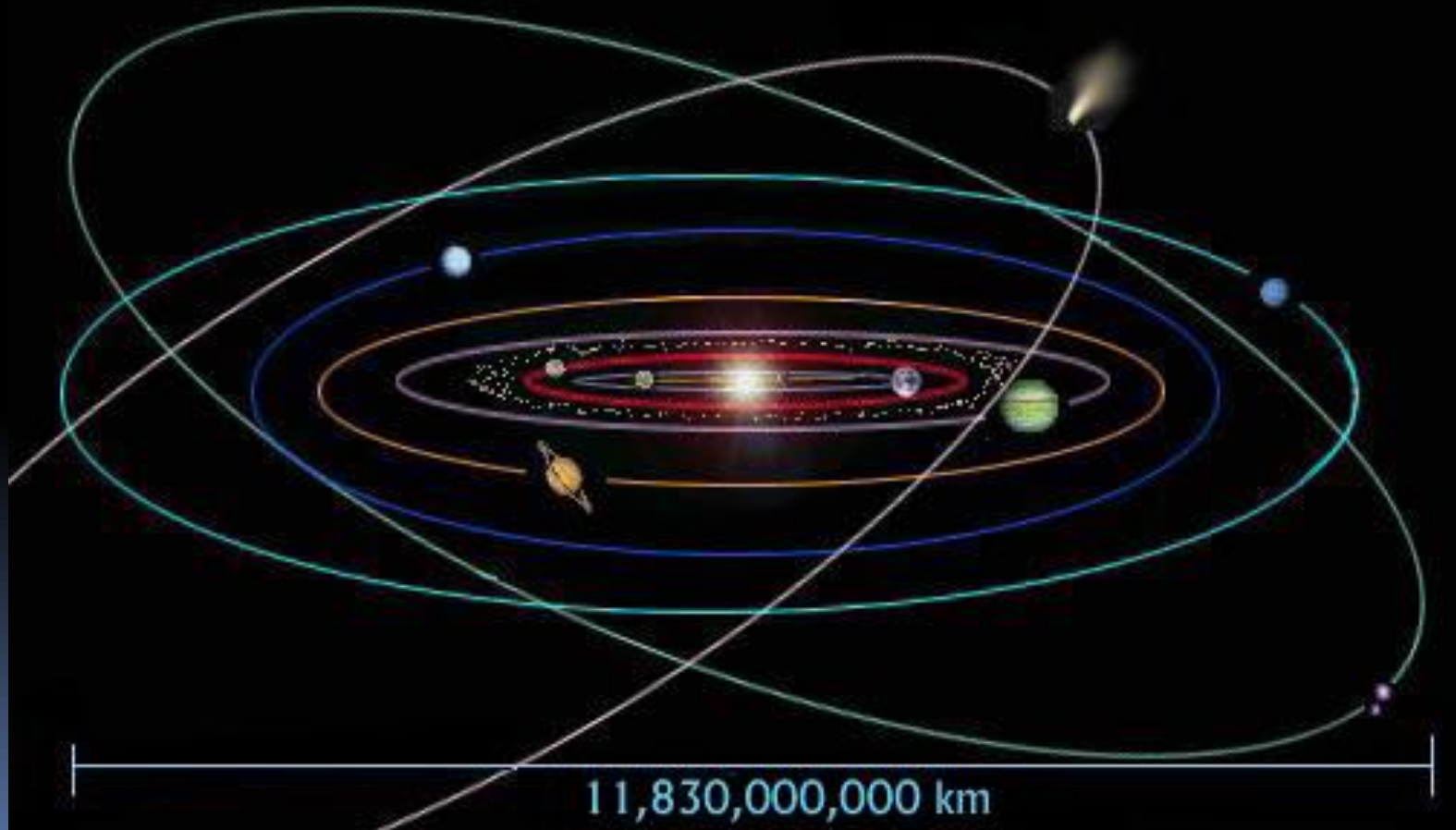# DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
AP PHYSICS

GIANCOLI SECTION 5-8 AND 5-10

SATELLITES AND "WEIGHTLESSNESS"
TYPES OF FORCES IN NATURE

11,830,000,000 km

Big Idea(s):

- Objects and systems have properties such as mass and charge. Systems may have internal structure.

- Fields existing in space can be used to explain interactions.

- The interactions of an object with other objects can be described by forces.

- Interactions between systems can result in changes in those systems.

Enduring Understanding(s):

- The internal structure of a system determines many properties of the system.

- Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

- A field associates a value of some physical quantity with every point in space. Field models are useful for describing interactions that occur at a distance (long-range forces) as well as a variety of other physical phenomena.

Enduring Understanding(s):

- A gravitational field is caused by an object with mass.

- All forces share certain common characteristics when considered by observers in inertial reference frames.

- Classically, the acceleration of an object interacting with other objects can be predicted by using .

Enduring Understanding(s):

- At the macroscopic level, forces can be categorized as either long-range (action-at-a-distance) forces or contact forces.

- Certain types of forces are considered fundamental.

- The acceleration of the center of mass of a system is related to the net force exerted on the system, where .

Essential Knowledge(s):

- A system is an object or a collection of objects. Objects are treated as having no internal structure.
  - A collection of particles in which internal interactions change little or not at all, or in which changes in these interactions are irrelevant to the question addressed, can be treated as an object.
- Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems.

Essential Knowledge(s):

- Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.
  - The gravitational mass of an object determines the amount of force exerted on the object by a gravitational field.
  - Near the Earth's surface, all objects fall (in a vacuum) with the same acceleration, regardless of their inertial mass.

Essential Knowledge(s):

- A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.

  - Vector fields are represented by field vectors indicating direction and magnitude.

  - When more than one source object with mass or electric charge is present, the field value can be determined by vector addition.

Essential Knowledge(s):

- A gravitational field at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.
  - On the Earth, this gravitational force is called weight.
  - The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force.
  - If the gravitational force is the only force exerted on the object, the observed free-fall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in newtons/kilogram) at that location.

Essential Knowledge(s):

- An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
  - Displacement, velocity, and acceleration are all vector quantities.
  - Displacement is change in position. Velocity is the rate of change of position with time. Acceleration is the rate of change of velocity with time. Changes in each property are expressed by subtracting initial values from final values.
  - A choice of reference frame determines the direction and the magnitude of each of these quantities.

Essential Knowledge(s):

- Forces are described by vectors.
  - Forces are detected by their influence on the motion of an object.
  - Forces have magnitude and direction.
- A force exerted on an object is always due to the interaction of that object with another object.
  - The acceleration of an object, but not necessarily its velocity, is always in the direction of the net force exerted on the object by other objects.

Essential Knowledge(s):

- If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

- Free-body diagrams are useful tools for visualizing forces being exerted on a single object and writing the equations that represent a physical situation.
  - An object can be drawn as if it was extracted from its environment and the interactions with the environment identified.
  - A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  - A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation. physics 2

Essential Knowledge(s):

- Gravitational force describes the interaction of one object that has mass with another object that has mass.

- Electric force results from the interaction of one object that has an electric charge with another object that has an electric charge.

- A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet.

Essential Knowledge(s):

- Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.

- Electromagnetic forces are exerted at all scales and can dominate at the human scale.

Essential Knowledge(s):

- The strong force is exerted at nuclear scales and dominates the interactions of nucleons.

- The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.

Essential Knowledge(s):

- The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.
  - The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.
  - Force and acceleration are both vectors, with acceleration in the same direction as the net force.

Learning Objective(s):

- The student is able to design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.

- The student is able to apply to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems.

- The student is able to apply to calculate the gravitational field due to an object with mass M, where the field is a vector directed toward the center of the object of mass M.

Learning Objective(s):

- The student is able to express the motion of an object using narrative, mathematical, and graphical representations.

- The student is able to design an experimental investigation of the motion of an object.

- The student is able to analyze experimental data describing the motion of an object and is able to express the results of the analysis using narrative, mathematical, and graphical representations.

Learning Objective(s):

- The student is able to represent forces in diagrams or mathematically using appropriately labeled vectors with magnitude, direction, and units during the analysis of a situation.

- The student is able to analyze a scenario and make claims (develop arguments, justify assertions) about the forces exerted on an object by other objects for different types of forces or components of forces.

- The student is able to describe a force as an interaction between two objects and identify both objects for any force.

Learning Objective(s):

- The student is able to make claims about the force on an object due to the presence of other objects with the same property: mass, electric charge.

- The student is able to predict the motion of an object subject to forces exerted by several objects using an application of Newton's second law in a variety of physical situations with acceleration in one dimension.

- The student is able to reexpress a free-body diagram representation into a mathematical representation and solve the mathematical representation for the acceleration of the object.

Learning Objective(s):

- The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

- The student is able to create and use free-body diagrams to analyze physical situations to solve problems with motion qualitatively and quantitatively.

- The student is able to articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored.

Learning Objective(s):

- The student is able to connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces.

- The student is able to connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved.

- The student is able to identify the strong force as the force that is responsible for holding the nucleus together.

Learning Objective(s):

- The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.

- The student is able to make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time.

Learning Objective(s):

- The student is able to evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified.

- The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system.

Girl in Elevator

F_N

F_g
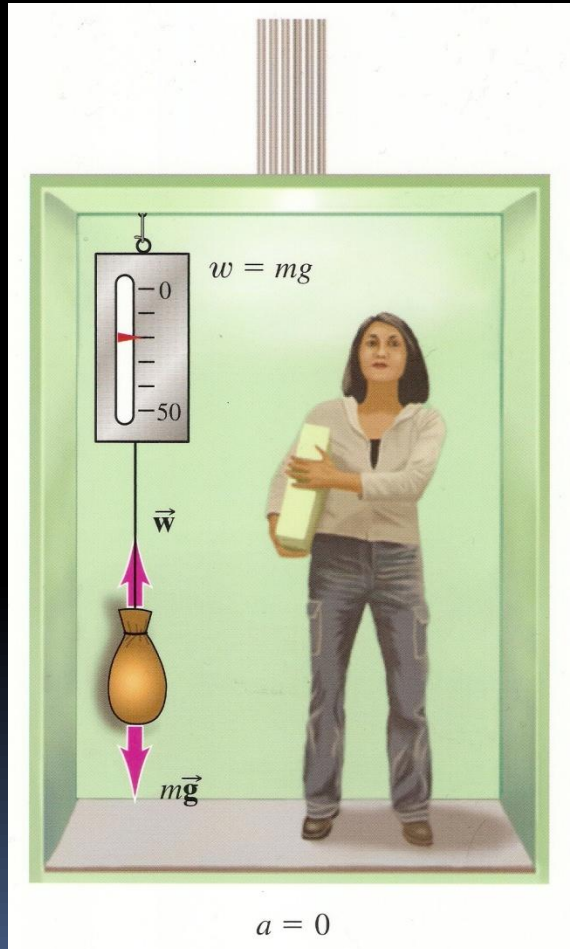
Girl in Elevator

- Elevator not moving
- Acceleration zero

$$\sum F = ma$$

$$F_N - F_g = ma$$

$$a = 0, ma = 0$$

$$F_N - F_g = 0$$

$$F_N = F_g$$

$$F_g = mg$$

$$F_N = mg$$

F_N

F_g

Girl in Elevator

- Elevator **_moving up_**
- Acceleration **_Positive_**

$$\sum F = ma$$

$$F_N - F_g = ma$$

$$F_N = ma + F_g$$

$$F_g = mg$$

$$F_N = ma + mg$$

F_N

F_g

Girl in Elevator

- Elevator *__moving down__*
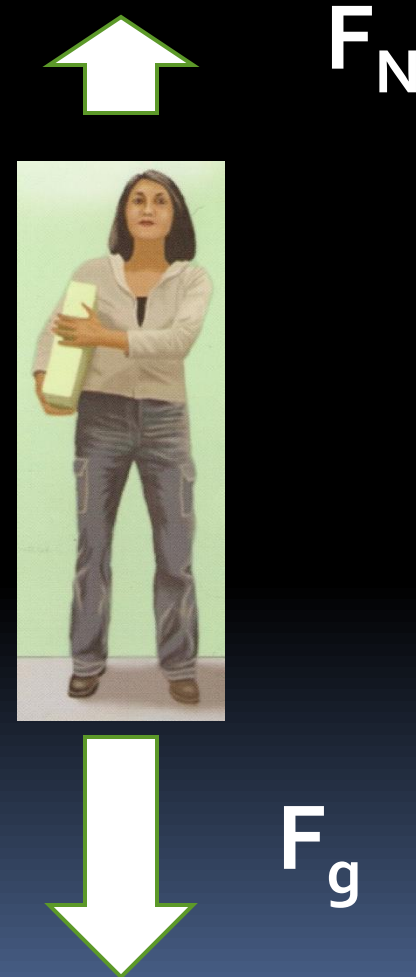- Acceleration *__Negative__*

$$\sum F = -ma$$

$$F_N - F_g = -ma$$

$$F_N = -ma + F_g$$

$$F_g = mg$$

$$F_N = -ma + mg$$

$$F_N = mg - ma$$

F_N

F_g

Girl in Elevator

- Elevator **_cable breaks_**

- Girl plummeting to her death, but remains calm

$$\sum F = -ma$$

$$-a = -g$$

$$F_N - F_g = -mg$$

$$F_N = -mg + F_g$$

$$F_N = -mg + mg$$

$$F_N = 0 \quad \textit{Weightlessness}$$

F$_N$

F$_g$

Girl in Elevator

- Elevator ***cable breaks***
- Girl reaches sudden stop at the end

$$\sum F = -ma$$

$$-a = -g$$

$$F_N - F_g = -mg$$

$$F_N = -mg + F_g$$

$$F_N = -mg + mg$$

$$F_N = 0$$

F_N
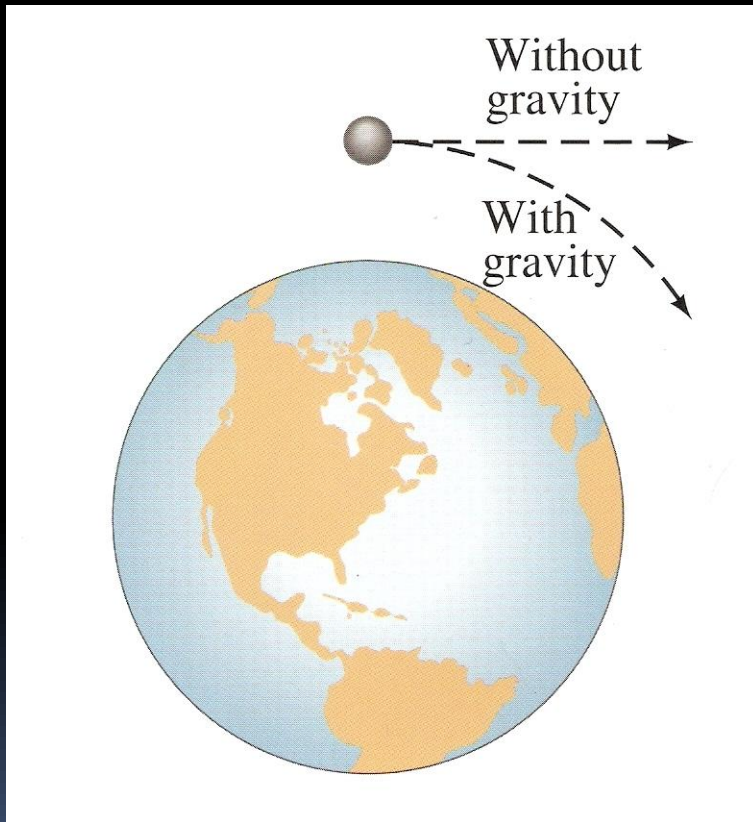
SPLAT!

F_g

Weightlessness

- Weightlessness on a Motorcycle
  - Motorcycle Jump
- Weightlessness on Skis
  - Ski Jump
- Weightlessness in a Cage
  - ?????

Weightlessness and Space

- How do you keep from losing satellites?

???

???

Weightlessness and Space

F_G ma_c

Weightlessness and Space

27,000 km/h circular

30,000 km/h elliptical
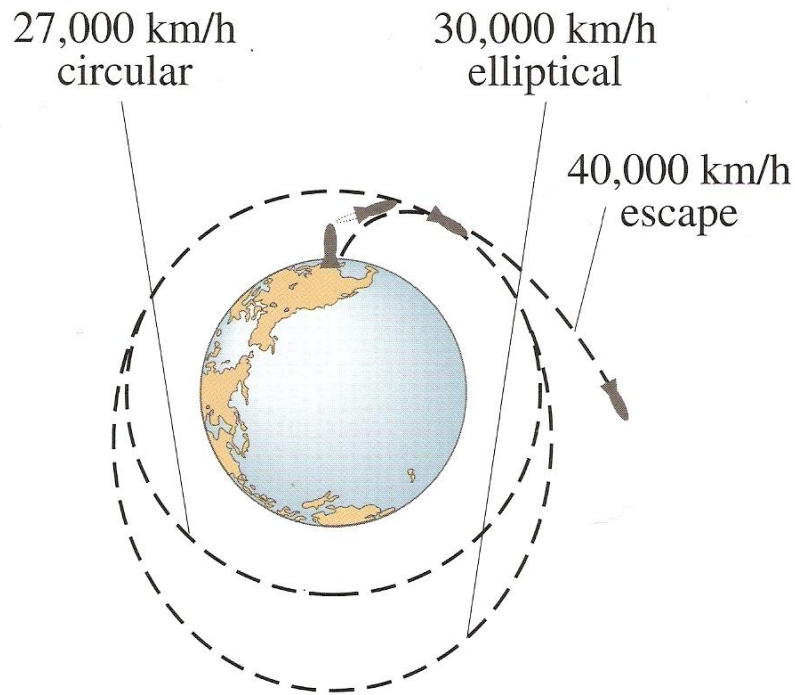
40,000 km/h escape

Figure 5-25 A moving satellite "falls" out of a straight-line path toward the Earth

F_G

ma_c

Weightlessness and Space
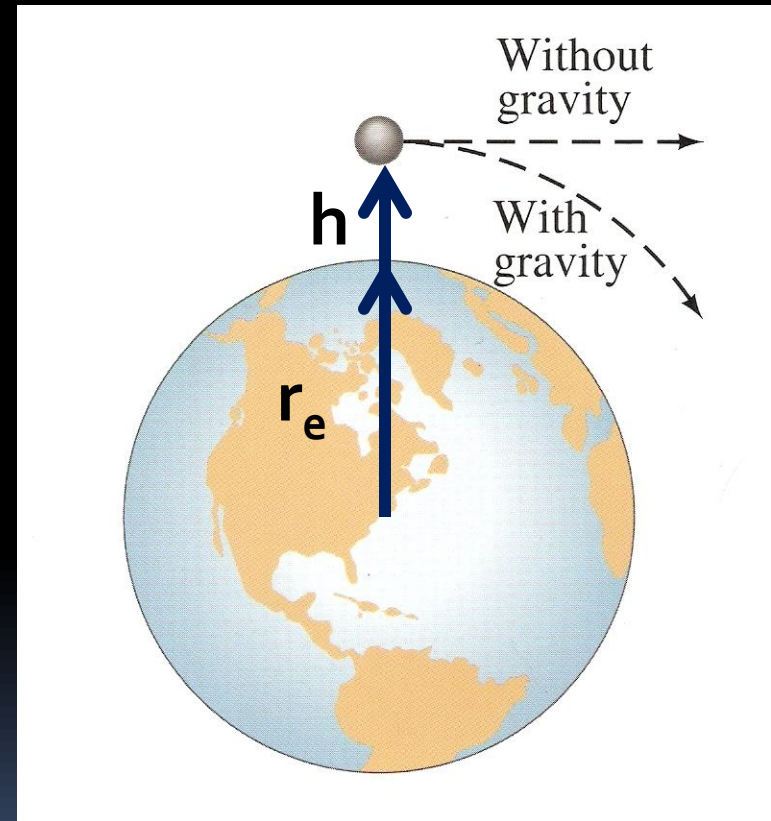
$$\sum F = ma_c$$

$$F_G = m_s a_c$$

$$a_c = \frac{v^2}{r}$$

$$F_G = G \frac{M_E m_s}{r^2}$$

F_G ma_c

Weightlessness and Space

$$r = r_e + h$$

Weightlessness and Space

$$\sum F = ma_c$$

$$F_G = ma_c$$

$$G\frac{M_E m_s}{r^2} = m_s\frac{v^2}{r}$$

$$G\frac{M_E}{r} = v^2$$

$$\sqrt{\frac{GM_E}{r}} = v$$

F$_G$ **ma$_c$**

Weightlessness and Space

- What happens if we change speed?

$$G\frac{M_E m_s}{r^2} = m_s \frac{v^2}{r}$$

$$G\frac{M_E}{r} = v^2$$

$$\sqrt{\frac{GM_E}{r}} = v$$

F_G

ma_c

Weightlessness and Space

$$G \frac{M_E m_s}{r^2} = m_s \frac{v^2}{r}$$
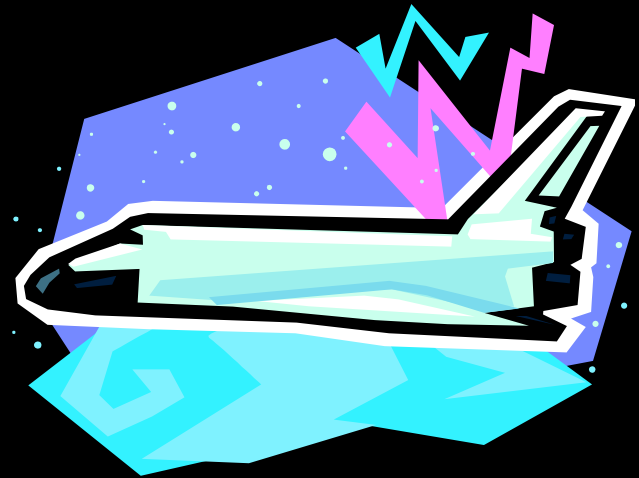
$$\sqrt{\frac{GM_E}{r}} = v$$

- If velocity increases, the force needed to keep the shuttle in orbit increases. Since the earth's gravity doesn't change, the shuttle will leave the circular orbit.

F_G ma_c

Weightlessness and Space

$$G\frac{M_E m_s}{r^2} = m_s \frac{v^2}{r}$$

$$\sqrt{\frac{GM_E}{r}} = v$$

- If velocity decreases, the gravitational force is now stronger than the radial acceleration and it will pull the shuttle toward the earth, which will increase gravitational force, and the shuttle will be pulled down to the earth's surface.
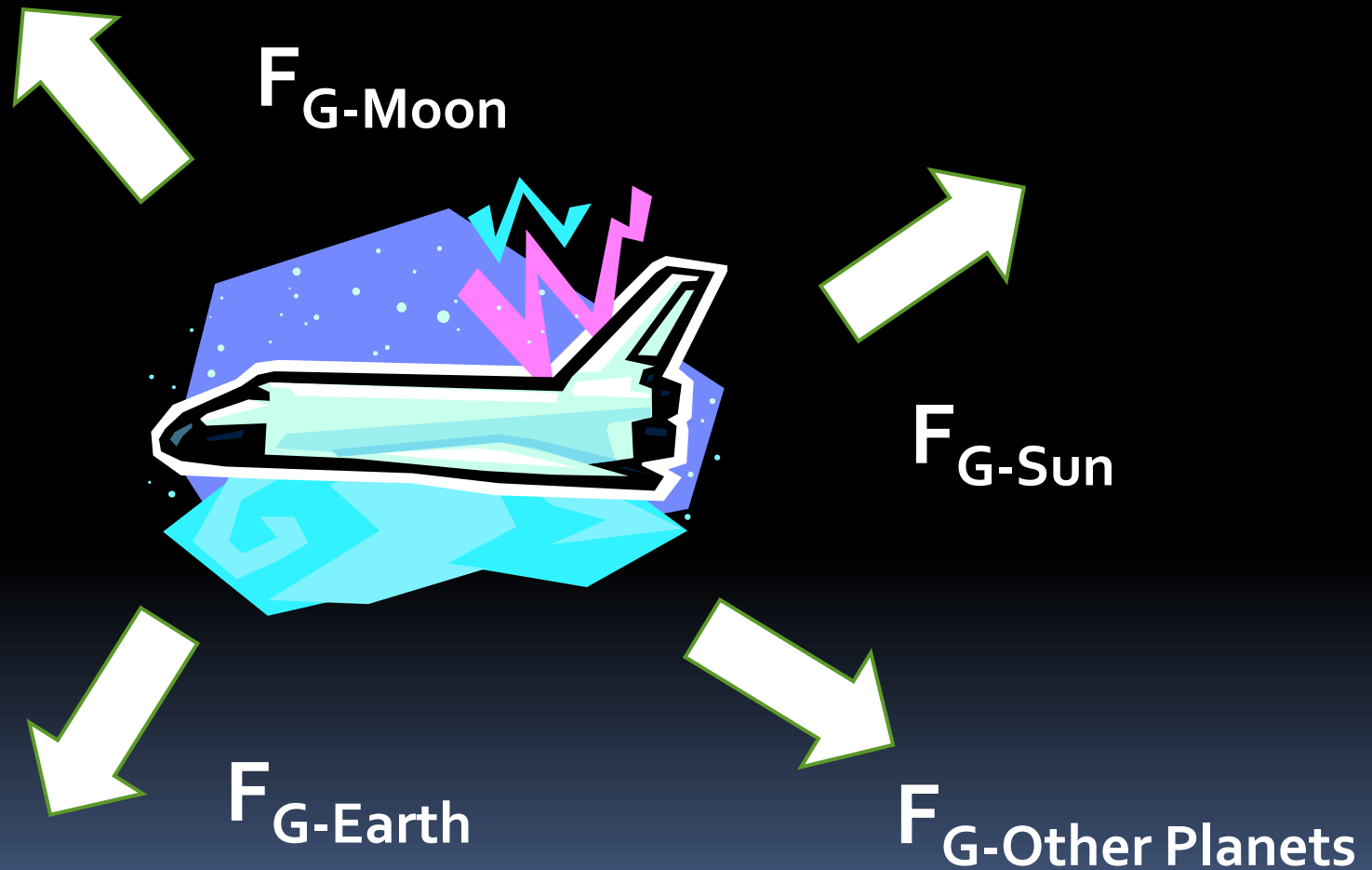
F_G

ma_c

Weightlessness and Space

- Only one speed for a given orbit (radius)
- Only one orbit (radius) for a given speed
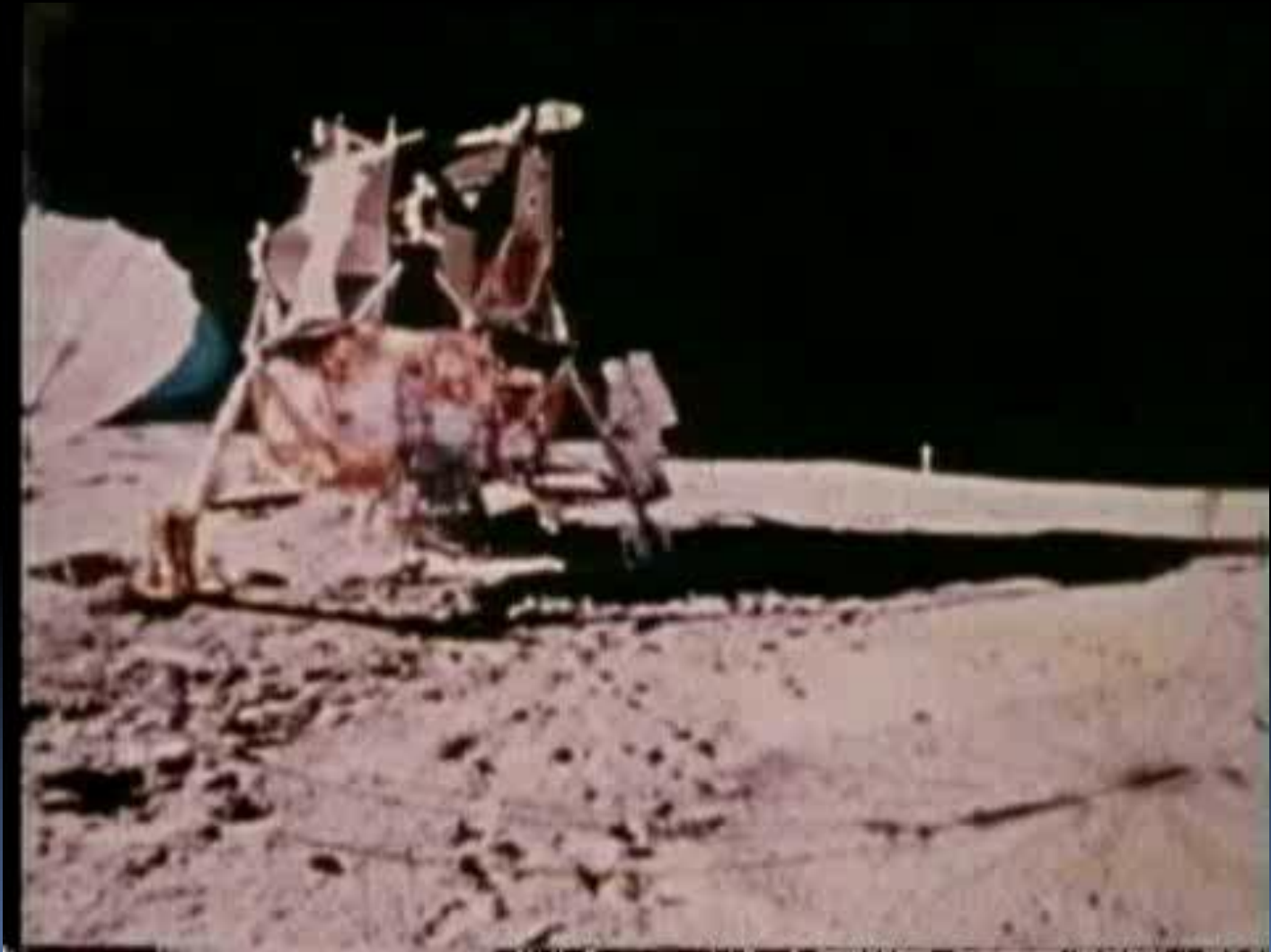
$$\sqrt{\frac{GM_E}{r}} = v$$

$$\frac{GM_E}{v^2} = r$$

F$_G$ **ma$_c$**

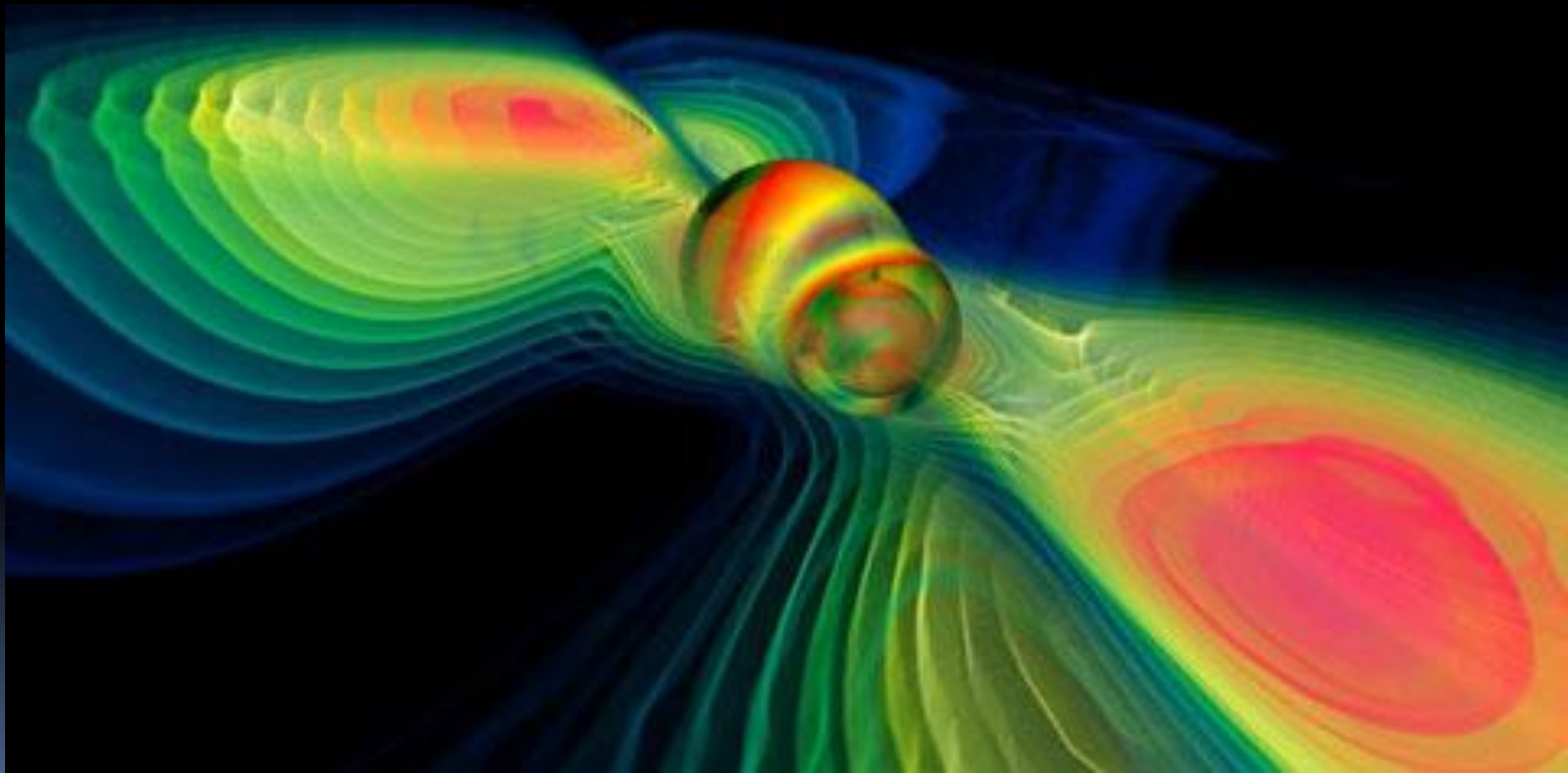# Space Away From Earth

Gravitational Force and Motion of Planets

GIANCOLI SECTION 5-10
TYPES OF FORCES IN NATURE

So What Forces Are There?

So What Forces Are There?

Fundamental Forces of Nature

- **The *gravitational force* is weak, but very long ranged. Furthermore, it is always attractive, and acts between any two pieces of matter in the Universe since mass is its source.**

So What Forces Are There?

Fundamental Forces of Nature

- **The *electromagnetic force* causes electric and magnetic effects such as the repulsion between like electrical charges or the interaction of bar magnets. It is long-ranged, but much weaker than the strong force. It can be attractive or repulsive, and acts only between pieces of matter carrying electrical charge.**

So What Forces Are There?

Fundamental Forces of Nature

- **The *weak nuclear force* is responsible for radioactive decay and neutrino interactions. It has a very short range and, as its name indicates, it is very weak.**

So What Forces Are There?

Fundamental Forces of Nature

electromagnetic force + weak nuclear force =

electro-weak nuclear force

So What Forces Are There?

Fundamental Forces of Nature

- **The *strong nuclear force* is very strong, but very short-ranged. It acts only over ranges of order 10^{-13} centimeters and is responsible for holding the nuclei of atoms together. It is basically attractive, but can be effectively repulsive in some circumstances.**

So What Forces Are There?

Fundamental Forces of Nature

- **Currently attempts are being made to relate all fundamental forces into one, Grand Unified Theory**

- My GUT instinct is that it won't happen anytime in the near future

Learning Objective(s):

- The student is able to design an experiment for collecting data to determine the relationship between the net force exerted on an object, its inertial mass, and its acceleration.

- The student is able to apply to calculate the gravitational force on an object with mass m in a gravitational field of strength g in the context of the effects of a net force on objects and systems.

- The student is able to apply to calculate the gravitational field due to an object with mass M, where the field is a vector directed toward the center of the object of mass M.

Learning Objective(s):

- The student is able to express the motion of an object using narrative, mathematical, and graphical representations.
- The student is able to design an experimental investigation of the motion of an object.
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Learning Objective(s):

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- The student is able to articulate situations when the gravitational force is the dominant force and when the electromagnetic, weak, and strong forces can be ignored.

Learning Objective(s):

- The student is able to connect the strength of the gravitational force between two objects to the spatial scale of the situation and the masses of the objects involved and compare that strength to other types of forces.

- The student is able to connect the strength of electromagnetic forces with the spatial scale of the situation, the magnitude of the electric charges, and the motion of the electrically charged objects involved.

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Learning Objective(s):

- The student is able to use representations of the center of mass of an isolated two-object system to analyze the motion of the system qualitatively and semi-quantitatively.

- The student is able to make predictions about the motion of a system based on the fact that acceleration is equal to the change in velocity per unit time, and velocity is equal to the change in position per unit time.

Learning Objective(s):

- The student is able to evaluate using given data whether all the forces on a system or whether all the parts of a system have been identified.

- The student is able to create mathematical models and analyze graphical relationships for acceleration, velocity, and position of the center of mass of a system and use them to calculate properties of the motion of the center of mass of a system.

Essential Knowledge(s):

- A system is an object or a collection of objects. Objects are treated as having no internal structure.
  - A collection of particles in which internal interactions change little or not at all, or in which changes in these interactions are irrelevant to the question addressed, can be treated as an object.
- Inertial mass is the property of an object or a system that determines how its motion changes when it interacts with other objects or systems.

Essential Knowledge(s):

- Gravitational mass is the property of an object or a system that determines the strength of the gravitational interaction with other objects, systems, or gravitational fields.
  - The gravitational mass of an object determines the amount of force exerted on the object by a gravitational field.
  - Near the Earth's surface, all objects fall (in a vacuum) with the same acceleration, regardless of their inertial mass.

Essential Knowledge(s):

- A vector field gives, as a function of position (and perhaps time), the value of a physical quantity that is described by a vector.

  - Vector fields are represented by field vectors indicating direction and magnitude.

  - When more than one source object with mass or electric charge is present, the field value can be determined by vector addition.

Essential Knowledge(s):

- A gravitational field at the location of an object with mass m causes a gravitational force of magnitude mg to be exerted on the object in the direction of the field.

  - On the Earth, this gravitational force is called weight.

  - The gravitational field at a point in space is measured by dividing the gravitational force exerted by the field on a test object at that point by the mass of the test object and has the same direction as the force.

  - If the gravitational force is the only force exerted on the object, the observed free-fall acceleration of the object (in meters per second squared) is numerically equal to the magnitude of the gravitational field (in newtons/kilogram) at that location.

Essential Knowledge(s):

- An observer in a particular reference frame can describe the motion of an object using such quantities as position, displacement, distance, velocity, speed, and acceleration.
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  - A choice of reference frame determines the direction and the magnitude of each of these quantities.

Essential Knowledge(s):

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- A force exerted on an object is always due to the interaction of that object with another object.
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Essential Knowledge(s):

- If an object of interest interacts with several other objects, the net force is the vector sum of the individual forces.

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  - A force exerted on an object can be represented as an arrow whose length represents the magnitude of the force and whose direction shows the direction of the force.
  - A coordinate system with one axis parallel to the direction of the acceleration simplifies the translation from the free-body diagram to the algebraic representation. physics 2

Essential Knowledge(s):

- Gravitational force describes the interaction of one object that has mass with another object that has mass.

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- A magnetic force results from the interaction of a moving charged object or a magnet with other moving charged objects or another magnet.

Essential Knowledge(s):

- Gravitational forces are exerted at all scales and dominate at the largest distance and mass scales.

- Electromagnetic forces are exerted at all scales and can dominate at the human scale.

Essential Knowledge(s):

- The strong force is exerted at nuclear scales and dominates the interactions of nucleons.

- The linear motion of a system can be described by the displacement, velocity, and acceleration of its center of mass.

Essential Knowledge(s):

- The acceleration is equal to the rate of change of velocity with time, and velocity is equal to the rate of change of position with time.

  - The acceleration of the center of mass of a system is directly proportional to the net force exerted on it by all objects interacting with the system and inversely proportional to the mass of the system.

  - Force and acceleration are both vectors, with acceleration in the same direction as the net force.

Enduring Understanding(s):

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- Objects and systems have properties of inertial mass and gravitational mass that are experimentally verified to be the same and that satisfy conservation principles.

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- All forces share certain common characteristics when considered by observers in inertial reference frames.
- Classically, the acceleration of an object interacting with other objects can be predicted by using .

Enduring Understanding(s):

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- Certain types of forces are considered fundamental.

- The acceleration of the center of mass of a system is related to the net force exerted on the system, where .

Big Idea(s):

- Objects and systems have properties such as mass and charge. Systems may have internal structure.

- Fields existing in space can be used to explain interactions.

- The interactions of an object with other objects can be described by forces.

- Interactions between systems can result in changes in those systems.

QUESTIONS?

Homework

#43-54