1-42

Dot or Scalar Product

— Not in text explicitly.

— But I realized in teaching this course, that the text (Cutnell & Johnson) have to work around not using it explicitly — over and over.

How many have seen it? Show of hands.

For our purposes, it is mostly just a notational convenience.

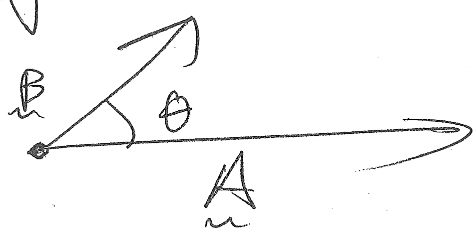
Dot or Scalar Product

— there are ways of multiplying vectors, but they have to be defined.

→ there is no direct, obvious intuitive generalization ~~[illegible]~~ from multiplying scalars.

Say $\underset{\sim}{A}$ and $\underset{\sim}{B}$ are general vectors.

There dot product is



$$\underset{\sim}{A} \bullet \underset{\sim}{B} = AB\cos\theta$$

dot is always explicit (hence name dot product)

magnitudes of $\underset{\sim}{A}$ & $\underset{\sim}{B}$

a scalar value (hence name scalar product)

θ is the angle between them.

Obvious consequences

a) $\underset{\sim}{A} \cdot \underset{\sim}{B} = AB\cos\theta$
$= BA\cos\theta = \underset{\sim}{B} \cdot \underset{\sim}{A}$

the dot product is commutative.

$\boxed{1-45}$

b) If $\underset{\sim}{A}$ and $\underset{\sim}{B}$ are aligned

$$\underset{\sim}{A} \cdot \underset{\sim}{B} = AB\cos(0°)$$
$$= AB$$

c) If $\underset{\sim}{A}$ & $\underset{\sim}{B}$ are antialigned

$$\underset{\sim}{A} \cdot \underset{\sim}{B} = AB\cos(180°)$$
$$= -AB$$

d) If $\underset{\sim}{A}$ & $\underset{\sim}{B}$ are perpendicular

$$\underset{\sim}{A} \cdot \underset{\sim}{B} = AB\cos(90°)$$
$$= 0$$

e) Components

$$\underset{\sim}{A} \cdot \underset{\sim}{B} = (A_x\hat{x} + A_y\hat{y} + A_z\hat{z}) \cdot (B_x\hat{x} + B_y\hat{y} + B_z\hat{z})$$

$$= A_x B_x + A_y B_y + A_z B_z$$

using (d)

- We'll make use of the dot product a fair bit, but nearly always just simplify ~~the text~~ formulae — I can't figure out why CJ hold back on this!

Chapter 2

Kinematics

Before ~~starting~~ out. I'd like to emphasize. This course is cumulative. Everything you learn before you have to know for what comes after.

2.1 — CJ are a bit longwinded I think in this chapter and students might look over p. 51 which is the summary page first. before reading the narratives. (Maybe always a good idea with CJ.)

Kinematics & Dynamics

Kinematics is just the description of motion.

- displacement (position)
- velocity, acceleration

all are vectors

Dynamics is kinematics plus forces which are causes of acceleration — and body deformations.

We take up dynamics in Ch. 4.

Scalars and Vectors of Kinematics

Recall a vector is identified by ~~bolld~~ boldface $\mathbf{A}$

$\vec{A}$

or $\underset{\sim}{A}$ on the board.

I kinematics we need vectors displacement, velocity, acceleration

~~vector magnitude~~

~~displa $\underset{\sim}{X}$ X~~

Vector	common symbol	Scalar Magnitude of the Vector
displacement	$\underset{\sim}{x}$	x distance
velocity	$\underset{\sim}{v}$	v speed
acceleration	$\underset{\sim}{a}$	a acceleration (no different name for the scalar version)

Everyone is a bit sloppy and says veloci when they mean speed.

We often need to express changes in these quantities.

Greek delta Δ is the physics symbol for change in

e.g., $\underset{\sim}{r}_1$ and $\underset{\sim}{r}_2$

$$\Delta \underset{\sim}{r} = \underset{\sim}{r}_2 - \underset{\sim}{r}_1$$

$\underset{\sim}{v}_1$ and $\underset{\sim}{v}_2$

$$\Delta \underset{\sim}{v} = \underset{\sim}{v}_2 - \underset{\sim}{v}_1$$

2.2 Velocity

is of course the change in displacement with time.

Say $\underset{\sim}{r}$ changed by $\Delta \underset{\sim}{r}$ in Δt

$$\underset{\sim}{v}_{avg} = \frac{\Delta \underset{\sim}{r}}{\Delta t}$$

the average velocity over time Δt.

Now imagine taking
Δt smaller & smaller
and reaching a limiting
~~b~~value of $\dfrac{\Delta \underset{\sim}{r}}{\Delta t}$

This value is the <u>instaneous velocity</u> which just
call <u>velocity</u> for brevity

$$\underset{\sim}{v} = \lim_{\Delta t \to 0} \frac{\Delta \underset{\sim}{r}}{\Delta t}$$

both $\Delta \underset{\sim}{r}$ & Δt shrink to nothing but there is a finite ratio.

at this point we are ~~one~~ on the threshold ~~the doorstep~~ (~~thre~~ threshold / doorstep) of calculus, but we won't step in → for this class ~~that~~ is the forbidden zone.

<u>Ex.</u> From here to Coeur d'Alene is ~90mi and you travel there in 1.5h.

$$\vec{v}_{avg} \cong \frac{90\,mi}{1.4\,h} \quad \text{in direction of Coeur d'Alene}$$

$$\cong 60\,\frac{mi}{h}$$

But along the way you did lots of speeding & slowing down both of which are accelerations and ~~lot~~ of zigzags changes in direction alone are accelerations in a physics sense — Acceleration is a vector

— your speedometer gives pretty much exactly your instantaneous speed on a human times scale and it changes when distance changes

— you could have dragged at 30 mi/h through small towns and speeded like a fiend in between. A point that will ... emphasized many times in this course

2.3 Acceleration

Acceleration is the change of velocity with time, and so is a vector

~~the~~

$$a_{avg} = \frac{\Delta v}{\Delta t}$$

$[a_{avg}] = \frac{m/s}{s} = m/s^2$ in MKS

is the average acceleration over time Δt.

The change of speed with time $a_{avg} = \frac{\Delta v}{\Delta t}$ is also called acceleration. A bit of overlap in the terminology. Context must decide.

The instantaneous acceleration is

$$\underset{\sim}{a} = \lim_{\Delta t \to 0} \frac{\Delta \underset{\sim}{v}}{\Delta t}$$

The ratio is finite even though numerator and denominator are zero.

and we usually just call this

the acceleration

Note acceleration can point opposite to ~~velovel~~ velocity for an object

~~Consuit~~

Ex $\underset{\sim}{v} > 0$
but $\Delta \underset{\sim}{v} < 0$
and $\underset{\sim}{a}_{avg} = \frac{\Delta \underset{\sim}{v}}{\Delta t} < 0$

and then we can call it a <u>deceleration</u> (CJ-33), but that term is just a sort of useful commentary not necessary to the description of motion.

One-dimensional Motion

In this case we can drop the vector signs for convience and simplicity.

$\underset{\sim}{x} \longrightarrow x$ for motion on the x-axis

$\underset{\sim}{v} \longrightarrow v$

$\underset{\sim}{a} \longrightarrow a$

But direction still counts ~~these~~ even though there are only 2 choices (2 senses (Ba-1102)), the +ve and -ve.

2.4 Constant Acceleration

This the main case of motion of this chapter.

There is one extremely important real case of this in everyday life.

— *free fall* near the Earth's surface when *air resistance* can be neglected.

But otherwise it is a bit of an idealization since in real motion accelerations are not often ~~very~~ very exactly constant.

- think ~~of~~ human or car motion.

— of course with negative electronic control you could

2-10

make a car, plane, ~~train~~ have a constant acceleration

just as with cruise control you can make a car have a nearly constant speed, but I don't see any ~~ever~~ great need for that.

But constant acceleration is ~~it is~~ analytically tractable.

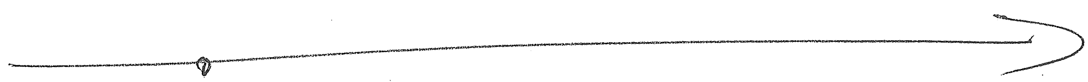
So it's a good case to learn how kinematics (and later dynamics) works and free-fall is always there as a real special case of importance

The 4 +1 = 5 kinematic equations { I'm going to give you a ~~?~~ th one for good behavior.

$\boxed{2-11}$

(for constant acceleration)
in 1-dimension.

Given a is a constant
— could be +ve to -ve



x

1) $v = at + v_0$

velocity at any time

time since time zero

initial velocity

spoken v — nought

a somewhat old-fashioned word for zero used in this context as the time zero quantities.

tant able on side Board or somewhere good.

This one is clearly since a is constant
$\Delta v = a \Delta t$.

2) $x = \frac{1}{2}at^2 + v_0 t + x_0$

displacement ~~position~~ at $t=0$.

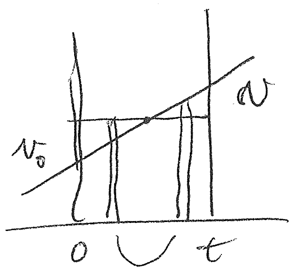
$\Delta x = \frac{1}{2}at^2 + v_0 t$

~~we assume here that at t = 0 x = 0 you could add an x~~

Usually possible to effectively choose $x_0 = 0$.

In many, but not all problems you can choose $x_0 = 0$

i.e., ~~set the obje~~ choose the ~~origin object~~ origin to be the object's position at time zero.



pairwise avg
Δt pair has
$v_{me} = \frac{1}{2}(v_0+v)$

$\therefore v_{avg} = \frac{1}{2}(v_0+v)$
overall.

Thus
$\Delta x = \frac{1}{2}(v_0+v)t$

~~but~~
$v = (at+v_0)$

$\Delta x = \frac{1}{2}at^2 + v_0 t$

CJ-34 offer a sort of derivation of eq (2)

but I don't think it is ~~so~~ rigorous — but it can make it so.

~~The truth is that~~ (2) can be only derived by calculus from (1) ~~or by some method~~ w although one could disguise that and not breath a word about calculus.

— not very hard but beyond our scope.

Equations (1) and (2) are independent

→ you <u>cannot</u> obtain one from the other by algebra. (you can by calculus as I just said)

derive one from ~~connect them~~ the ~~other~~ other

<u>Questions</u>

— With 2 independent equations how many <u>unknowns</u> can you solve for?

. . . .

wait, wait . . . . .

2 only

If you ~~they~~ have more unknowns, you can't solve.

How <u>many variables</u> in the 2 equations?

6 only.

or 5 if one just uses $\Delta N = N - N_c$

v, a, t, v_0, x, x_0

2-14

So in any problem given 4 ~~un~~knowns you can solve 2 unknowns ~~(with a minor qualification~~

All 1-d-kinematic-equation problems are like that.

- all the words accelerating tortoises, falling steamships, hopping kaangeroos are just ~~camflage~~ ~~camuflage~~

a very hard word to spell.

camouflage

camofl

camofl.

camou fla

- identify the 4 knowns solve for the 2 unknowns.
- all 1-d kinematic equations are like that.

There is a little help

There are 2^{+1} other kinematic equations that one obtains by algebra from ① & ②

They are **NOT** independent equations — they are derived algebraically from the first

& so you can still only solve for 2 unknowns

but they make finding those 2 unknowns a cinch.

A) eliminate a algebraically from equ ② using equ ①

$$v = at + v_0$$

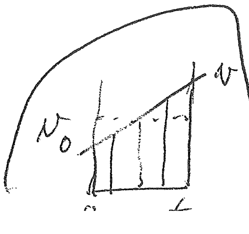
$$a = \frac{v - v_0}{t}$$

$$x = \frac{1}{2}\left(\frac{v - v_0}{t}\right)t^2 + v_0 t + x_0$$

$$③ \quad x = \underbrace{\tfrac{1}{2}(v_0 + v)}_{\text{this is the average velocity from time zero to } t} t + x_0$$

~~You can call this the~~

no a in it



this is the average velocity from time zero to t

I think this diagram amounts to calculus

3) eliminate t for a timeless equation

eliminate t from eqn ② using eqn ①

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

$$x = \frac{1}{2} a \left(\frac{v - v_0}{a}\right)^2 + v_0\left(\frac{v - v_0}{a}\right) + x_0$$

$$= \frac{1}{2}\frac{1}{a}\left(v^2 + v_0^2 - 2 v v_0\right) + \frac{1}{a}\left(v v_0 - v_0^2\right) + x_0$$

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

$$v^2 = v_0^2 + 2a(x - x_0)$$

No law forbids having a 5th one to complete the set.

5) $x = \frac{1}{2}at^2 + (v - at)t + x_0 = vt - \frac{1}{2}at^2 + x_0$

eliminate v_0 from ② using ①

Put Table off to the side for reference

	Summarize	Absent variable
1	$v = at + v_0$	$\Delta x, x, x_0$
2	$x = \frac{1}{2}at^2 + v_0 t + x_0$	v
~~4~~	$x = \frac{1}{2}(v_0 + v)t + x_0$	a
~~4~~ 3	$v^2 = v_0^2 + 2a(x - x_0)$	t
5	$x = vt - \frac{1}{2}at^2 + x_0$	v_0

x, x_0 are a special case. The other 4 variables can only ever give $x - x_0$ because of translation symmetry. There's no equation with x, but no x_0 and vice versa.

Really use Δx

Not in text but it completes the set logically

6 variables 2 unknowns.

One unknown is the subject of the question usually — most wanted

The other is unwanted.

So solve for the $\boxed{2-17}$

<u>most wanted</u> unknown

from the equation ~~that~~

without ~~without~~ the (unwanted / least) unknown

So one equation in one unknown.

2.5 Applications

x, x_0 have special role :: both are unknown you can't solve for them separately only for $x - x_0$ from any eqn. 2-5

Ex 8 accelerating spacecraft

spacecraft at $v = 3250$ m/s

at time zero $t = 0$

Then decelerates with an acceleration of magnitude $10\ m/s^2$ due to retrorocket

What is the acceleration itself?

$-10\ m/s^2$

What is v when $x = \cancel{x_0}$ 215 km

relative to initial position?

Let's cut out the ~~camou~~flage camou

camoflage camofladge camelflatdge

— the hopping kangeroos etc.

and reduce the problem
~~to~~ it's abstract essence.

2-18

$x_0 = 0$ we can make this choice when acceleration starts.

$x = 215$ km given since we are only interested in the distance from here

$= 215 \times 10^3$ m to make the units consistent MKS

4 variable ~~things~~ I know

$a = -10$ m/s²

$v_0 = 3250$ m/s

only 2 unknowns

unwanted (least wanted) t at then $x = 215$ km

most wanted v

What equation do we want?

Number ~~3~~ the timeless equation.

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$\simeq 10 \times 10^6 + (-20)\cdot(2 \times 10^5)$$

$$= 10^7 - 4 \times 10^6 = 6 \times 10^6 \ m/s$$

$v \cong \pm\, 2.5 \times 10^3 \, m/s$

There are two solutions.

Question: What does this mean?

— wait, wait

— think the rocket's slowing

firing its retros

— eventually it must come to a stop.

— then what?

— it reverses with negative velocity.

speeding up in the negative.

eventually it gets back to $x = 215 \times 10^3$ km going in reverse.

— It really will be at $x = 215 \times 10^3$ km twice, and so there really are two v solutions

Of course, the rocket ~~???~~ pilot may change the retros, but the equations know nothing about that.

They are a limited model of ~~???~~ reality. They only know what we tell them but they [illegible] for eternity

What if "a" were not given?

So 3 unknowns a, v, t and you still wanted v.

Well look at equations 1 & 2

<u>3 unknowns in 2</u> ~~variables~~ independent equations

~~not~~ solution is possible.

eqs. 3 - 4 won't help because they were created algebraically from 1 & 2 and are not independent and impose no other constraints.

2.6 Free Fall near Earth's surface

This is the one real case of <u>constant acceleration</u> if you can neglect air resistance.

— which for short falls of dense objects you can.

Near the Earth's surface — neglecting air resistance ~~the~~ (magnitude of) acceleration due to gravity on all bodies no matter what their mass is

This is a fiducial value

Earth ave 9.80665

equator 9.78033

pole 9.832

- local variation
- decreases with altitude

(Wik: Earth's gravity)

$$g = 9.8 \, m/s^2 \simeq 10 \, m/s^2$$

Question: ~~down~~ which direction does the acceleration point?

Downward to the Earth's center.

This means in freefall

in 1 s	$v = 9.8$ m/s
in 2 s	$v = 19.6$ m/s
in 3 s	$v = 29.4$ m/s

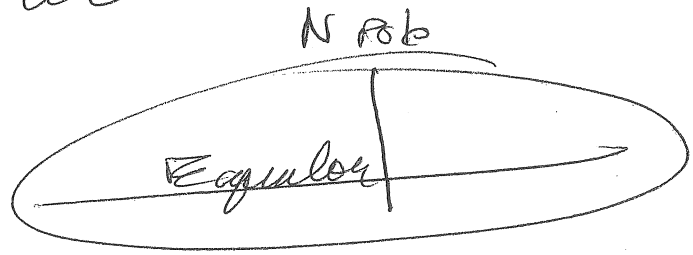
and so on.

Now the qualification — the inevitable qualifications.

g decreases a bit with altitude — it actually depends on the distance to the Earth's center, but the Earth is really very spherical so small variations like mountains make tiny differences.

— the Earth is a bit oblate

very exaggerate →



$g_{eq} = 9.78033\ m/s^2$ → farther from Earth center gravity weaker

$g_{pole} = 9.832\ m/s^2$ → closer to Earth center, gravity stronger

— also local variations due to local geology.

↳ tiny but measurable and ~~geologists~~ geologists use them to study local geological formation.

— gravity depends on mass as we'll see later and all mass attracts all other mass.

But the Earth is our biggest mass and the only one we notice attraction to.

I prefer to use

$$g = 9.8\ \mathrm{m/s^2}$$ as

a fiducial or reference value.

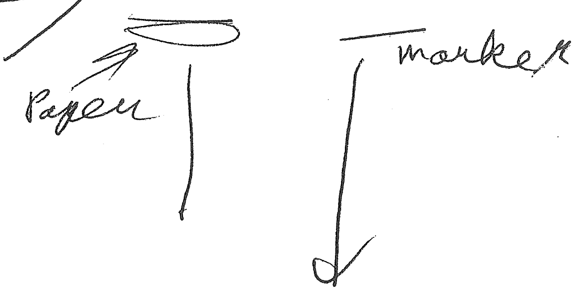
Remember Galileo

Leaning Tower of Pisa
– I was there in 1990, but at that time climbs were not allowed.

– dropping the balls.
– it is a myth that this story is a myth.
– his earliest biographer <u>Viviani</u> – a personal friend – told us he did it, and so we must believe it.

But it was probably no big deal
⇒ a demonstration for the students – not a controlled experiment

Demo in evacuated chamber
<u>Yanko</u>



Yes. You saw right
– they hit the ground at the same time.
– well OK "not", same time "not

But if there was no air resistance they would to within the accuracy of my ability to let go at the same time.

Omit ~~Air resistance~~ $\cancel{\propto v^2 A}$

See HRW-104

$$F = C v^2 A \rho_{air}$$

$$m a = F_g - C v^2 A \rho_{air}$$

$$a = g - C \frac{v^2 A \rho_{air}}{m}$$

$$= g - C \frac{v^2 \rho_{air}}{\frac{m}{V} L}$$

ρ

The air resistance effect on acceleration decreases with density approximately

$$\sim \frac{1}{\rho}.$$ ~~So slow~~

and so ~~high~~ density objects are less affected.

it increases with cross-section area ~~relative~~ ~~to the~~ perpendicular to direction of motion which

We'll discuss air resistance in a bit after we grind thru some examples.

Coordinate Choice

We are just concerned here with 1-d motion and so our kinematic equations apply.

But it is best to ~~use~~ use y for the position coordinate since that is the usual vertical coordinate and all motion is up-down.

Now which way should you make positive?

~~It depends.~~

You can choose either way up or down.

and everything works out the same.

But there are matters of convenience.

<u>My view</u> is if the problem is all downward. Just falling not rising, make down positive y.

But if there is rising and falling make up positive to accord with our normal sense of things.

<u>Ex 1</u>. Drop from rest a stone from a high building. What is it's velocity and displacement after 3 s. Neglect air resistance

Well this is an all-down problem.

— so I make down positive.

2-27

$a = g$

first 2 equations of kinematics

$v = gt + v_0$ ← 0 since from rest

$y = \frac{1}{2}gt^2 + v_0 t + y_0$ ← since we can choose the drop height to the zero.

$v = gt$

$y = \frac{1}{2}gt^2$

In this case vast experience tells me I only need the first two equations.
— you will soon have vast experience too.

$t = 3s$

$g = 9.8 \, m/s^2$

$v = 29.4 \, m/s$

$y = \frac{1}{2} \cdot 9.8 \cdot 9$

$= 4.9 \cdot 9$

$= 44.1 \, m$ which is also the distance a person will fall in 3 seconds.

Adam Scott, "Some call it

Ex2 ~~Toss~~ a coin up in the air with initial ~~velocity~~ velocity $5.00 \, m/s$.

(Take a coin out of my pocket and toss it, "I practiced this." "Sorry You look

This is an up-down problem, and so

I set up as positive y | 2-28

$$a = -g$$

need an explicit minus since by convention $g = 9.8\ m/s^2$ is only the magnitude of the acceleration due to gravity.

Omit

$$v = at + v_0$$

$$y = -\tfrac{1}{2}gt^2 + v_0 t + y_0 = 0$$

we set the initial height to zero.

How high does the coin go?

What are our knowns

$v_0 = 5\ m/s$

$y_0 = 0$

$a = -g$

$v = ?$

$t = ?$

$y = ?$

at the highest point.

$(\text{or } \Delta y = ?)$

2-29

Well we have 3 unknowns.

Seems we can't do the problem. ~~but we~~

Question: But we can? Why can we?

— Wait a long time.

— Think what happens at the top of a trajectory?

Yes $v = 0$ for an instant.

That gives us our 4th known and the problem is solvable.

~~We don't know~~ Our unknowns y, t.

at the moment we don't want t.

y is our "most wanted".

$\therefore$ we can use the timeless equation.

$$v^2 = v_0^2 + 2a(y - y_0)$$

to solve for y.

$$y = y_0 + \left(\frac{v^2 - v_0^2}{2a}\right)$$

$$= 0 + \left(\frac{0 - 5^2}{-2 \cdot 9.8}\right)$$

$$\simeq \frac{25}{20} = 1.25\,m \,!!$$

~~(Sensation!)~~ ~~really~~ ~~sensa~~ (Ans 1.28m

(My notes at this point say Sensation in the audience.)

Ex 3 Same story.

But now how long is the coin in the air before returning to release point.

$v_0 = 5$ m/s

$y_0 = 0$

$a = -g$

$v = ?$

$t = ?$

$y = ?$

3 unknowns again.

But we can solve.

Why? Wait interim,

$y = 0$

Now what equation should we use

t is <u>most wanted</u>

v ~~is~~ unwanted.

$$y = \frac{1}{2}at^2 + v_0 t + y_0$$

contains no v.

~~This is a quadr~~

What kind of equation is this <u>for t</u>? {algebraic terminology.

(My notes tell me, I'm to wait until you give.)

<u>Quadratic equation</u>.

$$0 = \underbrace{\tfrac{1}{2}a}_{-4.9}t^2 + \underbrace{v_0}_{5}t + \underbrace{y_0 - y}_{0}$$

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 4(\tfrac{1}{2}a)(y_0 - y)}}{2(\tfrac{1}{2}a)}$$

$$t = \frac{-5 \pm \sqrt{5^2}}{-9.8}$$

$$\simeq \frac{+5 \mp 5}{10}$$

$$= 0 \text{ or } 1 \text{ s}$$

Why do we have two solutions?
Well a quadratic equation always has two solutions.
(~~except the~~ except when the discriminant is zero, or they are complex, but then they are still two.)

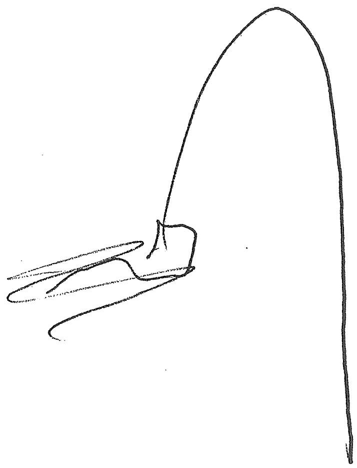
<u>But</u> what in the physics dictates two solutions?
Well we only asked the question when will coin be at the initial height and clearly it was there twice — once at the start and once later on.

$\boxed{2-33}$

But here's another puzzle.

Say I change the question and ask when is the coin at $y = -1$ m

(assuming the tosser fumbled the reception which I ~~always~~ usually do — but only on purpose.)



Same set up

$$0 = \frac{1}{2}at^2 + v_0 t + \underbrace{y_0 - y}_{\substack{0-(-1)\\ =1}}$$

$$t = \frac{-v_0 \pm \sqrt{v_0^2 - 4(\frac{1}{2}a)(y_0 - y)}}{2(\frac{1}{2}a)}$$

$$\simeq \frac{-5 \pm \sqrt{25 + 2\cdot 10\cdot 1}}{-10}$$

$$= \frac{+5 \pm \sqrt{45}}{10}$$

$$\simeq \frac{+5 \pm 6.5}{10} = \cancel{0 \text{ and}}\ -.15 + 1.15$$

The coin according
to the math was
at $y = -1$ at $t = .19s$

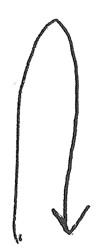
but in reality the coin
was never there.
You saw me take it
out of my pocket
~~pocket~~ and toss it.

The kinematic equations
extend forward and
backward to infinity
in time. ~~and back~~ ~~a~~ As far as ~~they~~
~~They only have limited~~
~~amoun~~ know the conditions
they describe are eternal.
The coin rose up from negative
infinity from infinitely long ago, reached
a maximum height,

and like Satan in "Paradise Lost" fell never to hope again.

Ex 4 You shoot a gun straight up into the air —— which as ~~I complet your~~ your instructor of physics, I forbid you ever to do.

But we are speaking ~~hyp~~ hypothetically here.



$v_{initial} = 1000 \, m/s$ which may be typical of powerful hunting rifles.

v_{final} when it returns to the ground ? when air resistance negligible

$v_f = v_i$

Remember the timeless equation | 2-36

$$v^2 = v_0^2 + 2a(y - y_0)$$

$y = y_0$ for return

$$v = \pm 1000 \text{ m/s}$$

+ is the initial case
− is the return

taking up as positive.

So it's not a good thing to ~~s~~hoot straight up.

~~Up~~ This analysis flawed because air resistance will be present.

← reaches a peak and then falls much lower than without air resistance

~~be~~ air resistance will ~~eventually stop downward acceleration and the slow the~~ decrease the acceleration downward.

I've not been able to find any precise information ~~on the~~ from an authoritative source on this issue.

But bullet terminal velocity is ~~probably~~ of order 100 m/s but I suspect it doesn't reach that coming down.

— still ~~it could be~~ seems likely to be tens of meters per second.

much less than most muzzle velocities, but ~~probably~~ still deadly.

Air Resistance

— the text doesn't have anything on it.

— But I thought as a real world physical thing, I thought I could add a word here.

Air resistance is a
force ~~which we haven't~~
and we haven't talked about
them yet, but you know
pushes and pulls.

Air resistance only turns on
when you move through
a medium
— and it always is opposite
the direction of motion.
— ~~never helps, always hurts~~
— always tends to decelerate.
it's actually a rather complex
force in general
— but it increases with
cross-sectional area
⊥'l to direction
of motion
and increases with
speed.

~~G~~ Gravity is a constant force near the Earth's.

~~Air~~

So when an object starts to gravity alone acts to ~~dece~~ accelerate downward.

— But as the object increases in speed, air resistance grows and eventually balances gravity and acceleration stops and the object reaches terminal velocity.

Object	Terminal Velo (m/s)	95% distance to terminal velo (m)
shot put shot	145	2500
human	60	430
raindrop	7	6
Parachutist	5	3
spread cat	~20 ~~m~~	7 or 8 storey ~ ~~70 or 80m~~ 30-40m

all ~~approx~~ typical — not exactly repeatable numbers.

— So you see it's not so bad to skydive without a parachute.

you don't accelerate forever, just to a cozy 60 m/s $\simeq$ 200 km/hr.

people have survived skydives with failed parachutes.

aim at a haystack or large snow drift.

— raindrops 7 m/s — nothing bar something so soft.

but just imagine ~~the~~ if there were no air resistance. — rain would be deadly.

— spread cats — if they fall from high enough, they twist themselves around and spread ~~out~~ to give big air resistance and then ~~tuck in th~~ reach down ~~out~~ in time with their feet for a "safe" landing.

7 or 8 storeys

— Now I don't recommend you try this with your cat.

It doesn't always work and even if it did your cat would probably be scared out of its wits and hate you forever. — and the whole Vick-thing

(Vic cat story)

two cats — one was cool, the other was — "you left me, I hate you" ready ~~to~~ make nice.

Show stupid cat video