Animation Foundations

17. Physics. Review and Exercises

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Today

0. Reminder physics basics
1. Parabolic movements (2D)
2. Parabolic movements (3D)
3. Drag and Friction
4. Inertia
5. Momentum and Torque

Reminder

Force Field

- What is a force field
- Examples (in 2D)
- Mathematical analysis

$$\vec{F} = q\vec{E}$$
$$\vec{F} = m\vec{g}$$

$$F = \frac{-G\, m_1 m_2}{r^2} \qquad \vec{F} = \frac{-G\, m_1 m_2}{r^2}\hat{r} \qquad \vec{g} = \frac{-G\, m_1}{r^2}\hat{r}$$

$$G = 6{,}673\ * 1010^{-11}(\vec{N} * m^2/kg^2)$$

Parabolic movements (2D)

Impulse shot

- What is an impulse shot?
- Examples? (in 2D)
- Mathematical analysis

Drag

- What is drag?
- Examples? (in 2D)
- Mathematical analysis
  - Friction
  - Dynamic Drag

Parabolic movements (2D)

Examples (in 2D):

1. vertical shot. How much time it stays in the air?

2. horizontal bullet. How far does it go?

3. diagonal shot. What is the maximal distance it can reach?

4. What is the right distance for a satellite or the moon to stay on orbit?

Parabolic movements (2D)

Some data (from the internet):

- Weight of a “typical” bullet: 10g
- Muzzle speed of a bullet on a “typical” gun: 300m/s2
- Strength of gravitation on surface: 9.81 m/s2
- Mass of the earth: 5.97e24
- Mass of the moon: 7.34e22

Typical friction levels (from Bourg et al.)

Surface condition	Ms	Mu	% diff.
Dry glass on glass	0.94	0.4	54%
Dry iron on iron	1.1	0.15	86%
Dry rubber on pavement	0.55	0.4	27%
Dry steel on steel	0.78	0.42	46%
Ice on ice	0.1	0.03	70%
Oiled steel on steel	0.1	0.08	20%

Parabolic movements (2D)

Exercise 1.

Kaitos’ planet is much smaller than the earth, but has a gravity 10 times greater than the earth.

Estimate the density of Kaito’s planet against the density of the earth

Ask for data, or estimate, as needed

Source: https://www.domestika.org/en/projects/131118-kaito-s-planet

Parabolic movements

Exercise 2.

What needs to be the Muzzle Velocity in order to shoot a bullet to go to outer space

- On earth
- On Kaitos' planet

(you can assume no drag)

Parabolic movements. Theory and Examples (3D)

Theoretical Assumptions:

- A rigid object and its
- Centre of mass
- Particle approximation

Examples (in 3D):

1. Diagonal shot with horizontal wind
2. Drop an object with diagonal wind

Check Also:

- Feynman et al. chapters 18 and 19
- Bourg et al. chapter 4 and 6

Parabolic movements Theory (3D)

Same Physical principles at play:

- Force field
- Impulse shot
- Drag

Important assumptions:

1. What is a rigid object?
2. What is the centre of mass?

$$\vec{x}_M = \frac{1}{M}\sum_i m_i \vec{x}_i$$

3. When is the particle approximation valid?

Reminder:

- Newton 1:

moving stuff stays moving

- Newton 2:

$$\vec{F} = m\,\vec{a}$$

$$\vec{a} = \frac{d^2\vec{x}}{dt^2} = \ddot{x}$$

Parabolic movements Theory (3D)

2 kinds of problems:

- Forces to Motion
  (in-game calculation)

- Motion to Force
  (wii or kinect controller)

Examples (in 3D):

1. Diagonal shot with horizontal wind

2. Drop an object with diagonal wind

Parabolic movements Theory (3D)

How to solve a dynamics problem:

0. Make a good analytic diagram

1. Find properties of mass (mass, centre of mass, moment of inertia)
2. Quantify forces (and moments)
3. Get sum of forces (and moments)
4. Solve eq. for linear (and angular) accelerations
5. Integrate to find linear (and angular) velocity
6. Integrate to find linear (and angular) motion

7. Write in code

Friction and drag Theory (2D + solid objects)

Physical principles at play:

- linear friction
  (box, no movement, slow mov.)
- linear drag
  (last week)
- quadratic effects
  (previous example)

Examples in 2D:

- slowing an object on a 2D ramp
- airplanes that fly

See also:

- section 12-2 Feynmann
- chapter 15 Bourg et al.

Friction and drag. Theory and Examples (2D + solid objects)

1.2.1 Physical principles at play:

Friction

- linear friction
  (box, no movement, slow mov.)
- linear drag
  (last week)
- quadratic effects
  (previous example)

Force field (gravity, etc.)

Initial conditions (velocity, etc.)

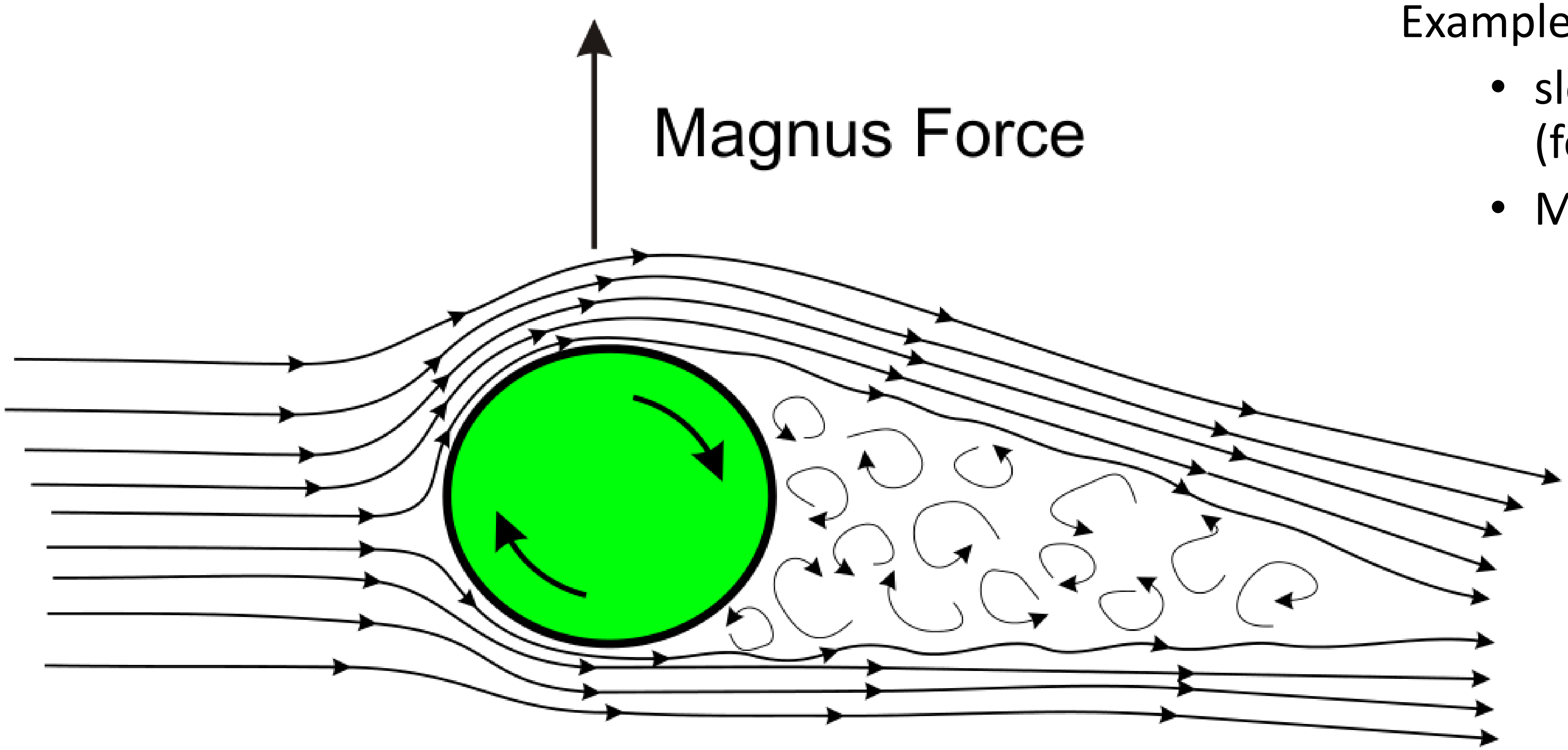
1.2.2 Examples of Friction in 2D:

- slowing an object on a 2D ramp
- airplanes that fly

See also:

- section 12-2 Feynmann
- chapter 15 Bourg et al.

Friction and drag
Examples (3D + solid objects)



Source: https://en.wikipedia.org/wiki/Magnus_effect

Examples of Friction in 3D:

- slowing an object on a 3D ramp (force decomposition)
- Magnus effect
  - See Bourg et al. Chapter 6

Inertia and Moment (of inertia) Theory

Physical principles at play

- What is inertia (Newton's first (galileo))
- What is momentum (Newton's third)
- Conservation of momentum
  (elastic collisions)
- Conservation of energy
  (non-elastic collisions)

$$\vec{p} = m\,\vec{v}$$

See also

- Section 10-1 Feynmann
- Section 10-2 Feynmann
- Section 10-4 Feynmann

Source: https://en.wikipedia.org/wiki/Magnus_effect

Inertia and Moment (of inertia).

Exercise (2D): Wonder-woman stops bullets on ice.

- Calculate at what speed she will move backwards
- Calculate how much distance she will go backwards
- Ask data as needed

Inertia and Moment (of inertia)

Exercise (2D)

Chinese jumping together send earth out of orbit

- Calculate the strength of the jump needed to deviate the angular velocity
- Ask data as needed

China's bizarre plot to knock Earth out of orbit

CHINA'S LATEST "great leap upward" threatens to knock Earth out of orbit when every one of its citizens jumps up and down September 27!

1.3 billion Chinese will jump up & down at the same time sending planet into spin Sept. 27!

By DAVE TAYLOR
Special correspondent

If everybody in China jumped up and down at the same time they would knock our Earth out of orbit, and that's exactly what the monsters are threatening to do just three months from now, on September 27!

The synchronized jump is clearly suicidal — when the Earth flies off into space China's population of 1.3 billion will die just like the rest of us.

But an expert on Chinese affairs says they really are planning to make good on their threat in an insane bid to prove that their backward and impoverished country is truly a force to be reckoned with.

"The Chinese are ready, willing and able to knock the Earth out of orbit and if everything goes according to plan, they'll do just that on September 27," declared Henk de Vries, whose scholarly texts on China and its people are known to experts around the world.

"Nobody knows where the idea came from but China's communist leadership is almost certainly to blame. With the disintegration of communist governments around the world they feel that they are on the verge of losing power as well.

"Their dreams of conquering the planet are all but shattered and they take the position 'if we can't have it, nobody can.'

"They possess nuclear weapons but have no plans to use them because knocking the Earth out of orbit is much quicker and more dramatic.

"The end will come with a whimper, not a bang. They're simply going to jump up and down."

Experts confirm that the forces generated when 1.3 billion jump up and down will break the Earth free of the sun's gravitational pull and send us sailing off into space like a pinball in a machine that never stops.

The logistics of such a jump are forbidding, of course, but de Vries says Chinese authorities should be able to synchronize the population by issuing orders over the country's state-controlled radio.

Not surprisingly, Chinese officials deny that any such plan is being contemplated.

But de Vries of Amsterdam insists that he has highly-placed sources in Beijing and warns:

"What I'm telling you is absolutely true and as much as I'd like to say otherwise, there's not a damn thing we can do to stop these fiends from killing us all."

Cops nab dive-bombing crow!

By JACK ALEXANDER
Staff writer

A crotchety old crow who dive-bombed kids, dumped on old folks and made life miserable for an entire town has recently been captured and caged.

For more than a month the brazen blackbird both entertained and terrorized people in the eastern Ohio hamlet of Shadyville.

"Some people thought the bird's shenanigans were funny while others wanted to send the pest to that great bird sanctuary in the sky," said a police officer.

The rambunctious raven had suddenly appeared in the sky over Shadyville. Folks believed he was a pet who had escaped or been set free. Cops said the feathery pest crash-landed on the heads of frightened children, tried to grab small animals and performed nasty little tricks on heads, shoulders and cars.

"I saw one 5-year-old girl pedaling her bike trying to flee the crow, but he caught up with her and landed on her head," said Mayor Anita Wiley.

Some youngsters carried tennis rackets for protection while many of the town's oldsters were afraid to leave their houses, said Mayor Wiley.

It seemed as if the boisterous bird "cackled" all the time, and imitated sirens, said the mayor. "It had become the talk of the town," she said.

The bird's favorite hangout was Shadyville high school, but he also entertained and pestered people at a downtown store.

"We saw him carrying a little boy's baseball cap down the street," said store employee Dawn Tenley. "I don't think the boy even realized it was missing."

But the elusive blackbird was captured one day when he flew into a car through the sunroof and couldn't find his way back out. The crow was turned over to school librarian Brenda Hoskinson, who has taken in many birds through the years.

GOTCHA! The cagey crow is now safely behind bars!

Source: **Weekly World News** 25 Juny 1991
As shown in google books

Angular Momentum and Torque
Theory and 2D examples

1.4.1 Physical Principles of Momentum and Torque

Momentum means
Angular Momentum

$$\vec{\tau} = cross(r, \vec{F})$$
$$\vec{L} = cross(r, \vec{p})$$

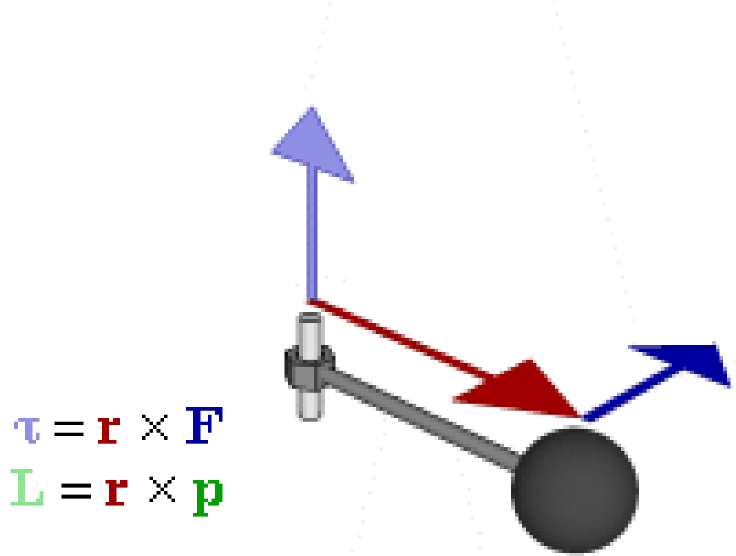
- intro of CROSS PRODUCT

See also:

- section 18-1 Feynmann
- chapter 4 in Bourg et al

1.4.2 Torque examples in 2D

- ice skater (see ice skater video from https://www.youtube.com/watch?v=VmeM0BNnGR0)



Source: https://en.wikipedia.org/wiki/Torque

Angular Momentum and Torque. 3D examples

Torque Examples in 3D

- See Terminator 3 chase (https://www.youtube.com/watch?v=pwkrUKkRqqk minute 1.45)

Important to have good understanding on Rotations

Complex Numbers

Euler Matrices

Quaternions