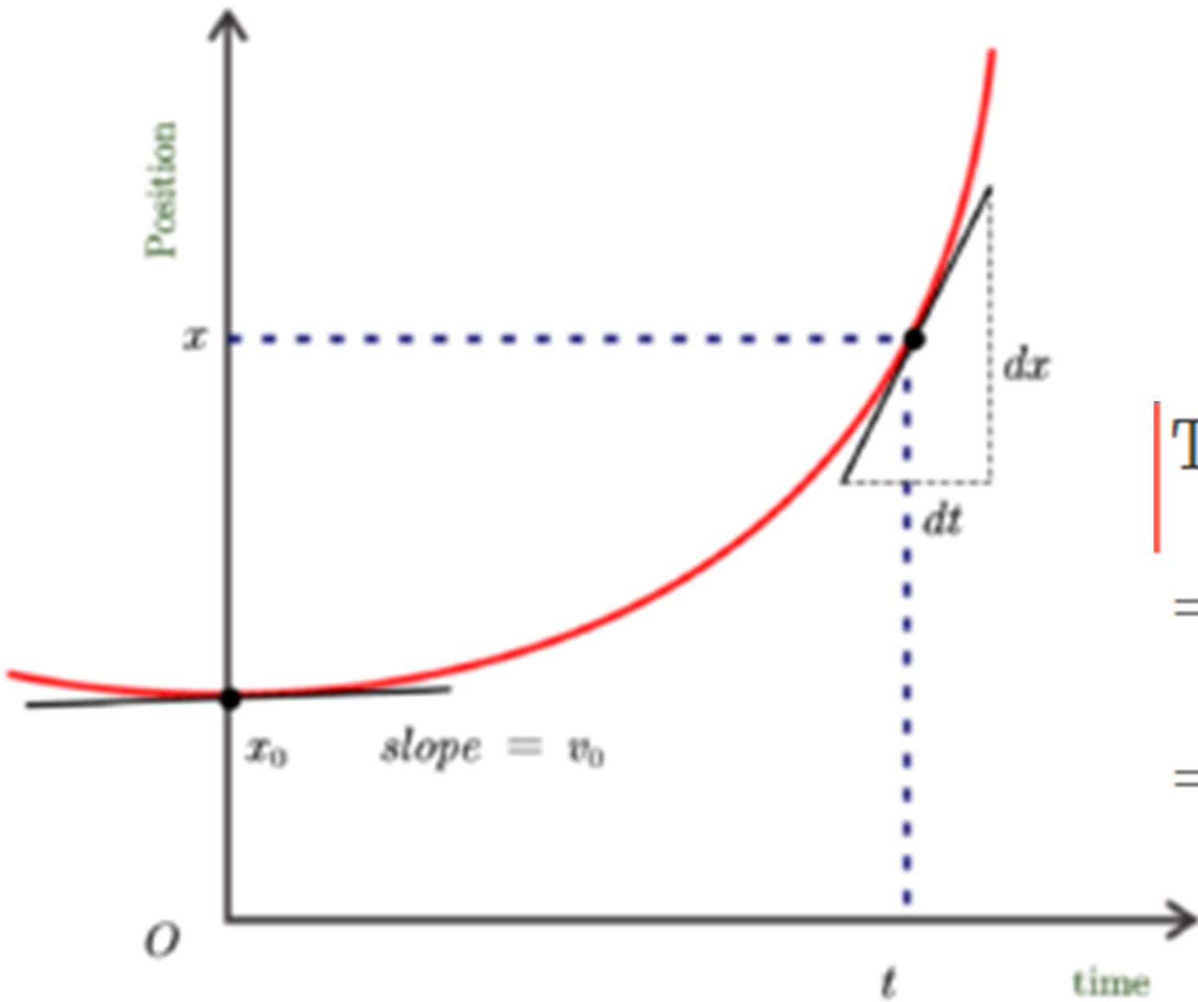
P
v
t
+6m
-5m
0m
+6m

https://www.thephysicsaviary.com/Physics/Programs/Labs/GraphingOfMotionLab/



he lines on the position-time graph show the velocities of different v



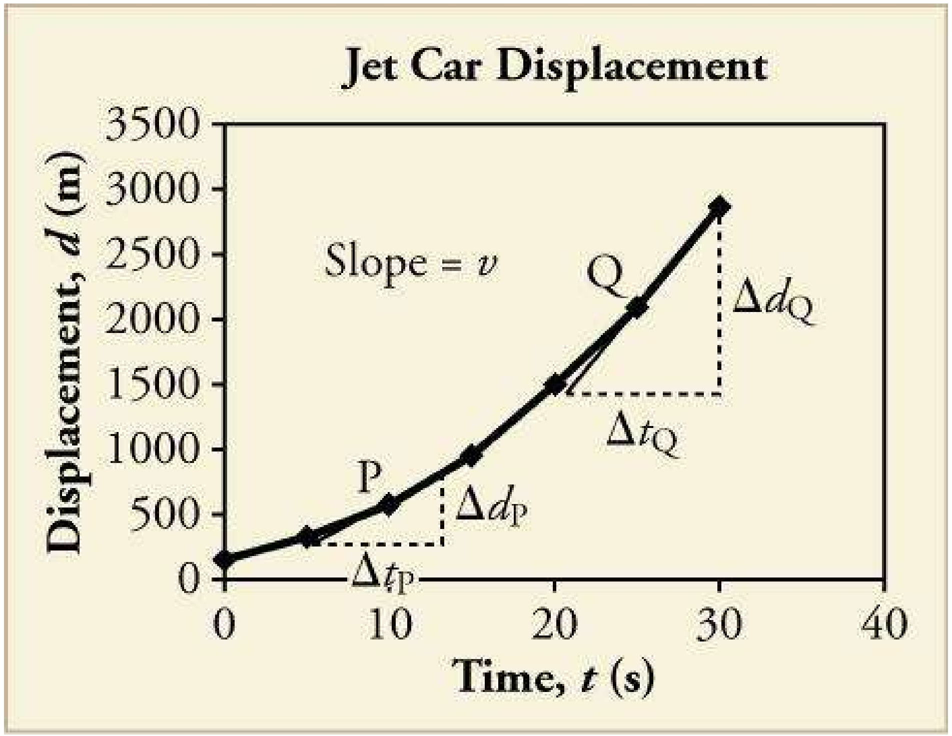


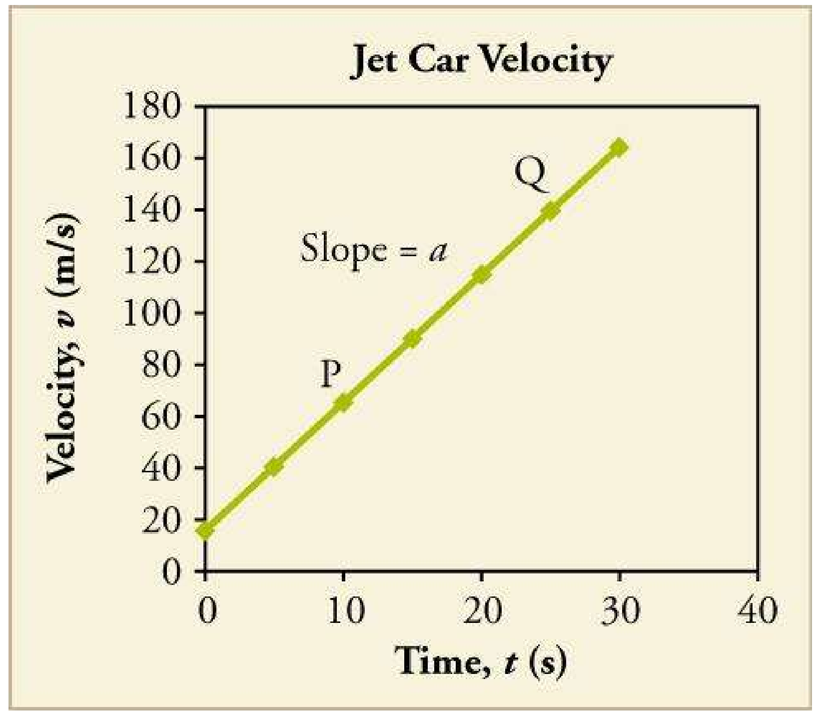
Position time graph for uniform acceleration

The slope of the x–t graph

$$= \frac{\text{Small change in vertical co-ordinate}}{Small change in horizontal co-ordinate}$$

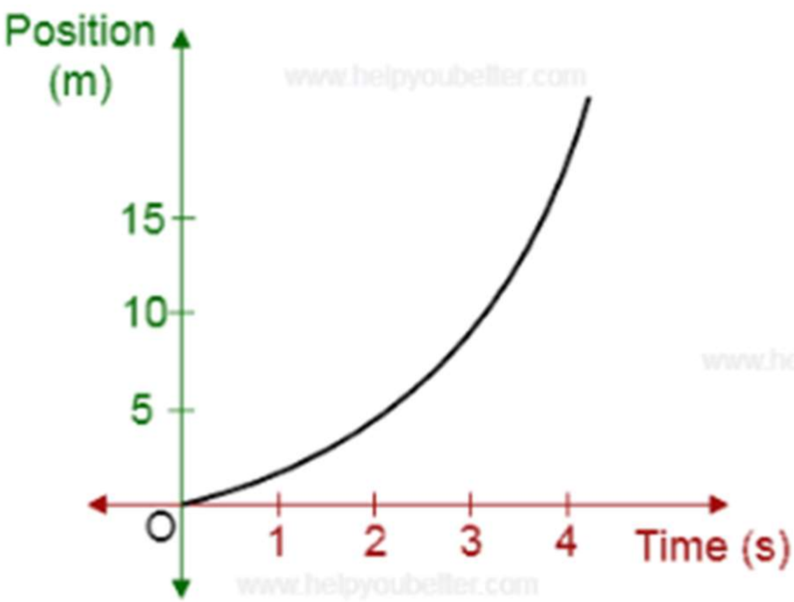
$$= \frac{dx}{dt} = \text{velocity at instant t}$$


Jet Car Displacement
Displacement, d (m)
3500
3000
2500
2000
1500
1000
500
0
Slope = v
Q
P
Δd_Q
Δt_Q
Δd_P
Δt_P
0
10
20
30
40
Time, t (s)

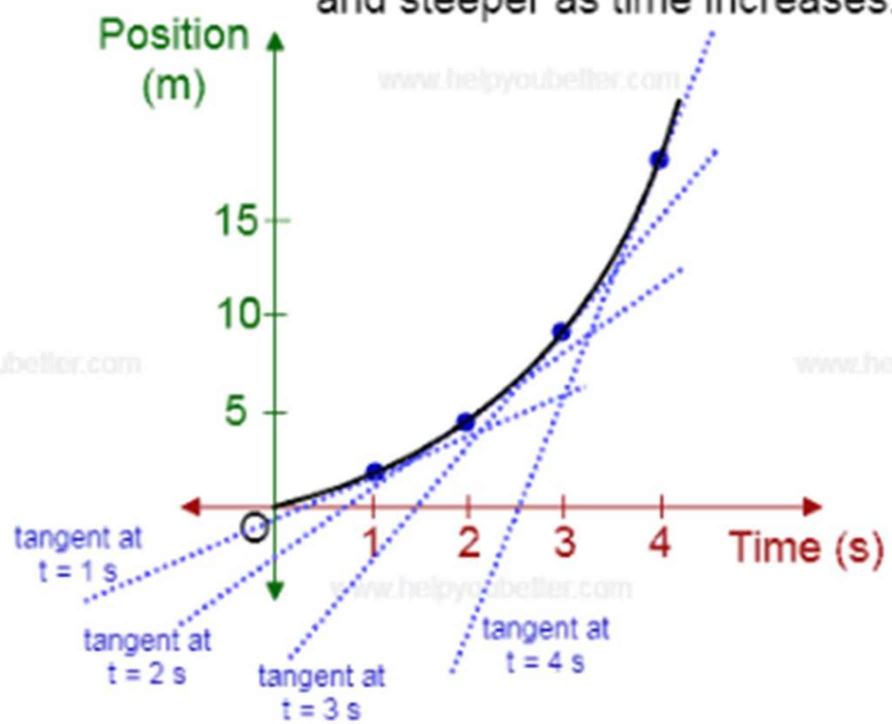

Jet Car Velocity
Velocity, v (m/s)
180
160
140
120
100
80
60
40
20
0
Q
Slope = a
P
0
10
20
30
40
Time, t (s)

Position time graph of an object moving with non uniform velocity :- when the object is moving faster and faster

P-T graph of an object moving faster and faster with non uniform velocity

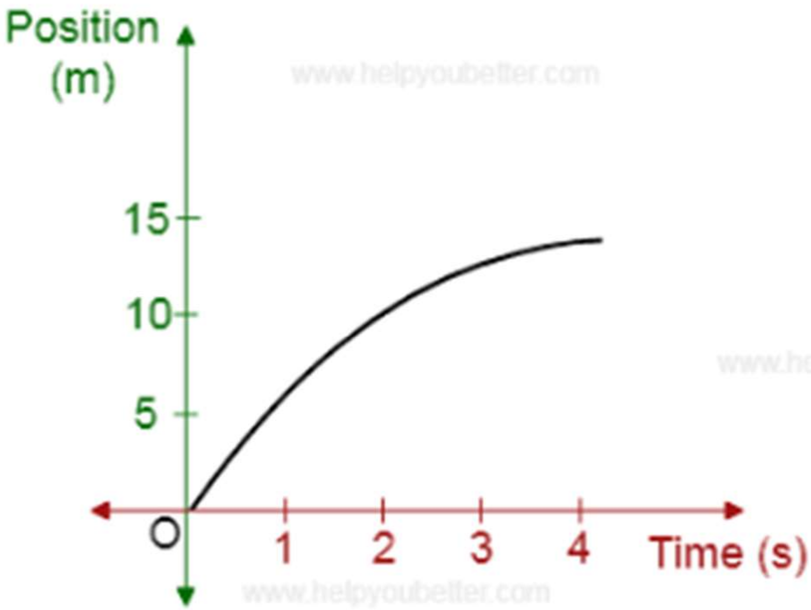


The object is moving faster and faster means the gradient is become steeper and steeper as time increases.

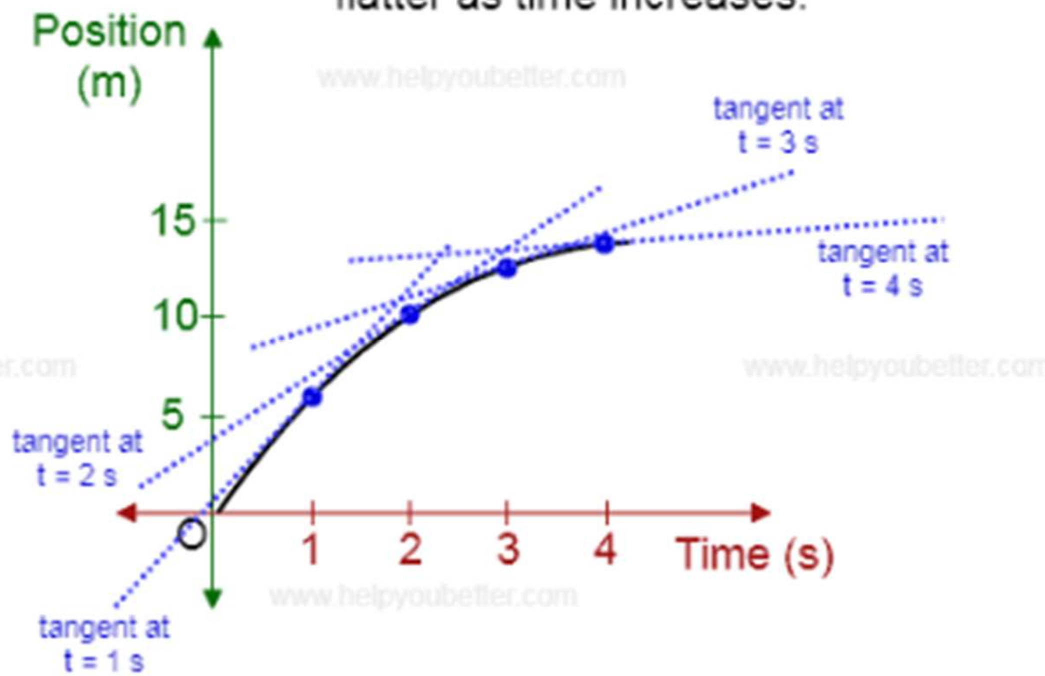


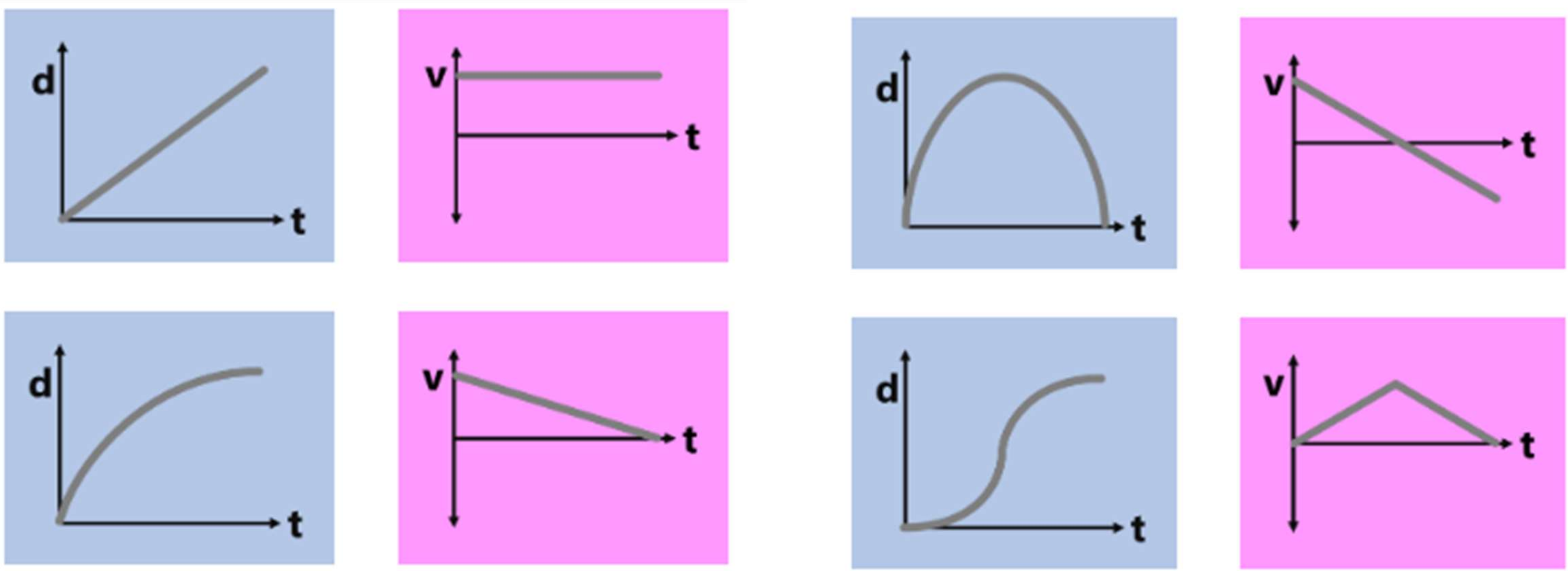
Position time graph of an object moving with non uniform velocity :- when the object is slowing down

P-T graph of a slowing down object moving with non uniform velocity



The object is slowing down means the gradient is become flatter and flatter as time increases.




d
t
v
t
d
t
v
t
d
t
v
t
d
t
v
t

https://www.youtube.com/watch?v=wW2Hf-i5-oU&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=8

Acceleration

Definition	Variable	Unit	Equation
Acceleration is the change in an object's velocity divided by the time the change takes place. Acceleration is a vector.	a	ms^{-2}	$a = \frac{\Delta V}{t} = \frac{V - U}{t}$

Example:

A car accelerates from rest at 10 ms^{-2} for 6 seconds. What is its final velocity?

G: $U = 0\ ms^{-1}$, $t = 6s$, $a = 10\ ms^{-2}$

U: $V = ?$

E: $a = \frac{V - U}{t}$

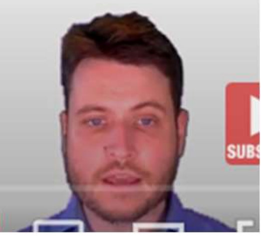
S: $t\,a = \frac{V - U}{\cancel{t}}\cancel{t}$

$ta = V - U$

$ta + U = V$

S: $6s*10\ ms^{-2} + 0\ ms^{-1} = V$

$60\ ms^{-1} = V$



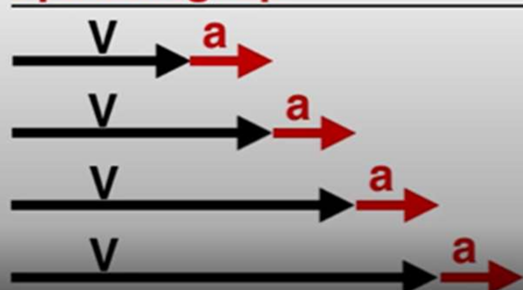
Acceleration

Definition	Variable	Unit	Equation
Acceleration is the change in an object's velocity divided by the time the change takes place. Acceleration is a vector.	a	ms^{-2}	$a = \frac{\Delta V}{t} = \frac{V - U}{t}$

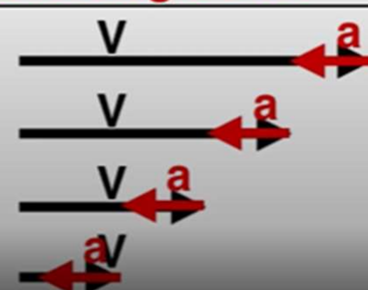
Why Acceleration is a Vector:

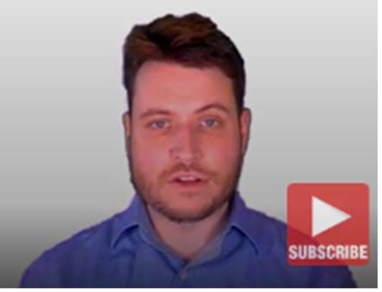
The direction of acceleration matters for how the velocity changes. If the acceleration points in the same direction as the velocity, the object will speed up. If the acceleration points in the opposite direction as velocity, the object will slow down.

Speeding Up

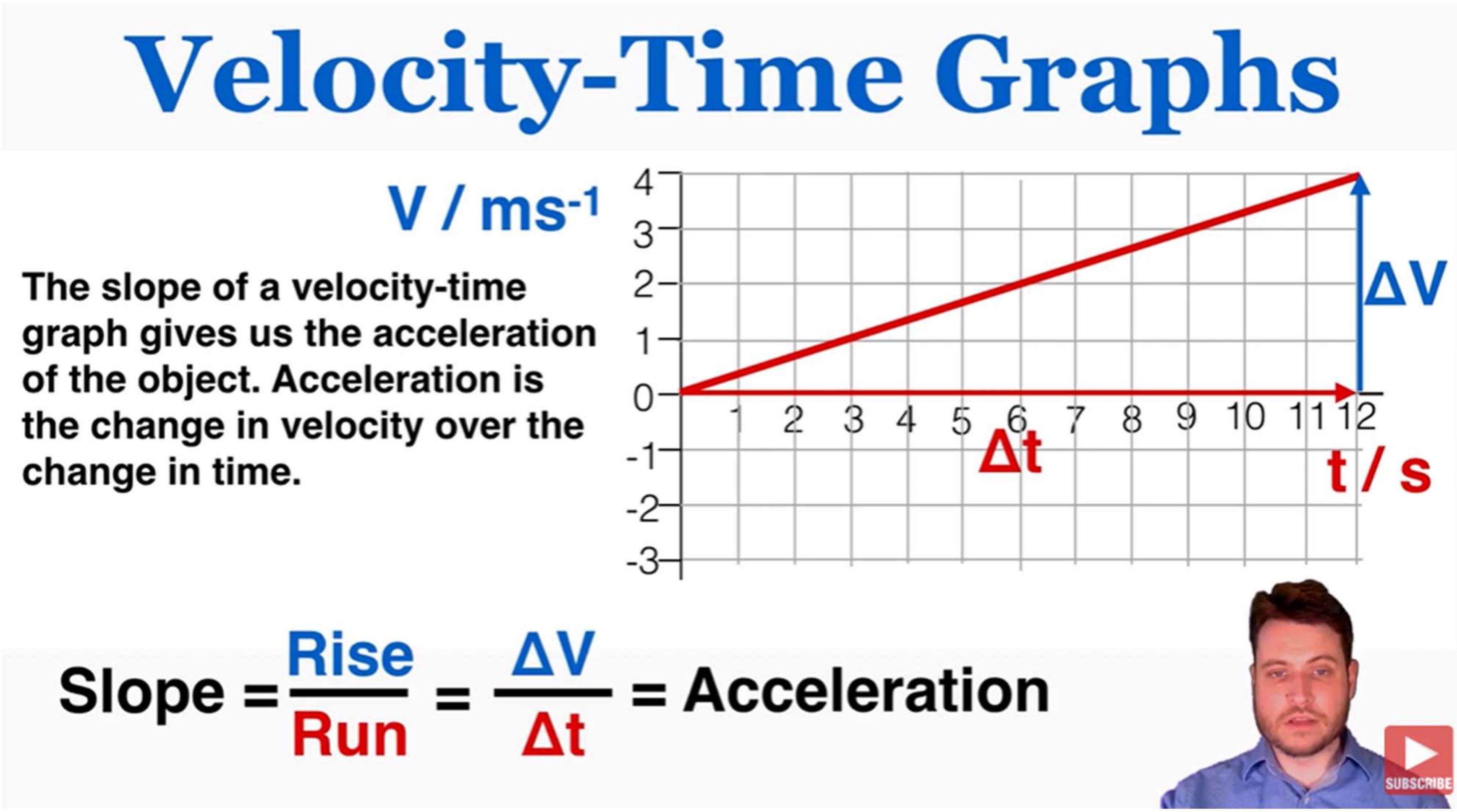


Slowing Down

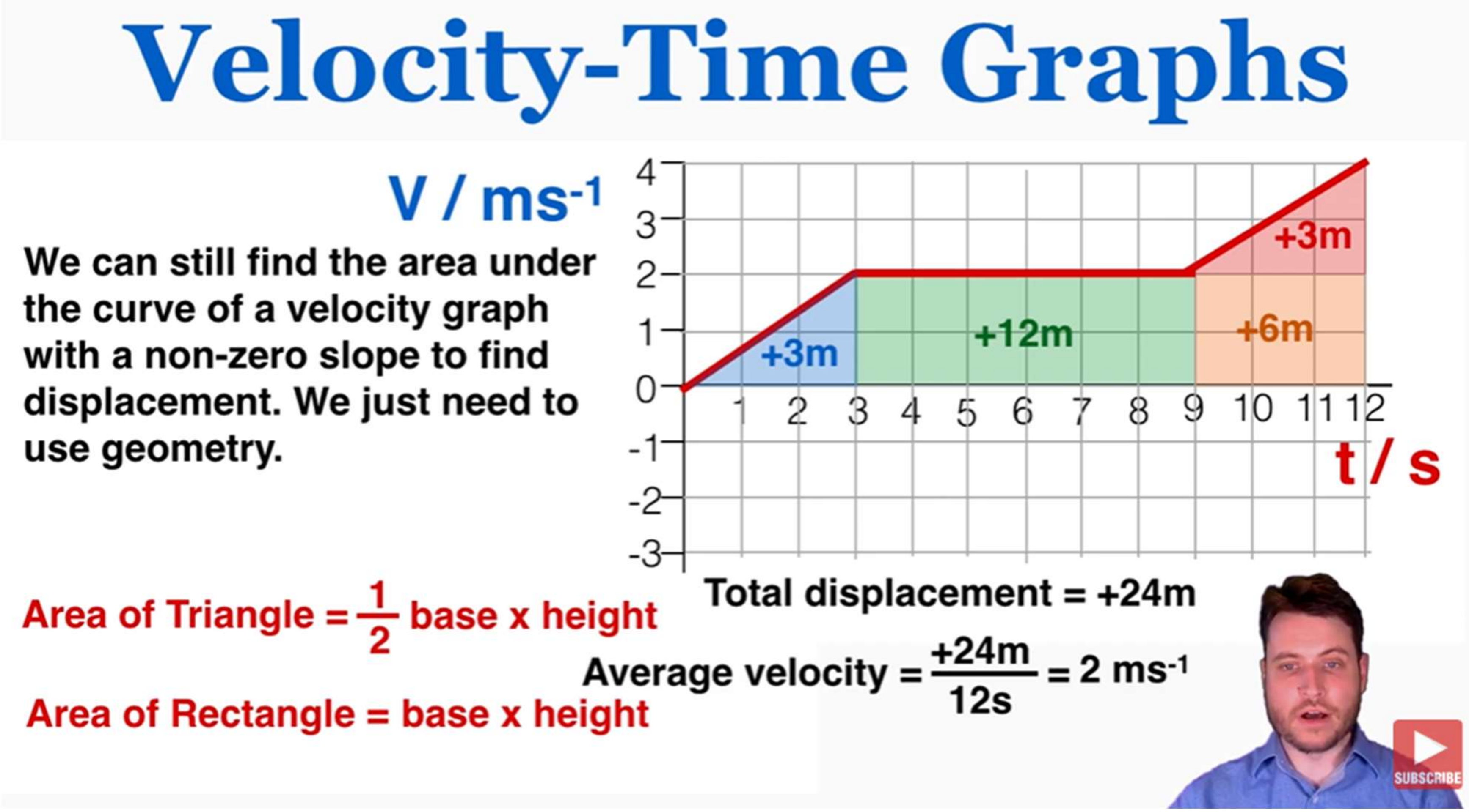




https://www.youtube.com/watch?v=leCHbvmocLo&list=PLeve
VE-rwOyLMMeJhlTKn33j4a7pml1ia&index=9



https://www.youtube.com/watch?v=leCHbvmocLo&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=9



Acceleration

Common misconception:

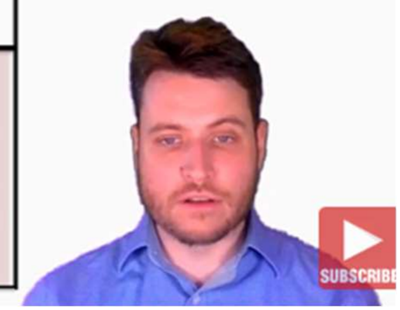
Positive acceleration means the object is getting faster. Negative acceleration means the object is getting slower.

Correct Understanding:

If the acceleration has the same sign as velocity, the object is getting faster. If the acceleration has the opposite sign as velocity, the object is getting slower.

	+ Start Velocity	- Start Velocity
+ Acceleration	$a = 1\ ms^{-2}$ $V_0 = 4\ ms^{-1}$ $V_1 = 5\ ms^{-1}$ $V_2 = 6\ ms^{-1}$ $V_3 = 7\ ms^{-1}$ $V_4 = 8\ ms^{-1}$	$a = 1\ ms^{-2}$ $V_0 = -4\ ms^{-1}$ $V_1 = -3\ ms^{-1}$ $V_2 = -2\ ms^{-1}$ $V_3 = -1\ ms^{-1}$ $V_4 = 0\ ms^{-1}$
- Acceleration	$a = -1\ ms^{-2}$ $V_0 = 4\ ms^{-1}$ $V_1 = 3\ ms^{-1}$ $V_2 = 2\ ms^{-1}$ $V_3 = 1\ ms^{-1}$ $V_4 = 0\ ms^{-1}$	$a = -1\ ms^{-2}$ $V_0 = -4\ ms^{-1}$ $V_1 = -5\ ms^{-1}$ $V_2 = -6\ ms^{-1}$ $V_3 = -7\ ms^{-1}$ $V_4 = -8\ ms^{-1}$

Same sign, object gets faster



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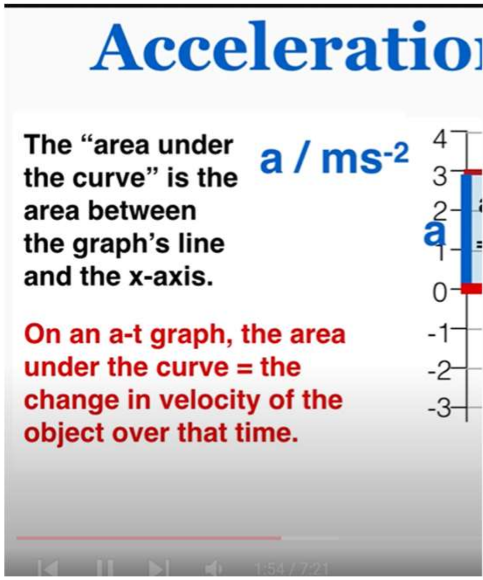
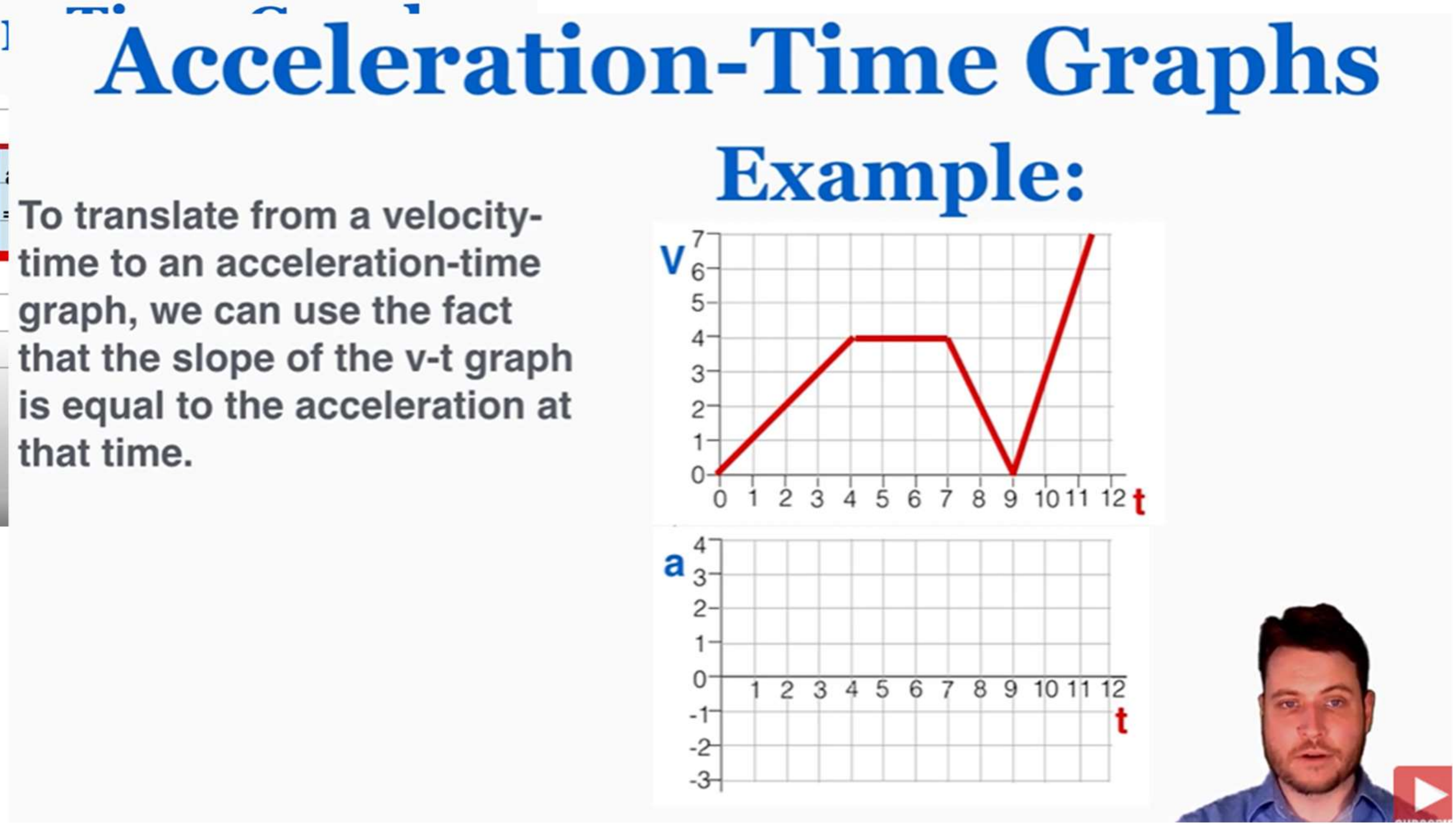
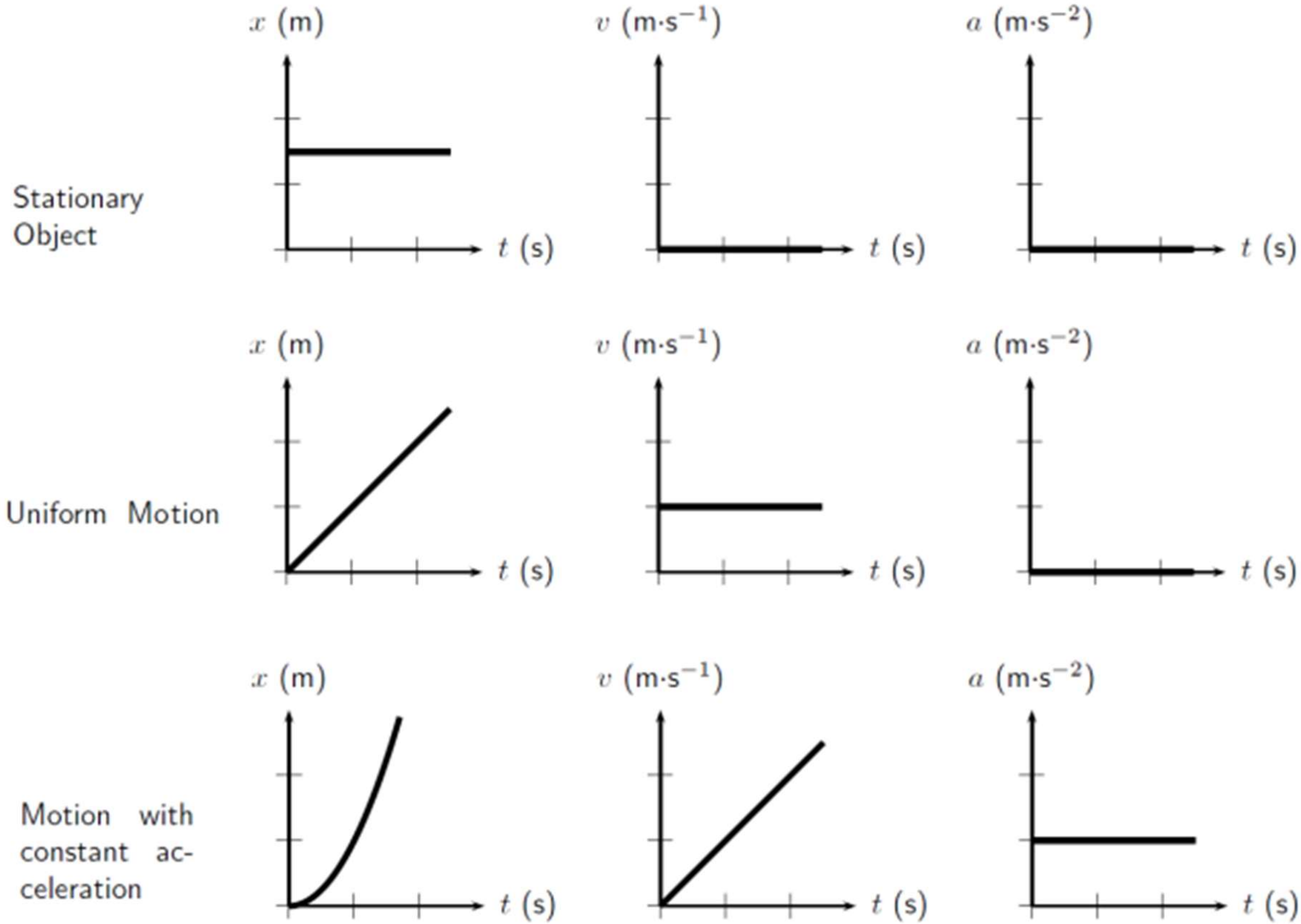




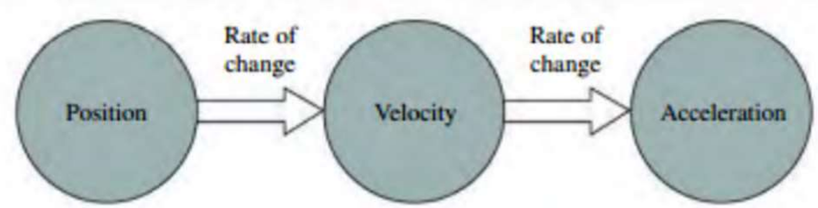


Stationary Object
Uniform Motion
Motion with constant acceleration
x (m)
v (m·s^{-1})
a (m·s^{-2})
t (s)

Motion in a Straight Line

Big Idea

The big ideas here are those of **kinematics**—the study of motion without regard to its cause. **Position**, **velocity**, and **acceleration** are the quantities that characterize motion:



$$\boxed{v = \frac{s}{t}} \qquad \boxed{s = vt}$$

$$\vec{a} = \frac{\Delta\vec{v}}{\Delta t} \text{ หรือ } \vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t_2 - t_1}$$

$\vec{a}$ = ความเร่ง (m/s^2)

$\Delta\vec{v}$ = ความเร็วสุดท้าย - ความเร็วเริ่มต้น (m)

Δt = ระยะเวลาทั้งหมดที่วัตถุใช้ในการเคลื่อนที่ (s)

กรณีมีความเร่ง

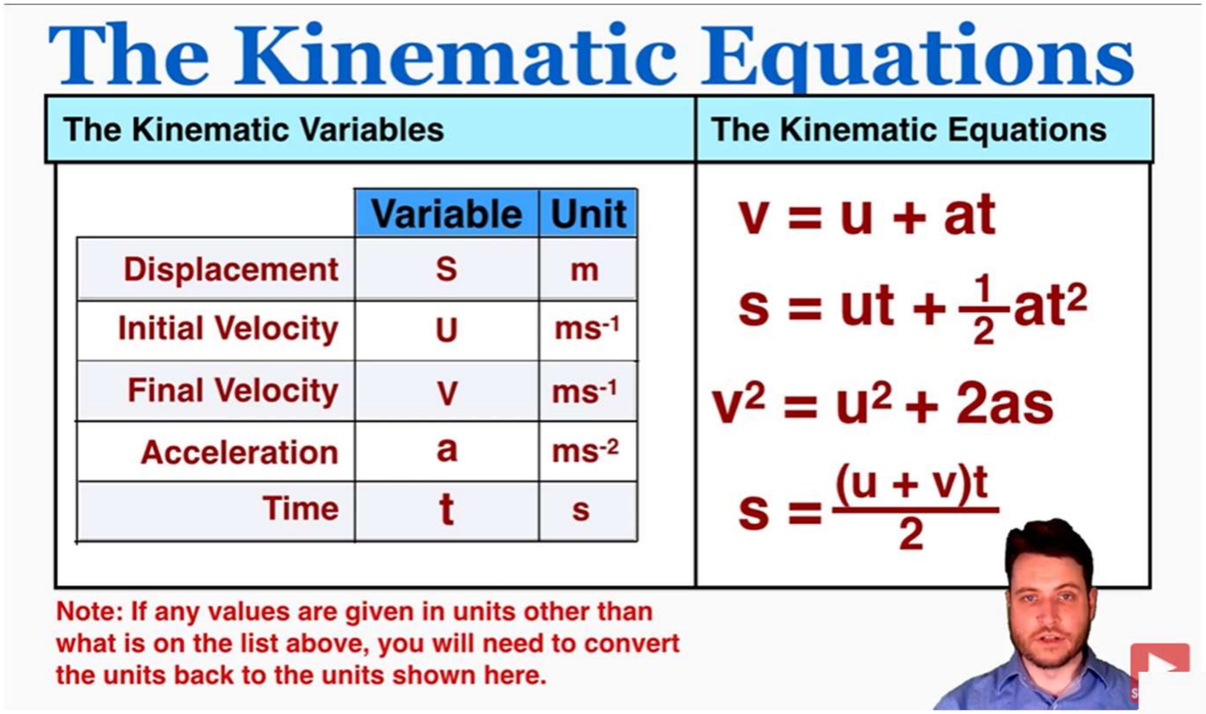
$$\boxed{v = u + at}$$

$$\boxed{v^2 = u^2 + 2as}$$

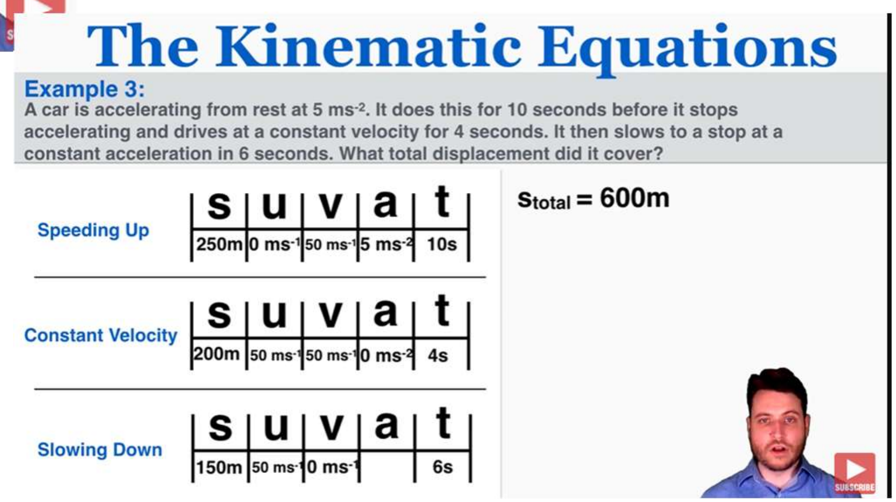
$$\boxed{s = ut + \frac{1}{2}at^2}$$

$$\boxed{s = vt - \frac{1}{2}at^2}$$

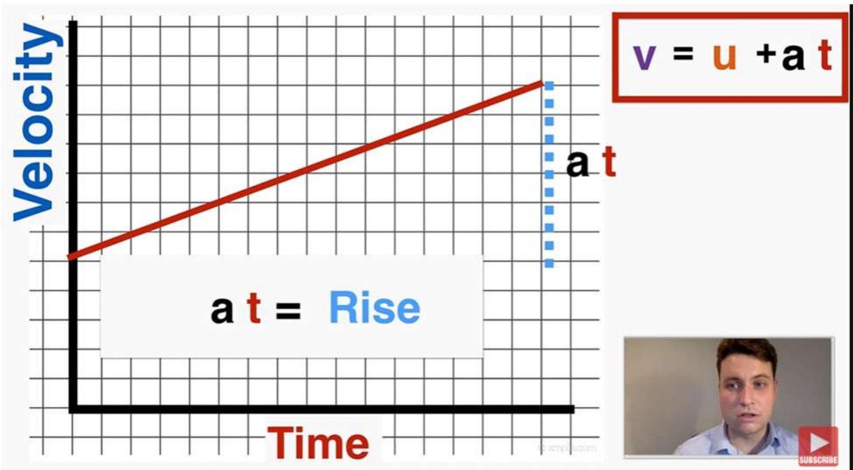
$$\boxed{s = \left(\frac{v+u}{2}\right)t}$$

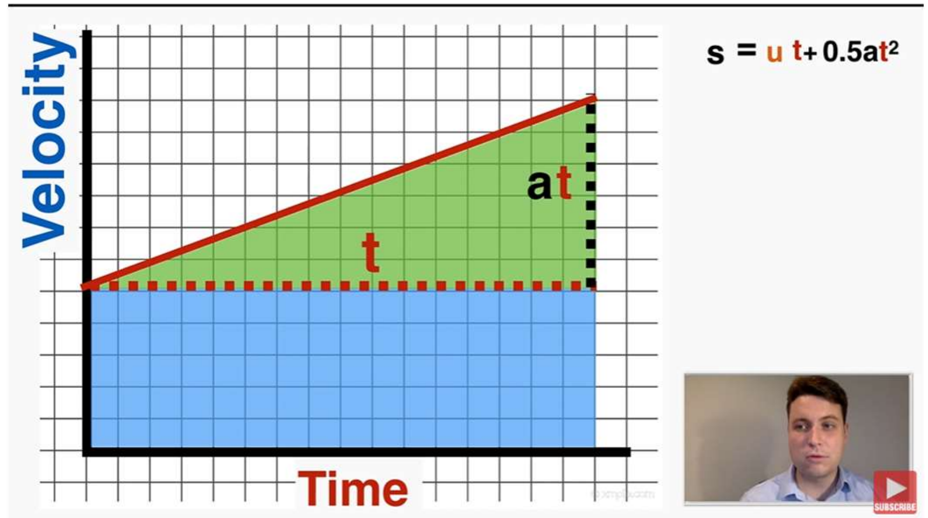


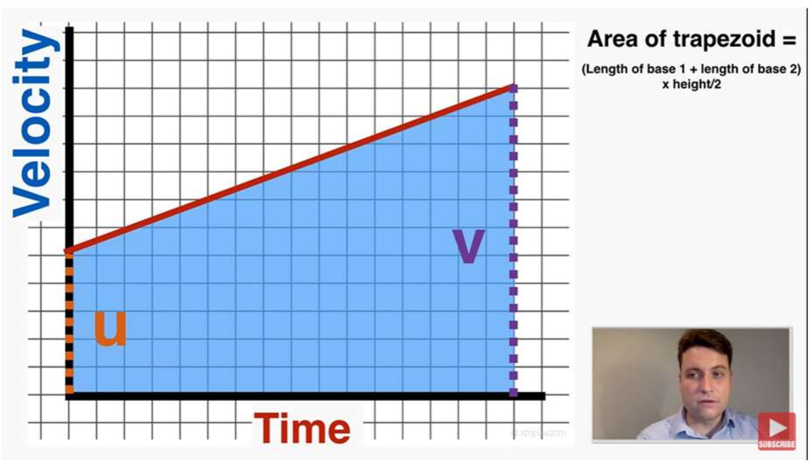
https://www.youtube.com/watch?v=Pt8bTYlNxd4&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=12

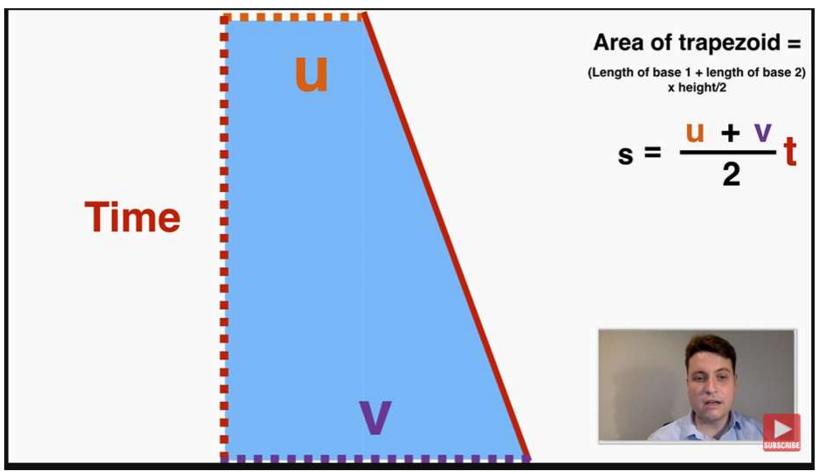


https://www.youtube.com/watch?v=z8GZvnTN7pg&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=13



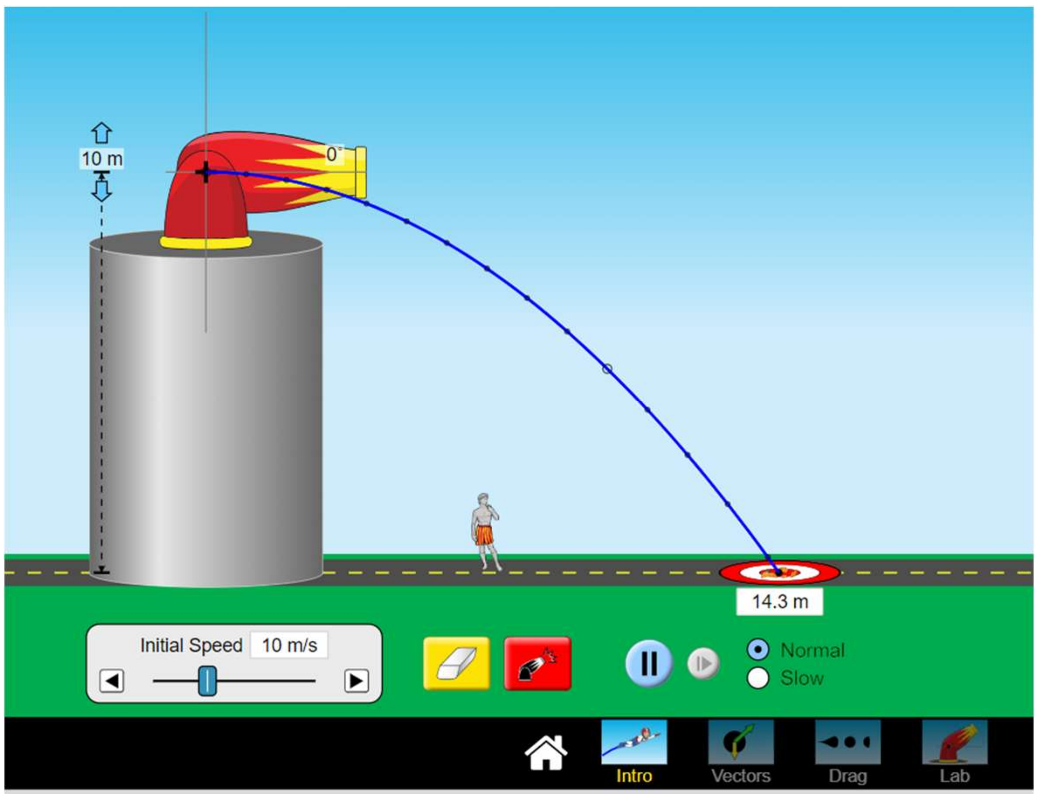


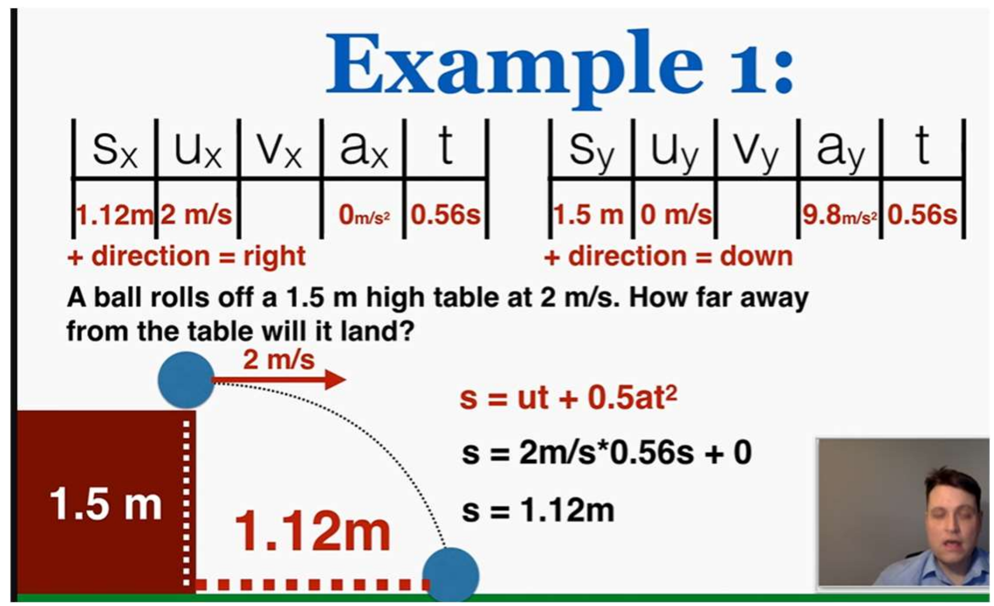


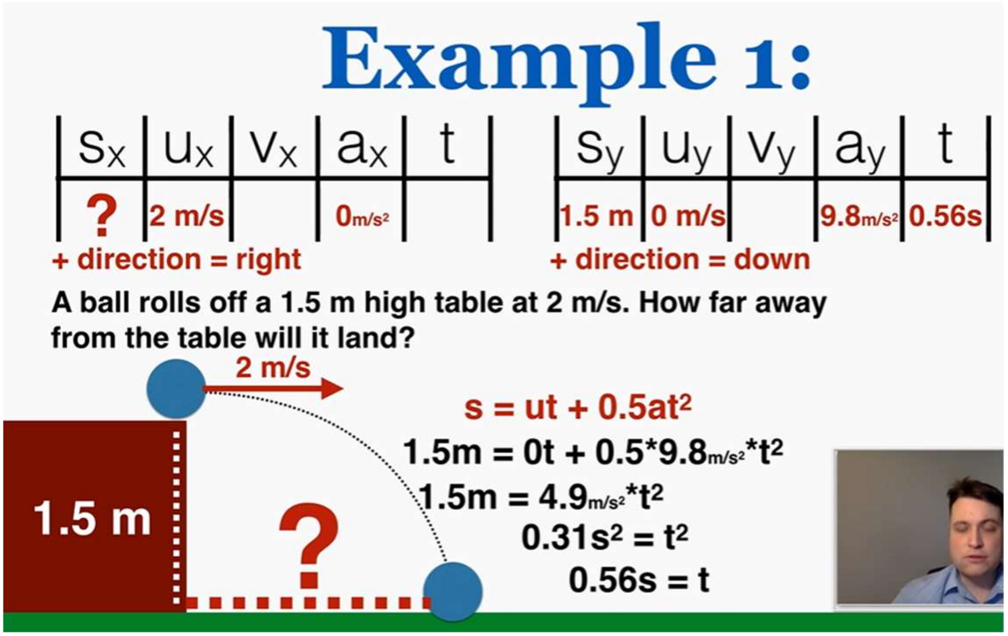


https://phet.colorado.edu/en/simulations/projectile-motion

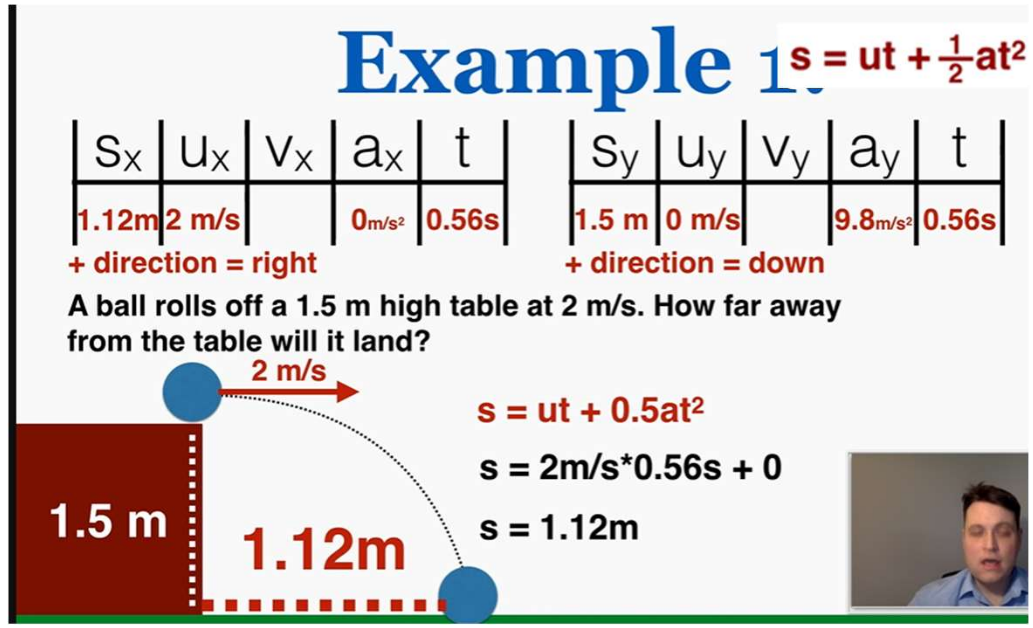
https://www.youtube.com/watch?v=jrvy1ZkvjQQ&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=15

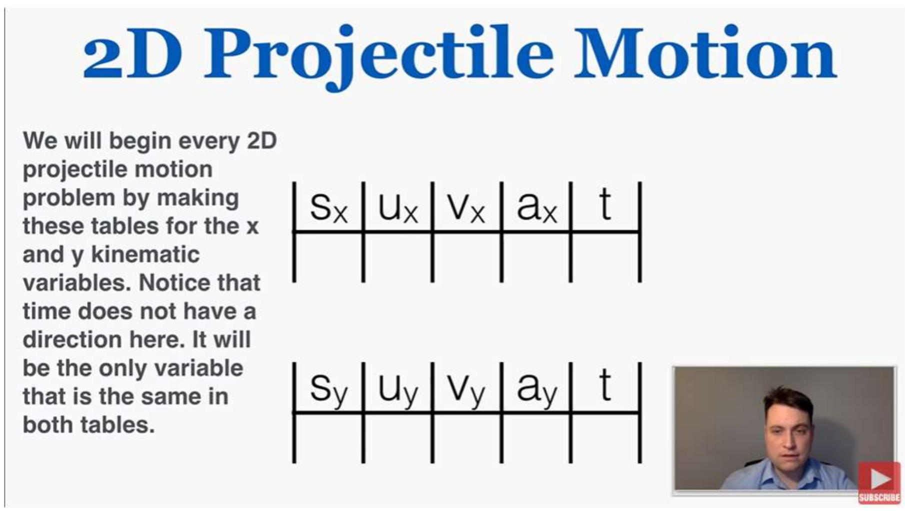


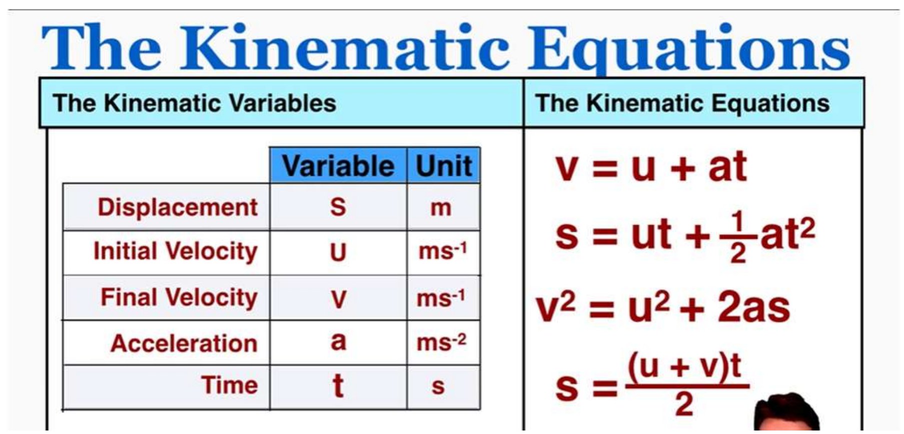




https://www.youtube.com/watch?v=jrvy1ZkvjQQ&list=PLeveVE-rwOyLMMeJhlTKn33j4a7pml1ia&index=15

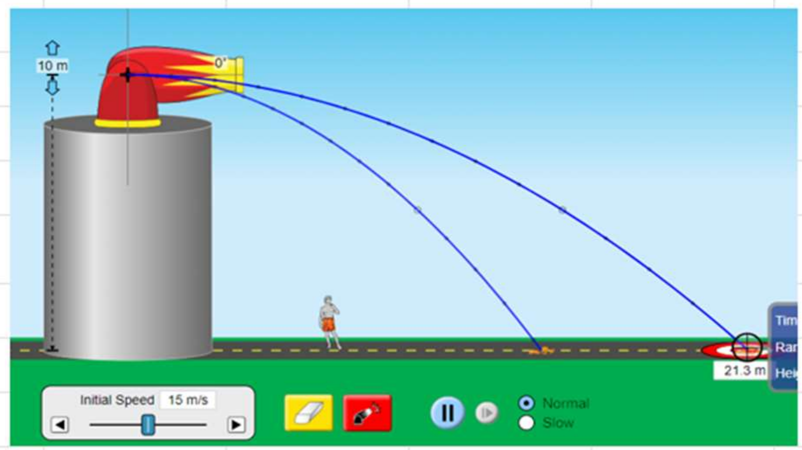


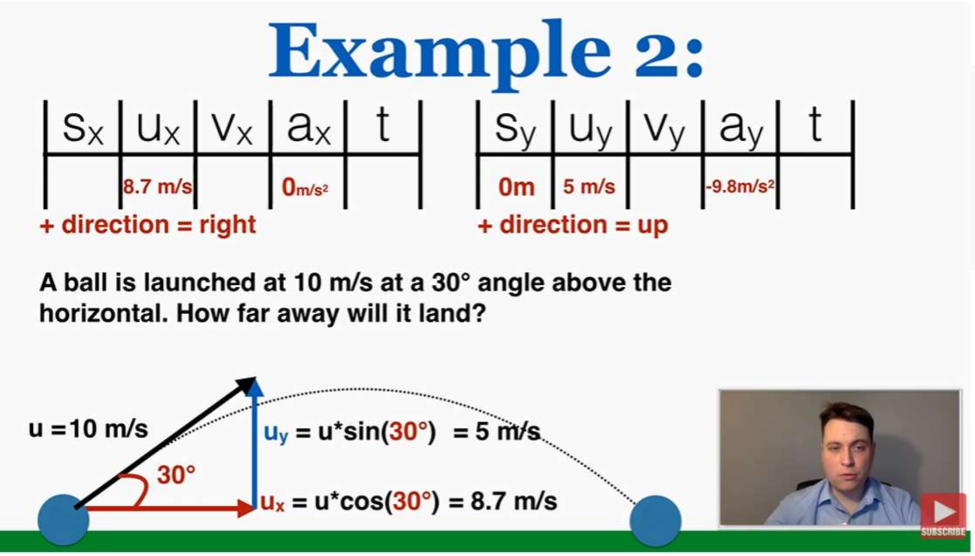




https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html

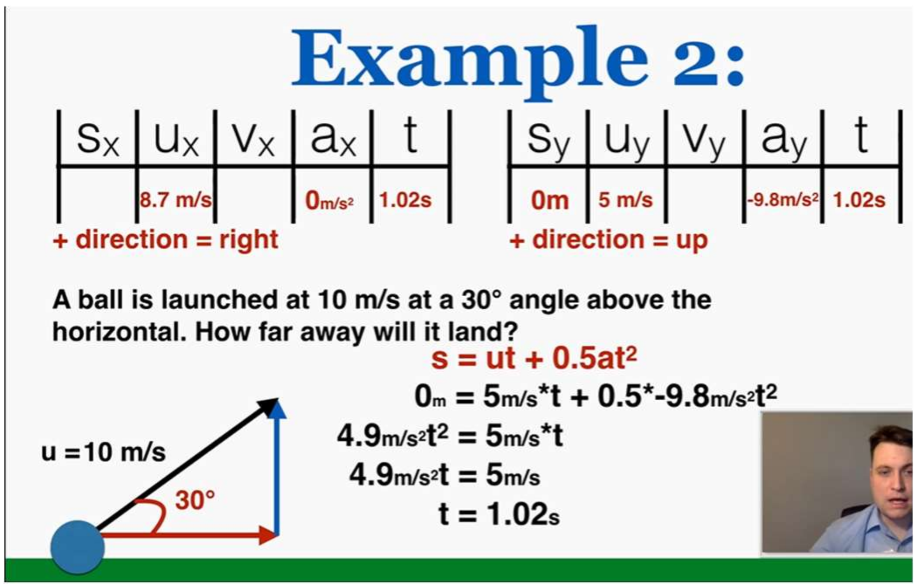
	A	B	C	D	E	F	G	H	I	J	K	L	M
1						$t = \sqrt{Sy/(0.5 * Ay)}$							
2		Sy	Uy	Vy	Ay	t							
3		1.5	0		9.8	0.56	=ROUND(SQRT(ROUND(B3/(0.5*E3),2)),2)						
4		10	0		9.8	1.43							
5		$s = ut + \frac{1}{2}at^2$											
6													
7													
8		Sx = Ux * t											
9		Sx	Ux	Vx	Ax	t							
10	=C10*F10	1.12	2		0	0.560	=F3						
11		21.5	15		0	1.430							
12													
13		$s = ut + \frac{1}{2}at^2$											

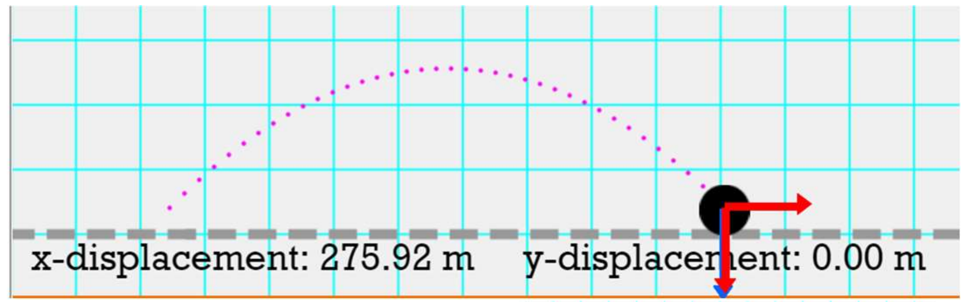


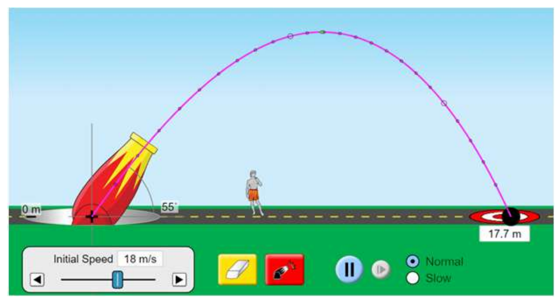


$$s = ut + 0.5at^2$$
$$s = 8.7 m/s * 1.02 s$$
$$s = 8.9 m$$

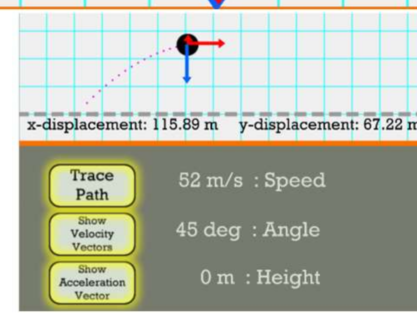
$$\boxed{\begin{aligned} v &= u + at \\ s &= ut + 0.5at^2 \\ v^2 &= u^2 + 2as \\ s &= 0.5(u + v)t \end{aligned}}$$



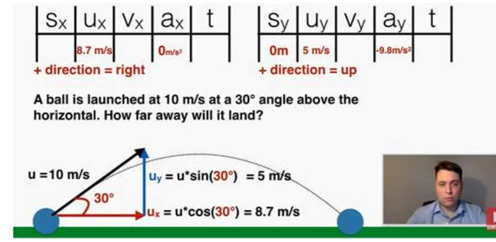




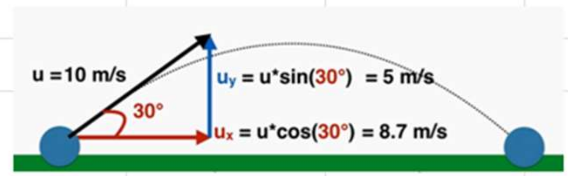
https://phet.colorado.edu/sims/html/projectile-motion/latest/projectile-motion_en.html



https://www.physicsclassroom.com/Physics-Interactives/Vectors-and-Projectiles/Projectile-Simulator/Projectile-Simulator-Interactive



	A	B	C	D	E	F	G	H
1		มุม	U		=ROUND($C2*COS(RADIANS(B2)),1)			
2		30	10	Ux	8.7	Uy	5	=ROUND(C2*SIN(RADIANS($B2)),2)
3		65	19	Ux	8.03	Uy	17.22	
4				Ux = U * Cos(มุม)			Uy = U * Sin (มุม)	
5			=G2			= ROUND(C7/(0.5*E7),2)		
6		Sy	Uy	Vy	Ay	t		
7		0	5		9.8	1.02	= ROUND(C7/(0.5*E7),2)	
8		0	17.22		9.8	3.51	$s = ut + \frac{1}{2}at^2$	
9								
10			=E2					
11		Sx	Ux	Vx	Ax	t		
12	=C12*F12	8.9	8.7		0	1.020	=F7	
13		28.2	8.03		1	3.510	$s = ut + \frac{1}{2}at^2$	
14								



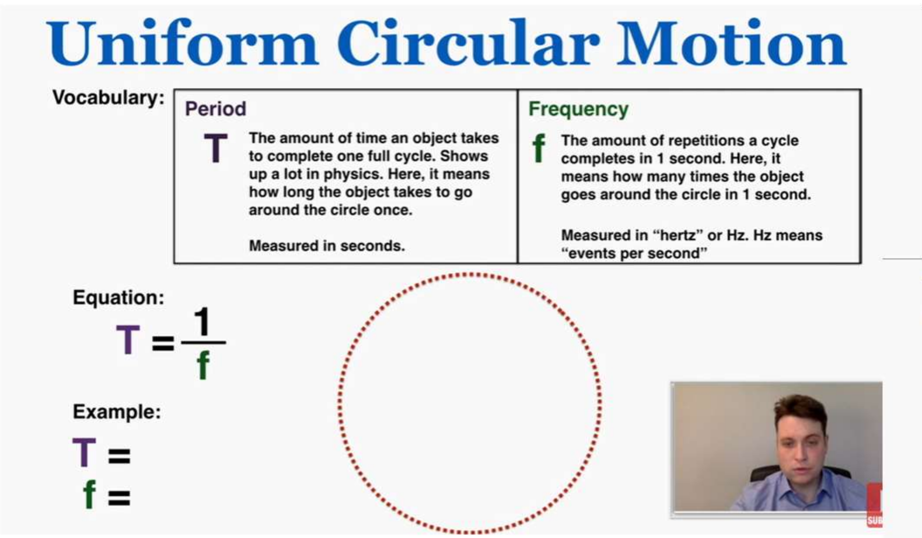
$$s = ut + 0.5at^2$$
$$0_m = 5_{m/s} \cdot t + 0.5 \cdot -9.8_{m/s^2} t^2$$
$$4.9_{m/s^2} t^2 = 5_{m/s} \cdot t$$
$$4.9_{m/s^2} t = 5_{m/s}$$
$$t = 1.02_s$$

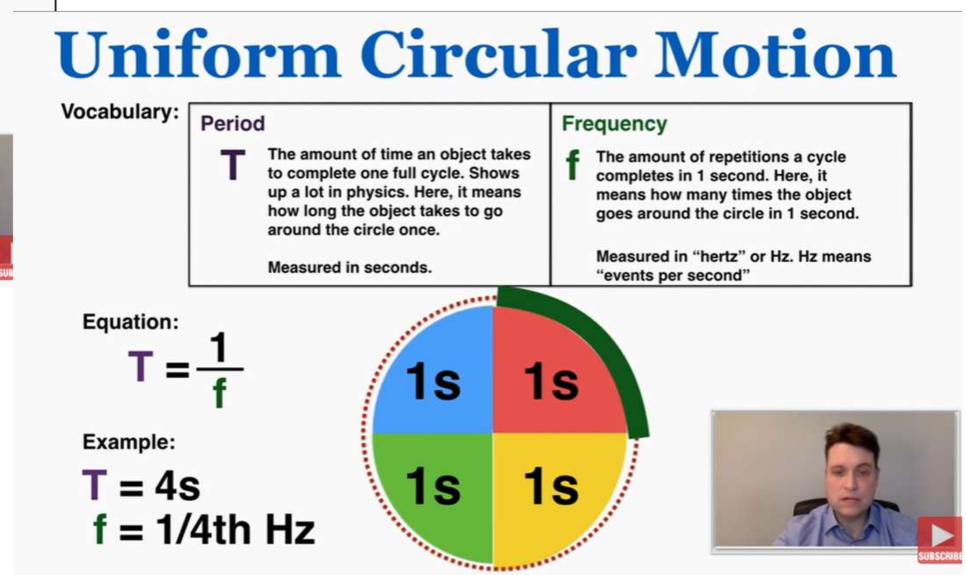
```
= SIN(PI() / 6) // Returns 0.5
```

Using Degrees

```
= SIN(30 * PI() / 180)
= SIN(RADIANS(30))
```

https://www.youtube.com/watch?v=_ZwjOOKQA08&list=PLeve
VE-rwOyLOeyiPN_wq5DQCbOiL6gsh

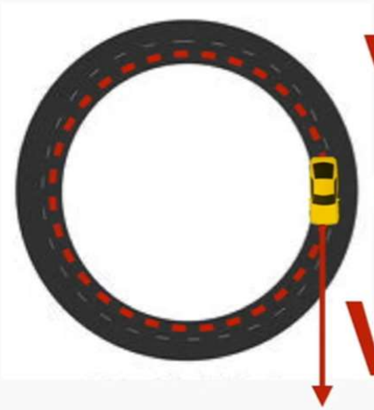




Uniform Circular Motion

Vocabulary:

Angular Velocity	Tangential Velocity
ω — The change in angle around a circle over the change in time. Measured in rad/s "radians per second". "Omega" is a Greek letter. Not W.	V_t — The distance the object moves around the circle over the change in time. Measured in m/s.



$$V_{car} > V_{boy}$$

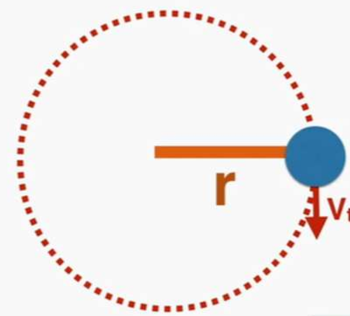
$$V_{boy} = \frac{d}{t}$$

$$V_{car} = \frac{d}{t}$$

Uniform Circular Motion

Equations:

$$V_t = \frac{d}{t} = \frac{2\pi r}{}$$



Uniform Circular Motion

Equations:

$$V_t = \frac{2\pi r}{T} = 2\pi r f$$

$$\omega = \frac{2\pi}{T} = 2\pi f$$

$$T = \frac{1}{f}$$

$$V_t = \omega r$$

$$a_c = \frac{V_t^{2}}{r}$$

Example 1:

A 1000 kg car takes 4 seconds to turn from north to west around a corner. If the radius of curvature of the road is 30 m, what force of friction do the car's wheels apply?

$$\Sigma F_c = m\frac{V_t^{\,2}}{r}$$

$$= 1000\text{ kg}\frac{V_t^{\,2}}{30\text{m}}$$

$$\Sigma F_c = F_f = ?$$

$$r = 30\text{m}$$

$$m = 1000\text{ kg}$$

$$T = 16\text{s}$$

$$V_t = 11.8\text{ m/s}$$

$$\Sigma F_c = 1000\text{ kg}\frac{(11.8\text{ m/s})^2}{30\text{m}} = 4641\text{ N} = F_f$$

Example 2:

The distance from the Earth to the sun is 149.6 million km.
How fast is the Earth moving around its orbit?
What is the Earth's acceleration toward the sun?

$$V_t = \frac{2\pi r}{T} = 2.98 \times 10^5 \text{ m/s}$$

$$r = 1.496 \times 10^{11} \text{ m}$$

$$T = 365 \text{ days} = 3.15 \times 10^7 \text{ s}$$

$$a_c = \frac{{V_t}^2}{r}$$

$$= 5.9 \times 10^{-3} \text{ m/s}^2$$