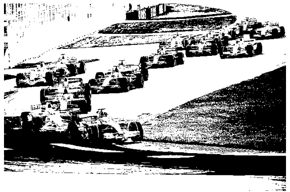
Kinematics: How things move



Peter Watson

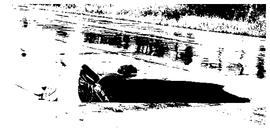
Transport

- What governs how efficient our cars can be?
- Are hybrid or plug-in cars the answer?
- Does public transport (buses and trains) use energy more efficiently?
- Can we reduce the pollution due to transport?
- Why is it so much easier (cheaper) to travel horizontally than vertically?

Chaps 2,3,4,7, weeks 1-2

Before we start ....

- If you go to Orleans



If a sink-hole opens up in front of you, should you

1. Accelerate so as to leap over the hole?
2. Stay at the same speed?
3. Brake as hard as possible so that you fall into it slowly?
4. Pray?

Description of Motion Kinematics

- We will work on a "need-to-know" basis. We want to understand the following
- Distance, Velocity and Acceleration
- Force
- Newton's Laws
- Gravitational Force
- Energy

Achilles and the tortoise

1. Achiles wants to catch a tortoise that is 100 m away.
2. He runs twice as fast. Can he catch it?

Does Achilles catch the tortoise?

We have an infinite series of moves

1. 100
2. 100 + 100/2 = 150
3. 100 + 100/2 + 100/4 = 175
4. 100 + 100/2 + 100/4 + 100/8 = 187.5
5. ....

∞. 100 + 100/2 + 100/4 + 100/8 +100/16 +.....= 2 00

- So we asked the wrong question: not how many moves does he take, but how far does he have to go.
- Infinite series can have a finite sum!

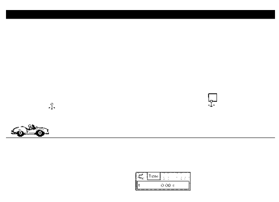
Average Speed

- is just distance/time
- $v = d/(t_1 - t_0)$
- e.g. if Achilles runs d=100m starting at 4.00.00 p.m. and ending at 4.00.20 p.m., then
- v=5 ms^{-1} (metres per second or m/s)

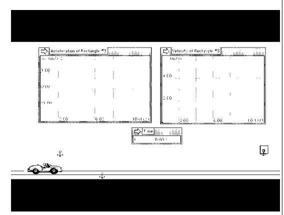
Note

- We measure distance in metres
- We measure time in seconds
- So we measure speed in metres/second
- Acceleration is the (change of speed) in a certain time.
- If w go from 5 ms^{-1} to 8 ms^{-1} in 6 seconds
- Acceleration $a = \frac{8-5}{6} = \frac{3ms^{-1}}{6s} = 0.5ms^{-2}$

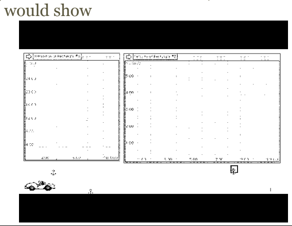
- e.g. A car travelling between traffic lights:
- Lights are 25 m apart
- car takes 10 s to travel between them, by accelerating to start with and then braking at the same rate.



- For first 5 seconds your foot is on the gas pedal (accelerator)
- For next 5 seconds your foot is on the brake pedal (decelerator!)
- Cars don't have accelerometers: if they did it would show
- +1m/s^2 for the first 5 s
- -1m/s^2 for the next 5 s

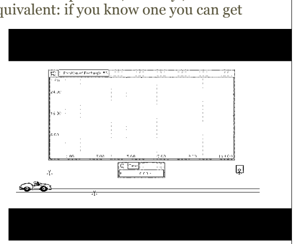


- Speed: For first 5 seconds speed increases uniformly
- For next 5 seconds speed decreases uniformly
- Cars do have a speedometer calibrated in km/hr: calibrated m/s it would show
- 0 m/s at t = 0 s
- 5 m/s at t = 5 s
- 0 m/s at t = 10 s



- Distance-Time plot
- Note that car starts slowly: position plot draws out a smooth curve
- Note that information about position, velocity , acceleration are equivalent: if you know one you can get the others.

Note in this case the average speed



Summary:

- If we have a constant acceleration a
- after t seconds our speed will be
- v=at
- our distance (from where we started) will be
- s=1/2at²
- in words,
- distance = 1/2 acceleration ×time ×time

Something useful:

How fast can a bus travel?

- On the open road, maybe 100 km/hr
- = 100/3.6 ~ 28 m/s
- Lets make a model:
- In town, max speed is 50 km/hr ~ 14 m/s
- stops are 200 m. apart, 40 seconds required to load passengers
- if acceleration is 0.5 m/s^2, what is average speed?

Mostly it's simpler to work in metres and seconds, not kilometres and hours

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- Will accelerate for 20 s, distance is 100m
- then decelerate for 20 s, distance is 100m
- total distance = 200 m √
- max speed is 10 m/s
- Average speed is (total distance)/(total time)
- = 200/70 ~ 2.9 m/s ~ 10 km/hr (!)

Why can't we accelerate at (say) 100 times the rate? Then we would get from one stop to the next in 1 s!

Text

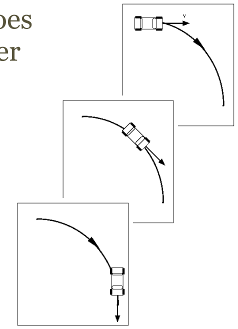
Note (sometimes important)

There is a difference between velocity and speed

- Velocity is speed with a direction: a vector
- If the car does this in 70 minutes its
- average speed = 60 km/hr
- average velocity =0!
- why?

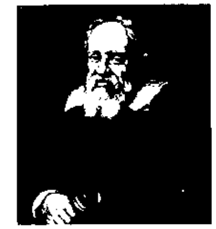
When a car goes round a corner

- its speed is constant
- its velocity changes



Gravity & Galileo

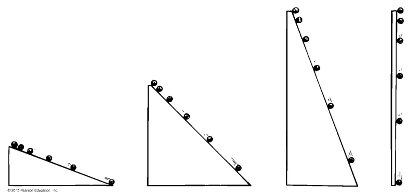
- Easiest accelerating system to understand



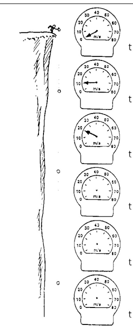
Gravitational acceleration

- To a good approximation, all objects falling near the Earth's surface have the same acceleration
- $a = -g$ where $g = 9.8\ ms^{-2}$
- How are grav. accn. and velocity connected?

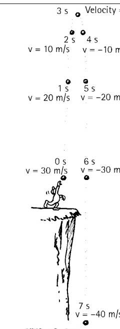
- This is hard to measure, but Galileo found a neat trick: make gravity weaker!



- A ball is dropped
- acceleration is downward.
- velocity increases uniformly



- A ball is thrown up in the air.
- During the first part of its motion (before it reaches its maximum height)
- velocity is upward, acceleration is downward.
- note the speed decreases to zero, then increases
- after
- velocity is downward, acceleration is downward.



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1. Trevor Oberhammer
2. If a penny were dropped from the top of the CN tower could it severely or fatally injure a person on the sidewalk below?
3. This is a good question because there are many different areas of physics to consider such as force, resistance, momentum and collisions. Could a small, flat and light object such as a penny really gain enough speed and momentum from that height to seriously harm someone? Or would it just really sting and possibly leave a bruise?
4. My estimate for the difficulty of this question would be a 4.

- height = 553 m
- How long does it take to hit the ground?
- How fast is it traveling when it hits?
- $h = 1/2\ g t^2$
- $v = gt$

Argument is wrong: in reality air-resistance would start being important. Will fix this later