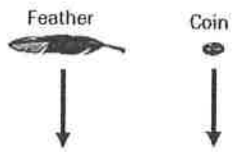
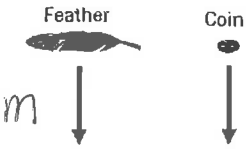
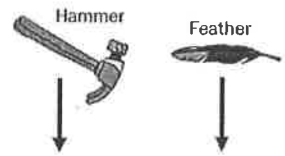
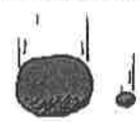
Free-Fall and Gravity

Describe the motion of a falling object. objects get faster as they fall they accelerate

Video 1	Video 2	Video 3
Observations:  w/air resistance coin wins	Observations:  in vacuum both hit ground at same time	Observations:  on the surface of moon (neglible air resistance) both reach surface at same time

<u>The Law of Falling Bodies:</u> Neglecting air resistance, ALL bodies fall with the same constant acceleration.



Freely falling: neglect air resistance

Compare the following locations.

	Air Resistance	$\vec{a}$ due to Gravity
Earth	yes	$-9.81\frac{m}{s^2}$ or $-9.8\frac{m}{s^2}$
Moon	no	$-1.61\frac{m}{s^2}$ or $-1.6\frac{m}{s^2}$
Deep Space	no	Ø

Acceleration due to Gravity

1. symbol "g" replaces "a"
2. approximation $10\frac{m}{s^2}$ for Earth
3. varies for each planet due to mass (or each body)
4. varies by location on Earth due to distribution of mass

Selected Values of "g"

Eugene	g = $9.8\frac{m}{s^2}$
Equator	g = $9.75\frac{m}{s^2}$
North Pole	g = $9.83\frac{m}{s^2}$
Moon	g = $1.6\frac{m}{s^2}$
Mars	g = $3.7\frac{m}{s^2}$

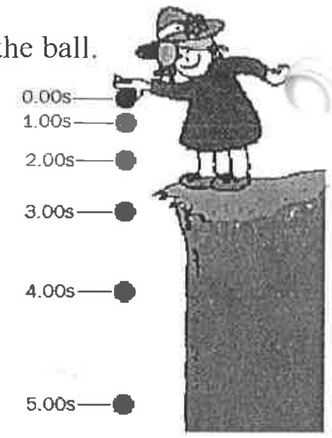
Complete the chart for the displacement, instantaneous velocity and acceleration of the ball.

time (s)	d (m)	v (m/s)	a (m/s²)
0	0	∅ m/s	-10
1	-5	-10	-10
2	-20	-20	-10
3	-45	-30	-10
4	-80	-40	-10
5	-125	-50	-10

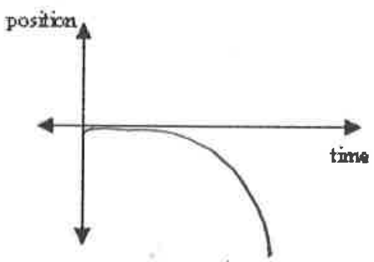
$\vec{d} = v_i t + \frac{1}{2}at^2$ (v_i = ∅ m/s)

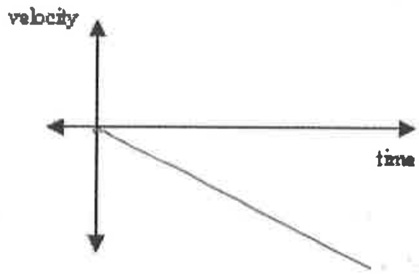
$V_f = V_i + at$ (V_i = ∅ m/s)

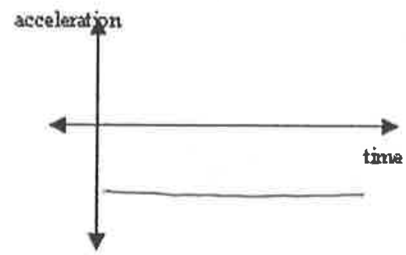
(+) ↕ (−)



Sketch the position, velocity and acceleration graphs for the falling ball. How would these change if distance and speed were graphed instead?







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1. A ball is dropped down a shaft and hits the bottom in 3.2 seconds. Determine:

   a) the depth of the shaft

   $\vec{a} = 9.8 \frac{m}{s^2}$

   $t = 3.2s$ $\vec{V_i} = \emptyset \frac{m}{s}$

   $\vec{d} = \frac{1}{2}\vec{a}t^2$

   $\vec{d} = {}^-50.m$

   or $d = 50.m$

   b) how fast the ball is going when it hits the bottom

   $\vec{V_f} = \vec{V_i} + \vec{a}t$

   $\vec{V_f} = \cancel{V_i} + \vec{a}t$

   $V_f = -31 \frac{m}{s}$

2. A stunt man jumps off the Brooklyn Bridge which is 40. meters high. Determine:

   a) the time it takes to hit the water

   $\vec{d} = \frac{1}{2}\vec{a}t^2$ $d = -40. m$ $\vec{a} = -9.8 \frac{m}{s^2}$

   $t = 2.9s$

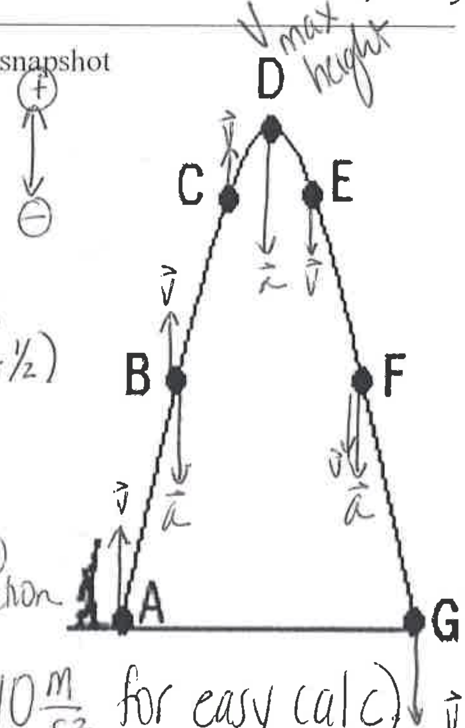
   b) his impact velocity V_f

   $V_f^2 = \cancel{V_i^2} + 2ad$

   $V_f = -28 \frac{m}{s}$

Throwing Up

A ball is thrown up into the air, as shown in the time-elapsed diagram. Each snapshot represents the position of the ball after one additional second of flight.



a) How long is it in the air? 6s

b) How long did it take to get to the top of its path? 3s

c) How fast was it going when it left the ground? $V_f^{\emptyset m/s} = V_i + at$ (max height) t (at ½)

speed d) Describe how its speed changes during the flight.

$30 \Rightarrow 0 \Rightarrow 30\frac{m}{s}$ $\frac{m}{s}$ $\qquad \emptyset = V_i + (-10\frac{m}{s^2})(3s) = 30\frac{m}{s}$

e) Describe how its velocity changes during the flight.

on the way up, velocity is decreasing in ⊕ direction
on the way down, velocity is increasing in ⊖ direction (use $-10\frac{m}{s^2}$ for easy calc)

f) Describe how its acceleration changes during the flight.

uniform acceleration

$\vec{d} = V_i t + \frac{1}{2}at^2$ or $V_f = V_i + at$

g) Sketch vectors on the diagram to indicate the velocity and acceleration of the ball at each instant.

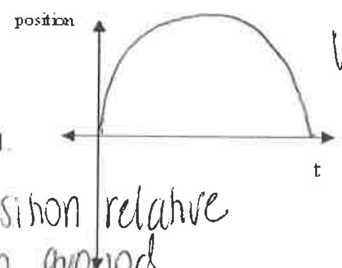
h) Complete the chart at right for the ball.

i) Sketch the graphs below for the ball.

example "B" $\vec{d} = (30\frac{m}{s})(1s) + \frac{1}{2}(-10\frac{m}{s^2})(1s)^2$ (t=1 second) $= 25m$

	Position (m)	Velocity (m/s)	Acceleration (m/s²)
A	0	30m/s	-10
B	25	20	
C	40	10	
D	45	0 m/s	
E	40	-10 m/s	
F	25	-20m/s	
G	0	$-30\frac{m}{s}$	

1\.



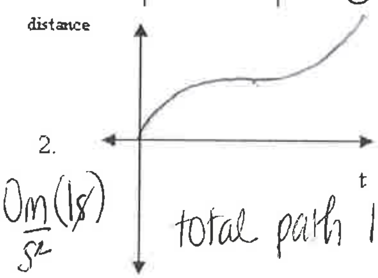
position relative to ground

$V_f = V_i + at$

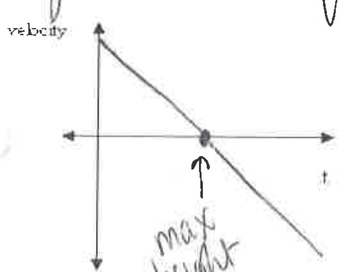
$V_f = 30\frac{m}{s} + -10\frac{m}{s^2}(1s)$

$V_f = 20\frac{m}{s}$

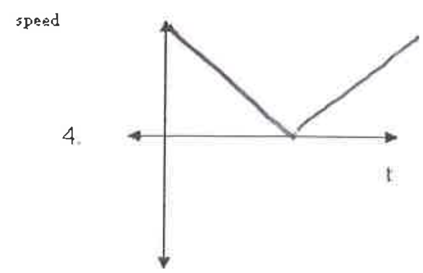
2\.



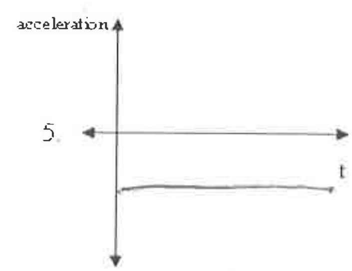
total path length



4\.



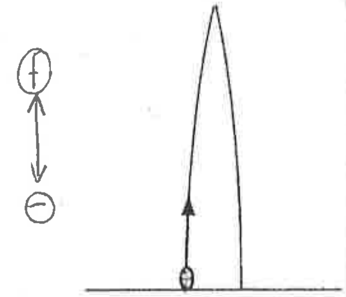
5\.



1. A football is punted straight up and remains airborne for 2.6 seconds. Determine:

a) the time it takes to get to the top of its flight $t = 2.6\,s$

t_{top} or $\frac{1}{2}$ total time $\boxed{1.3\,s}$



b) vertical launching velocity

$V_{f_{top}} = V_i + at$

$\emptyset \frac{m}{s} = V_i + (-9.8\frac{m}{s})(1.3s)$ $\boxed{V_i = 13\frac{m}{s}}$

c) highest point reached

$\vec{d} = V_i t + \frac{1}{2}at^2 = \boxed{8.3m}$ (if did not round V_i)

or $8.6\,m$ (if rounded V_i)

$13\frac{m}{s}$ $t = 1.3s$ $t = 1.3s$

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2. A ball is thrown straight up in the air with an initial velocity of 15 m/s. Determine:

a) the time it takes to get to the top of its flight $V_i = 15\frac{m}{s}$ $\vec{a} = -9.8\frac{m}{s^2}$ $V_{f_{top}} = \emptyset\frac{m}{s}$

$\vec{V}_f = \vec{V}_i + \vec{a}t$ $\frac{-\vec{V}_i}{\vec{a}} = t = \frac{-15\frac{m}{s}}{-9.8\frac{m}{s^2}} = \boxed{1.5\,s}$ (rounded)

b) highest point reached

$\vec{d}_{top} = V_i t + \frac{1}{2}at^2 = 15\frac{m}{s}(1.5s) + \frac{1}{2}(-9.8\frac{m}{s^2})(1.5s)^2$

$t = 1.5s$ $\boxed{\vec{d} = 11m}$

c) impact velocity

$V_f = V_i + at$

$V_f = 15\frac{m}{s} + (-9.8\frac{m}{s})(3.06s) = \boxed{-15\frac{m}{s}}$

(*) use $t = 3.06$ (unrounded)