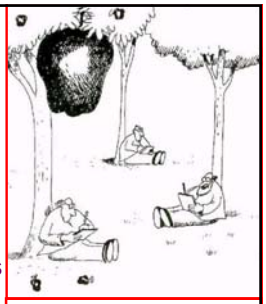
**"It is a mathematical fact that the casting of a pebble from my hand alters the centre of gravity of the universe."**

Thomas Carlyle, Scottish historian (1795-1881)

**"Our two greatest problems are gravity and paper work. We can lick gravity, but sometimes the paperwork is overwhelming."**

Wernher von Braun, Rocket engineer (1912-1977)



**"Nothing yet. How about you Newton?"**

Credit: Gary Larson, The Far Side



## PHY100 – And Once Again…

- Homepage

http://www.atmosp.physics.utoronto.ca/people/strong/phy100/phy100.html

- Portal/Blackboard
  - → I have activated the course on the Portal, but will be using the external homepage to provide course content
- Textbook
  - → *Physics: Concepts and Connections*, Fifth Edition, Art Hobson, Pearson Education (2010) – in the Bookstore
- Tutorials
  - → Second tutorial will be this week
  - → Quiz will be on material covered last week
- Office hours
  - → 3-4 PM, Tuesdays and Thursdays, room MP710A



## Tutorials

- Six groups / four time slots:

| SECTION | DAY & TIME | DATES | ROOM | TUTOR |
|---|---|---|---|---|
| T0101 | Tues, 12-1 | Jan 15 – April 2 | RW 142 | Ben Mossbarger |
| T0102 | Tues, 12-1 | Jan 15 – April 2 | LM 155 | Alma Bardon |
| T0201 | Weds, 12-1 | Jan 16 – April 3 | SS 2128 | Rikki Landau |
| T0301 | Weds, 1-2 | Jan 16 – April 3 | RW 142 | Jaspreet Sahota |
| T0401 | Thurs, 12-1 | Jan 17 – April 4 | RW 142 | Yunsheng (Bob) Tian |
| T0402 | Thurs, 12-1 | Jan 17 – April 4 | UC 177 | Graham Edge |

- Tutorial groups are capped at 33 students
- Last day to register on ROSI was January 20
- Tutorials (and quizzes) started last week
- You should be enrolled and attending!



## NOTE-TAKING SERVICES: ONLINE!

**Volunteering will be more convenient than ever before – a new online repository of notes that can be accessed 24 hrs a day, 7 days a week!**

Accessibility Services requires dependable volunteer note-takers in this course to assist students with disabilities. Benefits of volunteering:

- The quality and consistency of your notes will improve
- Gain valuable (and usefull) experience
- Receive a certificate of recognition

**Want to volunteer as a note-taker?**
**Volunteer with the service through the Accessibility Services website (http://www.accessibility.utoronto.ca/)**
**or review which courses have requests for note-takers at https://www.studentlife.utoronto.ca/accessibility/pcourselist.aspx**
(You can also add your courses if they are not on the list, and you will be notified if your services are required.)
**Currently a volunteer?**
Log in to the new system at
https://www.studentlife.utoronto.ca/accessibility/vollogin.aspx

*Contact as.notetaking@utoronto.ca if you have any questions, concerns, or require assistance.*



## Current Assignments ...

**For today:**

- Read Sections 5.2, 5.5, 5.6, and 2.6

**For Lecture 6:**

- Read notes on Chaos
  - → See homepage, syllabus table, box for Lecture 6

**Suggested Conceptual Exercises:**

- Chapter 5: 5, 7, 11, 13, 17, 21, 27, 29, 31, 33

**Attend your second tutorial this week**

**Homework #1**

- Handed out in Lecture 4, available on the homepage
- Due 11:00 AM, Thursday, January 31 in drop boxes
- Avoid plagiarism and copying others' work



## Collaboration and Plagiarism

- From the UofT "**ACADEMIC INTEGRITY HANDBOOK**"

*"Collaboration occurs when students work together inappropriately on individual assignments with the result that the work they submit is unacceptably similar. Students often do not consider this to be cheating because they are used to working together in high school, but it can result in an allegation of plagiarism and/or of providing/receiving unauthorized aid at UofT."*

- UofT encourages students to exchange ideas with each other. This is an essential part of the learning process and is not considered cheating or plagiarism.
- However, while you may discuss an assignment in a general fashion with your class mates, AFTER such discussions you are expected to go away and write up your own work separately.
- **Ensure that any work which you submit is entirely your own.**
- Do not provide a copy of your finished work (in text form or electronically), or even a draft of your work, to another student in case s/he is tempted to use it inappropriately in completing his/her own work. If s/he does, you too may face an allegation of academic misconduct under the *Code of Behaviour on Academic Matters.*

## Review of Lecture 4

**Textbook, Sections 4.4, 4.5, 5.1**

- Weight - the force of gravity
- The Law of Force Pairs (Newton's Third Law)
- The idea of gravity - falling objects
- Projectile motion



## Plan for Lecture 5

**Textbook, Sections 5.2, 5.5, 5.6, and 2.6**

- Newton's Law of Gravity
- "Weightlessness" and free fall
- The Newtonian worldview
- Beyond Newton



## Racing Balls

**Two balls are launched at the same time with equal speeds on the tracks shown. Which reaches the end first?**

1. A
2. B
3. They reach the end at the same time.




## Racing Balls

Flash animation

- http://www.upscale.utoronto.ca/GeneralInterest/Harrison/Flash/ClassMechanics/RacingBalls/RacingBalls.swf

Demo and explanation (check out on homepage)

- http://www.physics.umd.edu/lecdem/services/demos/demosc2/c2-11.htm



## Racing Balls

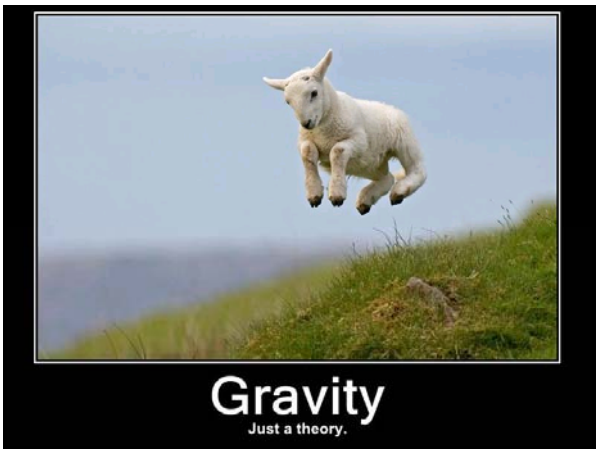
**Two balls are launched at the same time with equal speeds on the tracks shown. Which reaches the end first?**

1. A
2. B
3. They reach the end at the same time.




## Racing Balls - Why Does B Win?

- The balls roll together on the first flat section.
- As ball B rolls down the downward slope, its horizontal speed increases, so it moves ahead.
- When B rolls up the upward slope, it slows down to its original horizontal speed, but it never goes slower than A.
  - → B never falls behind A, and A never catches up.
- The balls the roll together at the same speed on the last flat section, with B ahead of A by a constant distance.




## §5.2 Gravity

- Not only does gravity keep the moon in its orbit around Earth; it also keeps the planets in their orbits around the sun, and the stars in their paths.
- But what about objects that are not astronomical in size? Does gravity have an effect on them as well? Yes, it does!
- Experiments show that the gravitational force between masses is larger if the masses are larger, and smaller if the masses are farther apart.

→ Newton put all this together in his Law of Gravity



## Newton's Law of Gravity

"The gravitational force between two masses is proportional to the product of the masses and inversely proportional to the square of the distance between their centers."

$$F_{gravity} \propto m_1 \times m_2 / d^2$$

Using metric units (m in kilograms, d in meters, F in newtons), the exact expression is:

$$\mathbf{F_{gravity} = G\, m_1 \times m_2 / d^2}$$

with $G = 6.7 \times 10^{-11}$ N m$^2$ / kg$^2$
= universal gravitational constant



## Conceptual Exercise 5.27

Suppose that two satellites are put into orbit, one around Earth and one around the moon, and suppose that the radii of the two orbits (the distance from the center of Earth and the moon) are the same. From the knowledge that Earth's mass is larger than the moon's mass, can you make any predictions about the speeds of the two orbits?



## Weight vs. Distance from Earth

As you move away from the center of Earth, the gravitational force on you decreases, although it is never really zero.

**Textbook Figure 5.6**



$R_{Earth} \approx 6400$ km



## You are at rest 1000 km above the surface of Earth

**What happens to you?**

1. You remain at rest as there is no gravity above the atmosphere (~100 km).
2. You remain at rest as you are in a weightless state and therefore gravity is zero.
3. Gravity is very small and it will take a long time for you to fall back to Earth.
4. Gravity is almost the same as near Earth's surface and you will quickly fall back to Earth.

*Hint: At 1000 km, g is 75% of the value at the surface.*

## Weightlessness in Space

So why do astronauts experience weightlessness?

Astronaut Marc Garneau during a parabolic flight: Credit: CSA/NASA

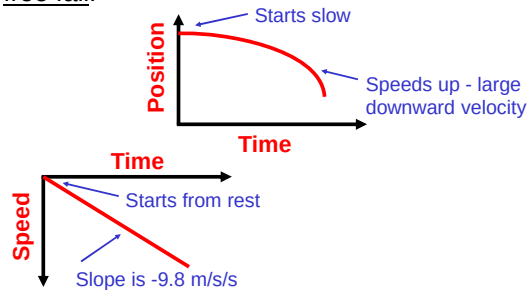
Although the gravitational force on them is not zero, they are "falling" around Earth.

They appear weightless because they are in free fall. This is apparent weightlessness.



## Weightlessness on Earth

Any object only acted upon by gravity is in free fall.






## "Weightlessness" on Earth

**Textbook Figure 5.8**





## You are in a spaceship orbiting Earth 1000 km above the surface

**You step on some bathroom scales. What will the scales read?**

1. Your weight as measured on the surface.
2. 75% of your weight as measured on surface.
3. You feel weightless so your mass is zero and the reading is zero.
4. Gravity causes the spaceship, you, and the scale to all free fall. You and the scale are at rest relative to each other, so the reading is zero.



## §5.5 The Mechanical Universe

Before Newton

- Everything was thought to have a purpose
- Humanity fulfilled the purpose of creation

After Newton

- Newton's laws implied a mechanical universe
- The behaviour of every physical system could be precisely predicted
- Implied the loss of free will
- Two realities: material world & spiritual world



## §2.6 & 5.5 The Mechanical Universe

Materialism – philosophy that says that matter is the only reality and that everything is determined by its mechanical motions.

"It is unbelievable that all nature, all the planets, should obey eternal laws, and that there should be a little animal, five feet high, who in contempt of these laws, could act as he pleased, solely according to his caprice."

Voltaire, French philosopher (1694-1778)

## Arguments Against Materialism

- Science starts from evidence
  - → Theory is secondary to sensory evidence
- Science is only one way of viewing reality
  - → Others: religious, aesthetic, intuitive
- All scientific ideas are tentative
  - → e.g., we don't know for certain that everything is made of atoms
- Newtonian physics is only approximately correct
  - → More recent theories are less supportive of materialism

See discussion of materialism in §2.6



## §5.6 Beyond Newton

Newtonian physics

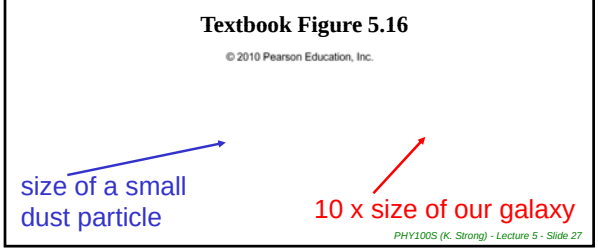
- Was confirmed by many experiments in the 18th and 19th centuries
- Came to be accepted as truth

Until...

- Results of new experiments did not agree with predictions of Newtonian physics
  - → very high speeds
  - → enormous gravitational forces
  - → vast distances
  - → tiny distances



## Figure 5.16




size of a small dust particle

10 x size of our galaxy