WELCOME TO 1103 PERIOD 6

Homework Exercise #5 is due today.

Please watch video 2, America Revealed: Electric Nation, for class discussion one week from today.
• Where is the center of gravity of an object?
• How does the acceleration of gravity affect falling objects?
• What is the difference between mass and weight?
Center of gravity

- The center of mass of an object is the point at which the force of gravity acts on the object.
- The center of mass of an object is the object’s center of gravity.
Center of gravity: lifting a rod

Is it possible to lift a heavy rod with strips of paper?

The net force of forces acting in the same direction is their sum.

Where is the rod’s center of gravity?
Center of gravity: stacking pennies

Why is it possible to pull the paper from under the pennies?

✓ Newton’s 1st Law: an object at rest stays at rest unless a force acts on the object.

Why is a taller stack of pennies more difficult?

✓ The frictional force is affected by the force pressing the objects together.

✓ A higher center of gravity makes an object less stable.
Center of gravity: balancing a meter stick

Why do your fingers move under the meter stick one at a time?

- Which force is greater – static or sliding friction?
- Where is the center of gravity of the meter stick?
- As your finger moves closer to the center of the meter stick, more of the stick’s weight rests on your finger. How does this affect the frictional force between your finger and the stick?
Force of gravity on falling objects

Drop two balls from the same height at the same time.

Neglecting air resistance, which one will reach the floor first – the larger, heavier ball, or the smaller, lighter ball?

Make a prediction before you drop the balls!
The acceleration of gravity

A falling object accelerates due to the force of gravity pulling it downward.

Objects near the Earth accelerate at the rate of 9.8 m/s$^2$ (or 32 ft/s$^2$).

What is the velocity of the penny after 4 seconds of fall?

\[ V_{\text{final}} = a \times t + V_{\text{initial}} \]
The acceleration of gravity

Neglecting air resistance, does the velocity of a falling object depend upon…

✔ Its size?
✔ Its mass (how much matter it contains)?
✔ Its shape?
✔ How long it falls?
Newton’s Law of Gravitational Force

\[ F = \frac{G M_1 M_2}{D^2} \]

- \( F \) = Gravitational force (newtons)
- \( M_1 \) = Mass of object 1 (kilograms)
- \( M_2 \) = Mass of object 2 (kilograms)
- \( D \) = Distance between the centers mass of the objects (meters)
- \( G \) = Gravitational constant of the universe = \( 6.67 \times 10^{-11} \) (N m\(^2\)/kg\(^2\))
Force of gravity equation

The distance $D$ is the distance between the centers of mass of the two objects.

✔ When we consider an object near the Earth’s surface, $D$ is the radius of the Earth.

✔ The Earth’s radius is so large that we can ignore the small additional distance the object is above the Earth’s surface.
The acceleration of gravity $= g$

Newton’s 2$^{nd}$ Law: $F = M \ a$

When referring to the acceleration of gravity, we replace the variable $a$ with $g$: $F = M \ g$

The gravitational force on a rock falling to Earth is:

$$F = M_{\text{Rock}} \ g \quad \text{or}$$

$$F = \frac{G \ M_{\text{Rock}} \ M_{\text{Earth}}}{D^2}$$

Set these two equations equal and solve for $g$. 
The acceleration of gravity = $g$

\[ F = M_{\text{Rock}} \ g \quad \text{and} \quad F = \frac{G \ M_{\text{Rock}} \ M_{\text{Earth}}}{D^2} \]

Set these two equations equal and solve for $g$:

\[ M_{\text{Rock}} \ g = \frac{G \ M_{\text{Rock}} \ M_{\text{Earth}}}{D^2} \]

\[ \frac{M_{\text{Rock}} \ g}{M_{\text{Rock}}} = \frac{G \ M_{\text{Rock}} \ M_{\text{Earth}}}{D^2} \]

\[ g = \frac{G \ M_{\text{Earth}}}{D^2} \]
The difference between $g$ and $G$

$g$ = the acceleration of gravity

- The value of $g$ differs for each planet.
- Near Earth, $g = 9.8 \text{ m/s}^2$ or $32 \text{ ft/s}^2$.

$G$ = the Universal Gravitational constant

- The value of $G$ is constant throughout the Universe.
- $G = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2$
Scientific notation on your calculator

- Using the gravitational force equation requires squaring a number written in scientific notation.
- On many calculators, you must enclose the number to be squared in parentheses before pressing the $X^2$ key.

Try this on your calculator: $(6.3712 \times 10^6 \text{ m})^2$

Answer: $4.0592 \times 10^{13} \text{ m}^2$
How is g related to G?

Gravitational force \( F \) = \( \frac{G M_{\text{Object}} M_{\text{Earth}}}{D^2} \)

Three of the quantities in the gravitational force equation are constants – their values do not change near the Earth:

\( M_{\text{Earth}} \) = mass of the Earth = \( 5.98 \times 10^{24} \) kg
\( D \) = Earth’s radius = \( 6.3712 \times 10^6 \) meters
\( G \) = Grav. constant = \( 6.67 \times 10^{-11} \) N m\(^2\)/kg\(^2\)
How $g$ is related to $G$, continued

We can simplify calculations by combining into one term the 3 terms:

\[
M_{\text{Earth}} = \text{mass of the Earth} = 5.98 \times 10^{24} \text{ kg}
\]

\[
D = \text{Earth’s radius} = 6.3712 \times 10^6 \text{ meters}
\]

\[
G = \text{Grav. constant} = 6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2
\]

\[
g = \frac{(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2) \times (5.98 \times 10^{24} \text{ kg})}{(6.3712 \times 10^6 \text{ m})^2} = 9.8 \text{ m/s}^2
\]

Since the mass and diameter of planets vary, the value of $g$ is different for each planet.
How does \( g \) simplify calculations?

We can find the attractive gravitational force between an object near the Earth and the Earth itself by substituting \( g \) into the gravitational force equation:

\[
F = \frac{G M_{Object} M_{Earth}}{D^2}
\]

Substitute: \( g = \frac{G M_{Earth}}{D^2} \)

Result: \( F = M_{Object} \times g \)

Near the Earth, the force of gravity on an object is:

\[
F = M_{Object} \times g = M_{Object} \times 9.8 \text{ m/s}^2
\]
Mass versus weight

The weight of an object equals the force of gravity acting on the object.

\[ \text{Weight} = \text{gravitational force} = \text{Mass} \times g \]

How can you find an object’s mass from its weight?

\[ \text{Mass} = \frac{\text{Weight}}{g} = \frac{\text{Weight}}{9.8 \text{ m/s}^2} \]

Would a person weigh more, less, or the same when standing on the Earth as compared to standing on the Moon?

Would the person’s mass be more, less, or the same on the Earth as compared to the Moon?
<table>
<thead>
<tr>
<th>Mass</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric</td>
<td>grams, kilograms</td>
</tr>
<tr>
<td>English</td>
<td>(slug)</td>
</tr>
<tr>
<td></td>
<td>Newton (N)</td>
</tr>
<tr>
<td></td>
<td>Pound (lb)</td>
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</tbody>
</table>
BEFORE THE NEXT CLASS…

✓ Read textbook chapter 7
✓ Complete Homework Exercise 6
✓ Bring a blank Activity Sheet 7 to class.