Chapter 4

Newton’s laws & gravity

NOTE TO THE STUDENT: The teacher version of these slides has MANY more clicker questions than your notes. That is done intentionally.

Science Vocabulary – meanings are different than everyday life

• __________ – speed _______________
• __________ – ___ change in ________
  – ____________________________
  – OR __________________________
• Your body feels ____________________.
• We’ll focus mostly on accelerations caused by _______ (falling down or ___________)
Calif. Science Standards for motion

- From California Science Standards, grade 2:
  - Students know the **way to change how something is moving** is by giving it a push or a pull. The **size of the change** is related to the strength, or the **amount of force**, of the push or pull.

- And from grade 8:
  - Students know the **velocity** of an object must be described by specifying both the direction and the speed of the object.
  - Students know **changes in velocity** may be due to changes in speed, direction, or both.

Science Vocabulary – part 2

- Matter = __________________________
- Mass = __________________________
- Force – ____________________________:
  - ________________
  - Forces __________________________
  - ________________________________
- Weight = ___________________________
  - the _____________________________
  - *Your book and I disagree on this. See “weightlessness” slide.
- Which objects are involved in the force of gravity?
  - Ask neighbor: what’s the second object for pencil falling down?
Gravity near ground

• Free fall
  – Toss something up, what happens on way up?
  – Drop something, what happens on way down?
• When things fall measure ____________ for:
  – ______________
  – ____________________.
• Paper & pen experiment; See for Yourself p 122.
• __________________ for __________
  ______________________________________
• Galileo observed this (in Pisa). Galileo’s observations helped Newton formulate ideas

Weightlessness

• When have YOU felt weightless? [ignore being in water]
• Weightless when you _______________
  ______________________________________
  • Weightless scenes in Apollo 13 were filmed this way!

• IMPORTANT NOTE: Your book says weight is the force a scale measures when you stand on it. I don’t care for this definition and won’t use it. Your book discusses weightlessness using its IMHO poor definition of weight. Its discussion is good, but I don’t like the terminology. I prefer the physics version used in these notes.
Falling Around
Put your drawing here:

• Newton’s cannon drawing.
• Gravity’s

See Interactive Figure 4.4 for an animation of this.

These cannonballs

California Elementary School
Science Standards for orbits

• From California Science Standards, grade 5:
  – Students know the path of a planet around the Sun is due to the gravitational attraction between the Sun and the planet.
• And from the high school standard:
  – Students know applying a force to an object perpendicular to the direction of its motion causes the object to change direction but not speed (e.g., Earth’s gravitational force causes a satellite in a circular orbit to change direction but not speed).
  – Students know circular motion requires the application of a constant force directed toward the center of the circle.
Falling around – part 2

- Are orbiting satellites falling? Yes or No?
  – Example: ISS: International Space Station.
- Are the people inside ISS falling? Y/N?
- So, ____________________________?
- Draw a cartoon in your own notes that illustrates why astronauts are weightless.
- Are they ________________ as they fall?

Newton changed the way people think

- Isaac Newton discovered rules governing velocity, acceleration, force, etc.
- He applied these __________________________
  __________________________ (space) and on Earth.
  – First person to do this.
  – He theorized: Scientific ideas are “universal”
- Things change for natural reasons
  – Ex: Motions (velocities) change due to forces
Newton’s 3rd law

• You’ve probably heard this law:
• For every action __________________
• __________________________________________________
  – __________________________
  – If object 1 pushes on object 2, then
  – ______________________________________________________
  – It does this without ____________

Newton’s 3rd law examples

How many objects are involved in a force? (non-clicker)
• On skates: you push on your friend’s back.
• Punching the wall (______________ the wall)
• Gravity pulling you down (name for this force is …)
• Walking (or running)
• Rockets blasting off…

<table>
<thead>
<tr>
<th>#</th>
<th>Your hands</th>
<th>Friend’s back</th>
<th>Your hands (giver) push on (force) friend’s back (receiver)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>2</td>
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<td>3</td>
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<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Rocket engine</td>
<td>Exhaust (gas)</td>
<td></td>
</tr>
</tbody>
</table>
California Elementary School
Science Standards for motion

• From California Science Standards, high school
  – Students know that when one object exerts
    a force on a second object, the second
    object always exerts a force of equal
    magnitude and in the opposite direction
    (Newton’s third law).

Results of forces

• Newton’s 3rd law says that:
  – all __________________ are equal.
    • ________________________________
  • ________________________________
  – ________________________________
• It ________________________________
  – ________________________________.
• Newton’s 2nd law is about how the__________
  ________________
  – Why the ______ “_____” and the ______“______”.
  – Why you see me__________, not _____________.
• N 2nd law: the low-mass object gets a larger
  ________________ despite getting the ___
  ______. REMINDER: You feel ____________.
New Topic

• Newton’s Universal Law of Gravity

Universal Law of Gravity:

• Newton hypothesized that _____________________
  ____________________________________________.

• The mathematic relationship is called
  an Inverse Square Law and it looks like this:
Gravity is forcing you towards the person next to you.

0  1. True
0  2. False

Is there gravity on the Moon?

0  1. Yes
0  2. No
Gravity from multiple objects

For each version of you, draw the direction the right planet's gravity pulls you with an arrow. Bigger arrow = more force.
Repeat for the left planet, use a different color or arrow in your notes.

Gravity results from 2 objects

- Left and right planets are ______________, red person ________________: only one of 3 things can happen:
  - ______________ than right planet
    - Red person ________________
  - ______________ than left planet
    - Red person ________________
  - The ________________
    - Red person ________________
Which best describes the net force on the person shown, halfway between the 2 twin planets?

1. Very strong to the right
2. Very strong to the left
3. Very strong on each side
4. Zero

California Elementary School
Science Standards for motion

• From California Science Standards, grade 8
  – Students know when an object is subject to two or more forces at once, the result is the cumulative effect of all the forces.
  – Students know when the forces on an object are balanced, the motion of the object does not change.
  – Students know that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).
  – Students know the greater the mass of an object, the more force is needed to achieve the same rate of change in motion. (i.e. acceleration)
California Elementary School
Science Standards for motion

• From California Science Standards, high school
  – Students know that when forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton’s first law).

Gravity vs. Newton’s 3rd law

• _______ is a _______________________.
• Newton’s 3rd law (N3L) says ______________

_____________________

These two forces _____________. They _______________.
They are ____________

_____________________

These are the ______________

_____________________.

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Lecture Tutorial

• Work with a partner on the tutorial on pages 29-31

If you were twice as far from Earth as you are now, how would gravity change?

0 1. It would be four times as strong
0 2. It would be twice as strong
0 3. It would be the same
0 4. It would be half as strong
0 5. It would be $1/4^{th}$ as strong
Real triple-size planets

• We just said planets that are 3x the Earth’s size have _________ gravity.
• Do you think real planets that are 3x bigger than Earth have weaker gravity?
• Why not?

Which is a stronger force? Read the answers carefully.

0 1. Earth pulling on you
0 2. Moon pulling on you
0 3. Both are the same
New topic

- Objects falling

You have two balls of equal size and smoothness, and you can ignore air resistance. One is heavy, the other much lighter. You hold one in each hand at the same height above the ground. You release them at the same time. What will happen?

1. The heavier one will hit the ground first.
2. They will hit the ground at the same time.
3. The lighter one will hit the ground first.
California Elementary School Science Standards for gravity

• From California Science Standards, high school

  a. Students know the relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth.

Gravity causing acceleration

• Planet’s gravity pulls you down.
• If ___________________________…
  – you ___________________________!
• Remember: ________________
• Newton’s 2nd Law: ________________
• $F_{g \text{ on you}} =$ … Math Trick

  \[ F_{g \text{ on you}} = \]
Masses

- Earth’s mass is ________________________.
  - ____________________________kg (___ zeroes)
  - ____ is ___________ times heavier than a 220 lb person.

- When a pen falls down, why does the pen move & the Earth doesn’t? [clicker question first].

- Earth ________________________.

- Similar to _________________________. → Found ____+ planets around other stars (since 1995)!

Which is closer to you?

0  1. New York City
0  2. The top of Earth’s atmosphere
0  3. They are the same distance
Gravity’s acceleration in space

• A previous slide showed us:

• What is the _______________ in the expression above?
• RHETROCAL QUESTION: How does this affect astronauts?
• How far are the astronauts from Earth?

• _______________
• For a total distance of …

• Has the distance changed by a big percentage?

• That ___________________________
• (How high up does the atmosphere go?)

Escaping – pages 138-139

• Is it true that all things that go up, come back down?
• Does gravity turn off for objects _______________
  _______________?
• How can they _______________?
  – Newton’s cannon drawing, revisited. ____________.
• If you _______________ _______________
  _______________.

• How is that possible?
  – _______________, Gravity __________ as you get further.
    – However, gravity will always _______________
• This _________________ is called _______________
Escape Speed

• The __________ depends on:
  – ______________________________, and
  – ______________________________.
  – In other words:
    ______________________________

• To escape from the ____________, you have to move 11 km/s (7 miles per sec = ___________).

• Is it easier or harder to escape Earth if halfway to the Moon?

• For the math people out there: the escape speed is
  \[ \sqrt{\frac{2GM_{\text{star or planet}}}{\text{dist}}} = (\sqrt{2})v_{\text{circle}} \]

• To escape from the solar system ____________ ____________, v = 42 km/s (26 miles/sec)

• Do you need to go faster or slower if near Mercury?

Atmospheric Retention

• Why don’t the atoms and molecules in Earth’s atmosphere escape into space? ______________

• What determines if a ____________________________?
  – ______________________________

• What determines the _____________ of a world?

• What determines _____________________________?
  – ______________________________ AND ______________________________!
  – Name the 2 least massive elements. Will they move faster or slower than CO₂?

• Why _____________ have an atmosphere? 2 reasons.

• What about the Moon?

• Why doesn’t Earth have any _____________ in its atmosphere? Why is it ________________?

• ______________________________(Thermal escape)
Summary

1. Defining Force
2. Falling around
3. Weightlessness
4. Newton’s 3rd law of Forces (not motion)
5. Newton’s 1st & 2nd laws of motion
7. Falling down – equal accelerations
8. Escaping = not coming back.
   • NOT escaping gravity!