Lecture 15

Mon: HW by 5pm
Read 5.1 – 5.2

Weds: Review

Fri: Exam – Previous exams 2023 Test 1 all except Q3
2022 Test 1 all except Q3, Q4

Newton's Second Law

Newton's second law provides a framework for determining acceleration from the forces acting on an object. Specifically

acceleration of object = net force on object / mass of object $\quad a = F_{net}/M$

OR

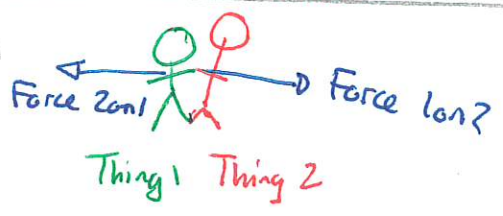
net force on object = mass of object × acceleration of object $\quad F_{net} = ma$

Newton's Third Law

The remaining piece of Newtonian mechanics considers interactions between two objects. These are described in terms of pairs of forces

Newton's Third Law

If object 1 exerts a force on object 2 then object 2 exerts a force on object 1. The sizes of these forces are identical but their directions are opposite



Quiz 1 95%

Quiz 2 90%

1 Bob and Earth

Bob has mass 81.6 kg and the Earth has mass 6.0×10^{24} kg. Bob jumps off a table and drops to the Earth's surface.

a) Determine the gravitational force exerted by Earth on Bob.

b) Determine Bob's acceleration.

c) Determine the force exerted by Bob on Earth.

d) Determine Earth's acceleration.

e) Do you expect that the force exerted by Bob on Earth will have much effect on Earth?

Answers: a) gravitational force = mass $\times$ 9.8 m/s^2

$= 81.6\,kg \times 9.8\,m/s^2$

$= 800N$

b) acceleration = net force/mass = $800N / 81.6kg$

$= 9.8\,m/s^2$

c) By Newton's third Law 800N

d) acceleration = net force/mass $= 800N / 6.0 \times 10^{24}\,kg$

$= 1.3 \times 10^{-22}\,m/s^2$

e) This is a miniscule acceleration and the effect will hardly be noticeable

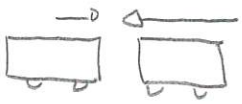
Collisions

We often use Newtons Third Law in analysis of collisions. To do so we first rewrite the third law in terms to

Momentum = mass x velocity

and then Newton's Third Law eventually states that the total momentum of an isolated system stays constant. This is relatively easy to check in lab situations

earlier

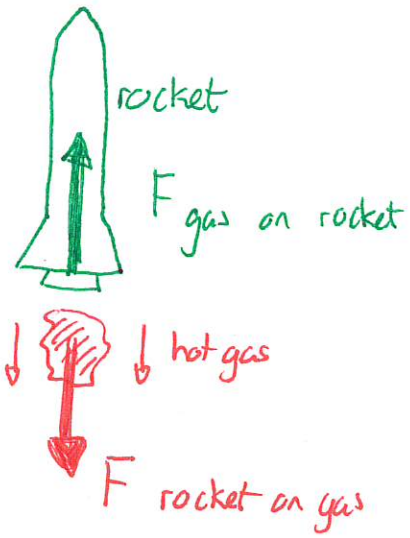


later ?? ??

Rocket Propulsion

Newton's Third Law explains rocket propulsion, including through the atmosphere but also in space. This works via:

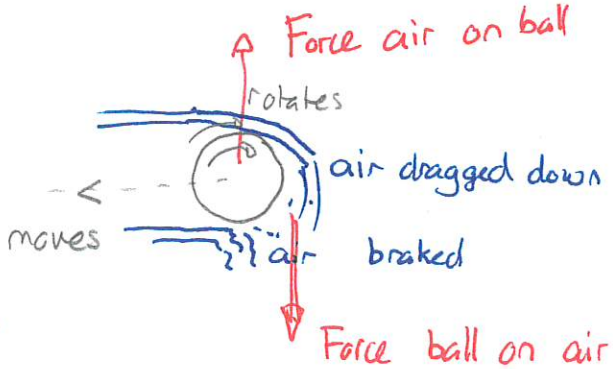
1) Rocket ignites and ejects hot gas.
2) The rocket exerts a force on the hot gas as it ejects it.
3) The hot gas exerts a force on the rocket



DEMO: Mentos Skateboard rocket

Curving balls in sports

The third law explains how balls curve as they spin and move through the air



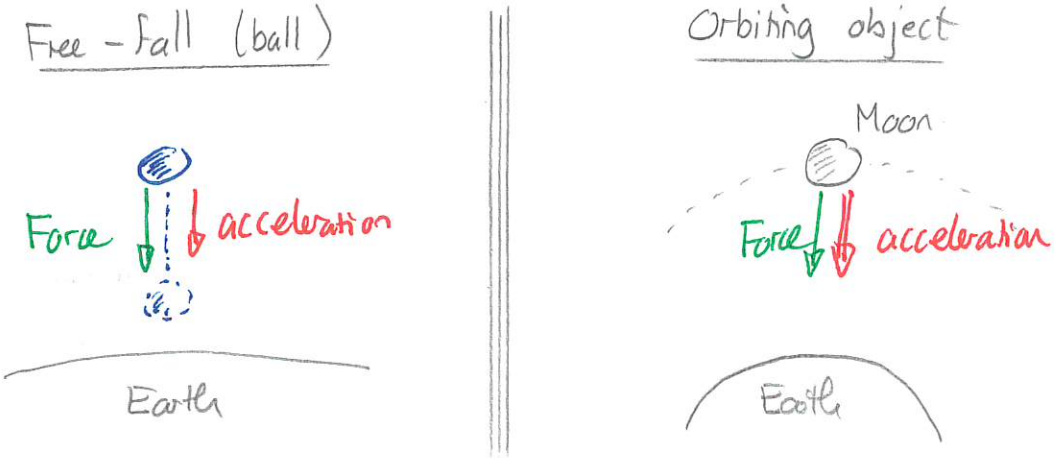
DEMO: Veritasium - Science of Curveballs
or
- What is the Magnus Force?

Motion of Celestial Objects

Some of the earliest applications of Newton's Laws were to the motion of celestial objects such as the Moon, the planets, etc,... It emerged that exactly the same framework could be used to describe freely falling objects and celestial motion.

Quiz 3

The accelerations are both non-zero since the velocities constantly change



Clearly the only object that could provide the force needed is Earth. Newton proposed that these two forces were essentially the same. We can illustrate this via a hypothetical projectile launch situation.

DEMO: PhET Projectile Motion → launch horizontally

Quiz 4

DEMO: Newton's Cannon → Speeds 2000, 5000, 6500, 7000

The conclusion was

> The gravitational force that produces free-fall and projectile motion is the same as that which produces the orbit of celestial bodies.