Genphysics q2 mod2 Newton's Law of Universal Gravitation

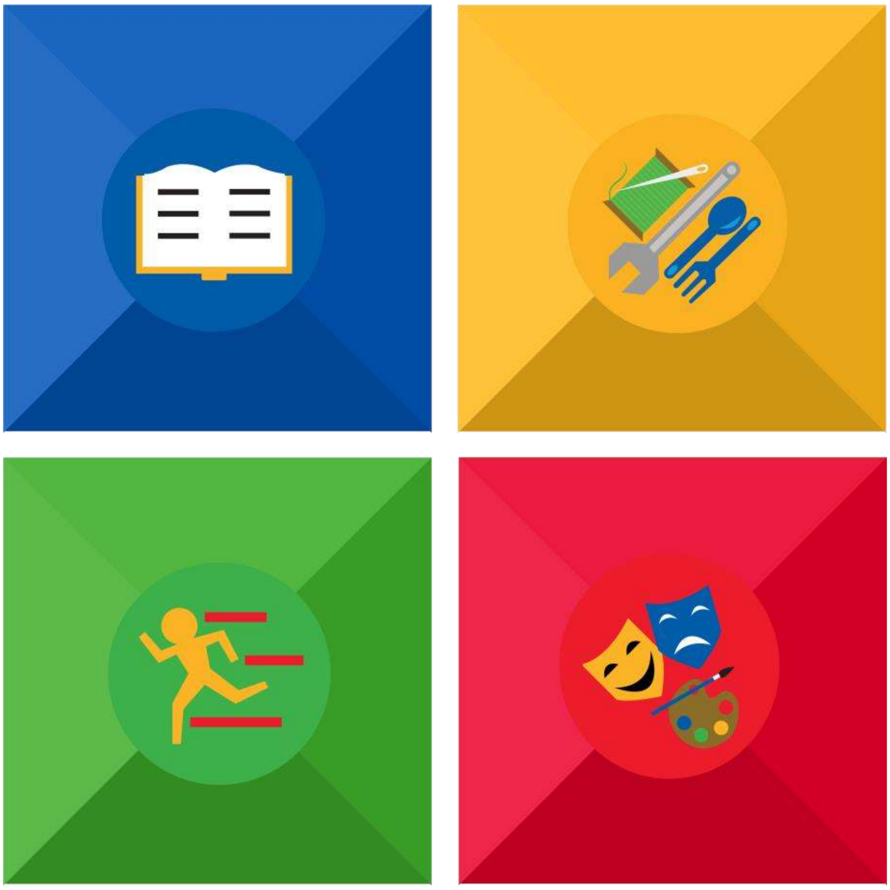
Mechanical Engineering (University of San Carlos)

Senior High School

General Physics 1

Quarter 2 – Module 2:

Lesson 1:Newton's Law of Universal Gravitation Gravitational Field, and Gravitational Potential Energy



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General Physics 1

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Lesson 1:Newton's Law of Universal Gravitation Gravitational Field,

and Gravitational Potential Energy

Introductory Message

For the facilitator:

Welcome to the General Physics - Grade12 Alternative Delivery Mode (ADM) Module on Lesson 1: Newton's Law of Universal Gravitational Field, and Gravitational Potential Energy!

This module was collaboratively designed, developed and reviewed by educators both from public and private institutions to assist you, the teacher or facilitator in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

This learning resource hopes to engage the learners into guided and independent learning activities at their own pace and time. Furthermore, this also aims to help learners acquire the needed 21st century skills while taking into consideration their needs and circumstances.

In addition to the material in the main text, you will also see this box in the body of the module:

Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their own learning. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to the General Physics - Grade12 Alternative Delivery Mode (ADM) Module on Lesson 1: Newton's Law of Universal Gravitational Field, and Gravitational Potential Energy!

The hand is one of the most symbolized part of the human body. It is often used to depict skill, action and purpose. Through our hands we may learn, create and accomplish. Hence, the hand in this learning resource signifies that you as a learner is capable and empowered to successfully achieve the relevant competencies and skills at your own pace and time. Your academic success lies in your own hands!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be enabled to process the contents of the learning resource while being an active learner.

This module has the following parts and corresponding icons:

What I Need to Know	This will give you an idea of the skills or competencies you are expected to learn in the module.
What I Know	This part includes an activity that aims to check what you already know about the lesson to take. If you get all the answers correct (100%), you may decide to skip this module.
What's In	This is a brief drill or review to help you link the current lesson with the previous one.
What's New	In this portion, the new lesson will be introduced to you in various ways such as a story, a song, a poem, a problem opener, an activity or a situation.
What is It	This section provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.
What's More	This comprises activities for independent practice to solidify your understanding and skills of the topic. You may check the answers to the exercises using the Answer Key at the end of the module.
What I Have Learned	This includes questions or blank sentence/paragraph to be filled in to process what you learned from the lesson.
What I Can Do	This section provides an activity which will help you transfer your new knowledge or skill into real life situations or concerns.

Assessment	This is a task which aims to evaluate your level of mastery in achieving the learning competency.
Additional Activities	In this portion, another activity will be given to you to enrich your knowledge or skill of the lesson learned. This also tends retention of learned concepts.
Answer Key	This contains answers to all activities in the module.

At the end of this module you will also find:

References	This is a list of all sources used in developing this module.

The following are some reminders in using this module:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Don't forget to answer *What I Know* before moving on to the other activities included in the module.
3. Read the instruction carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and checking your answers.
5. Finish the task at hand before proceeding to the next.
6. Return this module to your teacher/facilitator once you are through with it.

If you encounter any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and gain deep understanding of the relevant competencies. You can do it!

What I Need to Know

This module was designed and written to make easier for you to understand and to assist you to master the lesson in Newton's Law of Universal Gravitation, gravitational field and gravitational potential energy. In our everyday life we are used to see falling objects like for example, coconut fruit from the coconut tree fell on the ground same thing as falling apple from the tree, this made Newton's think about the problem of the motion of the planet. What makes the coconut and apple fall? And why coconut and apple fell straight to the ground? What is the force between apple and the ground? You will find the answer to this questions following discussion on the topic of Newton's law of universal gravitation, gravitational field and gravitational potential energy.

At the end of the module, you are expected to:

a. use Newton's law of gravitation to infer gravitational force, weight, and acceleration due to gravity (**STEM_GP12G-IIb- 16);**

b. discuss the physical significance of gravitational field (**STEM_GP12G-IIb-18)**; and

c. apply the concept of gravitational potential energy in physics problems (**STEM_GP12G-IIb- 19).**

What I Know

DIRECTION: Read and analyze the following expressions below. Choose the letter that best describe your answer. Use a separate sheet of paper as your answer sheet.

1. The evidence that stimulated Newton to propose the law of universal gravitation emerged from a study of __________.
   A. the motion of the moon and other celestial or heavenly bodies
   B. the fall of an apple to the earth
   C. the gravitational interaction of smaller objects upon the earth
   D. there is no evidence.

2. The discovery of “Universal Gravitation” is associated with:
   A. Robert Hook
   B. Isaac Newton
   C. James Joule
   D. Max Plank

3. The force of gravity on you is greatest when you are standing _____.
   A. far above Earth's surface
   B. just above Earth's surface
   C. on Earth's surface
   D. below Earth’s surface

4. Two objects move toward each other because of gravitational attraction. As the objects get closer and closer, the force between them _____.
   A. remains constant
   B. decreases
   C. increases
   D. no effect

5. According to Newton’s law of universal gravitation, the force of gravitational attraction between a planet and an object located upon the planet’s surface depends upon ______________.
   A. the radius of the planet
   B. the mass of the object
   C. the mass of the planet
   D. All of the above

6. The gravitational field is directed.
   A. towards the earth

B. away from earth
C. with no direction
D. in a specific direction making angle with earth

7. The gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not, is known as

A. force of inertia
B. force of limiting friction
C. force of gravity
D. field force

8. The force due to which everybody of the universe attracts every other body is

A. force of gravitation
B. force of limiting friction
C. force of inertia
D. force of mechanics

9. The Earth attracts a body with a force equal to its____________

A. weight
B. area
C. volume
D. pollution

10. In the mathematical form of Newton's law of universal gravitation, the symbol **G** stands for _______________.

A. gravity
B. the acceleration of gravity
C. the gravitational constant
D. the gravitational potential energy

11. Energy object possesses due to its position is called

A. kinetic energy

B. mechanical energy

C. potential energy

D. chemical energy

12. Change in Gravitational Potential Energy can be written as:
   A. mgh
   B. mh
   C. mg
   D. gh

13. Gravitational potential is always
   A. infinite
   B. zero
   C. positive
   D. negative

14. You and your friend want to go to the top of the Eiffel Tower. Your friend takes the elevator straight up. You decide to walk up the spiral stairway, taking longer to do so. Compare the gravitational potential energy (U) of you and your friend, after you both reach the top.
   A. Both of you have the same amount of potential energy.
   B. It is impossible to tell, since the distances are unknown.
   C. Your friend's U is greater than your U, because she got to the top faster.
   D. It is impossible to tell, since the times are unknown.

15. A very massive object A and a less massive object B move toward each other under the influence of mutual gravitation. Which force, if either, is greater?
   A. The force on B
   B. The force on A
   C. Both forces are the same
   D. cannot be determined

Lesson 1 Newton's Law of Universal Gravitation, Gravitational Field, and Gravitational Potential Energy

Are you familiar with the popular story of Newton, who was sitting under an apple tree, an apple fell on his head, "aha moment" that prompted him and he suddenly thought of the Universal Law of Gravitation. As the legends told, this is almost certainly not true in its details, but the story contains origins of what actually happened.

What's In

What really Happened with the apple?
According to early books, Newton was inspired to create the connection between falling bodies and astronomical motions. At that moment, he saw an apple fell from a tree and made him wonder why the fruit always fell straight to the ground; why did it not swing off to the left or right? By Newton's 2nd law, which we learned from the previous lesson, there must be a force that acts on the apple to cause this acceleration, and let's call this force as "gravity". The apple started in the tree and landed on the earth, which means there must be a force of attraction between the apple and the earth, this is where the concept of the Law of Universal gravitation originated.

Notes to the Teacher

This module prepares students to the lesson of Newton's Law of Gravitation, Gravitational field and Gravitational Potential energy.

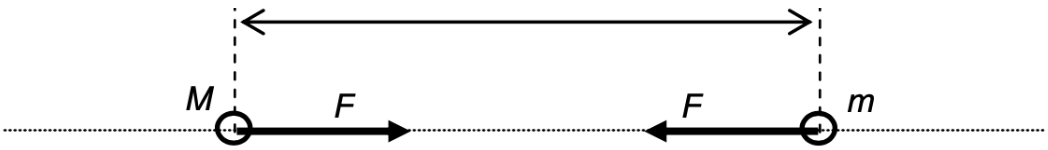
What's New

In the topic of dynamics, forces, mass, momentum and energy, we have been dealing with weights of various objects. Weight is name given to the force acting on the object due to gravity. The force of attraction between two objects must be proportion to the objects' masses, this is known as the gravitational force. To explain this, we use Newton's Law of Universal Gravitation.

<u>NEWTON'S LAW OF UNIVERSAL GRAVITATION</u>

Gravitation is a natural occurrence by which physical objects attract each other due to their masses. There is a force that appears whenever masses are present, and this is a non-contact force. In relation to this, Newton concluded that this non-contact gravitational force must be responsible for the falling of an apple from a tree, as it is also the cause for the rotation of the moon about the earth. According to Newton's Law of universal Gravitation which states that:

Every object in the Universe attracts every other object with a force directed along the line of centers for the two objects that is proportional to the product of their masses and inversely proportional to the square of the separation between the two objects.



This means that for two point masses M and m, separated by distance r, the magnitude of the gravitational force attracting them towards each other is:

$$\boxed{F = \frac{GMm}{r^2}}$$

where:
F is the magnitude of the gravitational force [N]
G, the constant of universal gravitation, is 6.67×10^{-11} N m^2 kg^{-2}
M is one of the point mass [kg]
m is the other point mass [kg]
r is the centre–to–centre distance between the two point masses [m]

Example 1

(a) Calculate the gravitational force exerted between the Earth and its Moon, given mass of the Earth, $M_E = 6.0 \times 10^{24}$ kg; mass of the Moon, $M_M = 7.4 \times 10^{22}$ kg; distance between the centers of the Earth and Moon, $D = 3.8 \times 10^8$ m.

Solution

Gravitational force: $F = \frac{GMm}{r^2} = \frac{(6.67 \times 10^{-11}\ N.m^2/kg^2)\ (6.0 \times 10^{24}\ kg)\ (7 \times 10^{24}\ kg)}{(3.8 \times 10^8\ m)^2}$

$= \mathbf{2.05 \times 10^{20}\ N}$

(b) What is the gravitational force, between two bowling balls of 7.26 kg each, with their centers separated by 0.30m?

Solution

Gravitational force: $F = \frac{GMm}{r^2} = \frac{(6.67 \times 10^{-11}\ N.m^2/kg^2)\ (7.26\ kg)\ (7.26\ kg)}{(0.30\ m)^2}$

$\mathbf{= 3.9 \times 10^{-8}\ N}$

Practice Problem

What is the gravitational force between two 15 kg packages that are 0.35 m apart?

Applications and relevance to daily life

Gravitational force is very evident in our everyday life. Like for example, when you throw a ball into the air, the ball will fall back to the ground, as Isaac Newton says; “What Goes Up, Must Come Down”. It also plays a very important role in many processes on earth. The gravitational attraction of both the Moon and Sun on the earth’s oceans cause ocean tide. Also in terms of planetary motion, gravitational force is responsible for keeping the Earth in its orbit around the Sun. The knowledge of universal gravitation, is also important in understanding space travel.

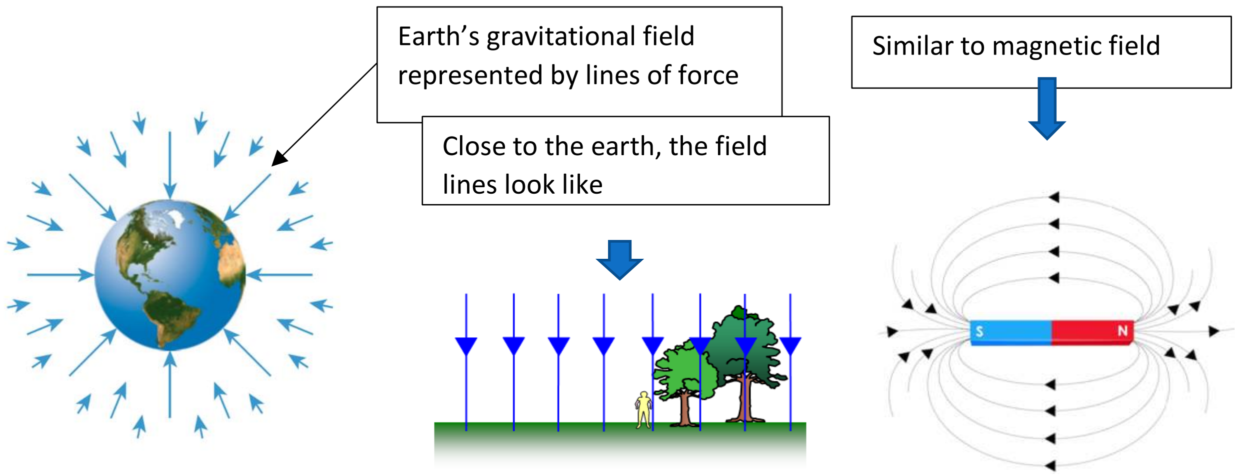
GRAVITATIONAL FIELD

The concept of gravitational field started when Newton wondered how the sun could exert a force on planet earth, which was hundreds of millions of kilometers away. How can two objects exert attractive force on each other when they are not in contact with each other? It is because gravitational fields affect anything that has mass. Newton realized that all objects with mass attract each other. Gravitational attractive forces between two objects only affect their motion when at least one of the objects is very massive. This explains why we are aware of the force that attracts us and other objects towards the Earth – the Earth is very massive. The mass of the Earth is
about 6×10^{24} kg.

When you pick up an object such as a coin, there is a direct contact between you and the coin. This direct contact exerts a force on the coin, causing it to move in the way that it does. However, the coin also has a weight due to its presence in the Earth's gravitational field. How is this force exerted, even when there is no direct contact between the Earth and the coin? A force is exerted on the coin from the Earth because the coin is in the Earth's ***gravitational field*** . We can define the field due to a body as the region of space surrounding it where other bodies will feel a force due to it.

What is gravitational field?

The concept of magnetism, which developed by Michael Faraday, was also applied to **gravity**. This is the concept of the field to explain how a magnet attract objects. A **gravitational field (vector)** is the force field that exists in the space around every mass or group of masses. This field cannot be touched or seen, but we can try to model it using *field lines* or *lines of force* . In a field line diagram below, the direction of the field line at a point gives the direction of the force of attraction that would be felt by a small mass placed there. The relative density of field lines on the diagram is an indication of the strength of the field. We can compare this with the more familiar magnetic field patterns.
How would the earth's gravitational field look like? See diagram below:



Gravitational Field Strength (symbol: g and units: N kg^{-1} or m s^{-2})

Based on Newton's law of Universal gravitation $F = \frac{GMm}{r^2}$ we may derive the gravitational field strength(**g**):

Thus, **g** = GM

Example 1

Data required: G = 6.67×10^{-11} N m^2 kg^{-2}, mass of the Earth = 6.0×10^{24} kg, radius of the Earth = 6.4×10^6 m.
(a.) Treating the Earth as a perfect sphere, Find the field strength at the

Earth's surface. Use the given data to solve the problem.

Solution

g=$GM/r^2 = (6.67 \times 10^{-11}\ N\ m^2kg^{-2} \times 6.0 \times 10^{24}\ kg)/\ (6.4 \times 10^6\ m)^2$ = **<u>9.8 N kg^{-1}</u>**

(b.) Compute **g** at a distance of 4.5×10^7m from the center of a spherical object whose mass is 3.0×10^{23}kg.

Solution

g =$GM/r^2 = (6.67 \times 10^{-11}\ N\ m^2kg^{-2} \times 3.0 \times 10^{23}\ kg)/(4.5 \times 10^7\ m)^2$ = **<u>0.0099m/s^2</u>**

Practice Problem

Compute **g** for the surface of the moon. Its radius is 1.7×10^6 m and its mass is 7.4×10^{22} kg.

<u>Applications and relevance to daily life</u>

The earth and moon exert a force, or pull, on each other even though they are not in contact. In other words, the two bodies interact with one another's **gravitational field**. Another **example** is the interaction of the earth and a satellite in orbit around it.

What's More

<u>GRAVITATIONAL POTENTIAL ENERGY</u>

Gravity is a force which tries to pull two objects toward each other. The Earth's gravity is what keeps you standing on the ground, and what makes objects to fall. Everything on this planet is held by gravity. The house we live in, the buildings, the plants, water, animals, and the air we breathe are all held by gravity. Same thing in the universe the planets, the moons, and the stars have gravity. People living within the earth have gravity. Consider an object that is present at some height, earth's gravitational force acts on that object to attract it towards the earth's surface, therefore, it is called gravitational potential energy.

What is gravitational potential energy?

It is a potential energy associated with a body's weight and its height above the ground. Example of this is a water stored in a dam and a skateboard on top of a ramp.

Gravitational Potential Energy depends on the mass and height:

There is a direct relation between gravitational potential energy and the mass and height of an object. More massive objects have greater gravitational potential energy. And the higher that an object is elevated, the greater the gravitational potential energy. These relationship are expressed by the given equation below:

$$\boxed{PE_{grav} = mgh}$$

where:
PE_{grav}, is the gravitational potential energy [J].
m, represents the mass of the object [kg]
g, represents the gravitational field strength (9.8 N/kg on Earth)
h, represent the height of the object [m]

To rearrange mass: $\boxed{m = PE_{grav} / gh}$

To rearrange height: $\boxed{h = PE_{grav} / mg}$

NOTE: 1 newton [N] = 1 joule/meter [J/m]

1 Joule [J] = 1 newton/meter [N/m] therefore, 1N = 1J

Example 1
A cart is loaded with a brick and pulled at constant speed along an inclined plane to the height of a seat-top. If the mass of the loaded cart is 5.0 kg and the height of the seat top is 0.55 meters, then what is the potential energy of the loaded cart at the height of the seat-top?

Solution
PE_{grav} = mgh
PE_{grav} = (5 kg)(9.8 N/kg)(0.55 m)
PE_{grav} = 26.95J

Example 2
A larger block of stone is held at a height of 15m having gained 4500J of GPE. How much does it weight?

Solution
m = PE_{grav} /gh = 4500J /(9.8 N/kg)(15 m)
m= 30.61 kg

Example 3
An object whose mass is 43kg is hanging on a thin wire. The object has a gravitational potential energy of 3160.5J. How high is the object above the ground?

Solution
h = PE_{grav} /mg = 3160.5J /(43kg)(9.8 N/kg)
h= 7.5m

Practice Problem

1.An object has a gravitational potential energy that is 833 J? Its height above ground is 4.25 m. What is its mass?

2. What is the gravitational potential energy of a 150kg object suspended 5m above the earth's surface?

3. An object has a gravitational potential energy of 41772.5J and has mass of 1550kg. How high is it above the ground?

Applications and relevance to daily life

When you go to mountain trip and see a rock resting on the edge of the cliff remember that it has some energy stored in it in the form of gravitational potential energy. Another is water that is held in dam reservoirs for irrigation, and generating electricity in hydropower plants. Since the water held in reservoirs is at rest and is prohibited from flowing the energy present in, it will be a potential energy because this is the type of energy which is at rest.

What I Have Learned

FILL IN THE BLANKS

Direction: Use the word below to complete the passages.

Gravitational field - Apple – Isaac Newton – Gravity – Weight – Contact -Universal Gravitation -Height – Sun - Massive

______________is the force that keeps us grounded on the earth. If the Earth's ________________ suddenly disappeared we would float away into space. ______________ first conceptualized the theory of gravity. It is said he thought of the idea when an ___________ fell on the ground. Later proposed the law of __________________.

The concept of gravitational field start when Newton's wondered how the __________could exert a force on planet earth, how these planets will exert attractive forces on each other when they are not in ___________with each other. Gravitational attractive force between two objects only affect their motion when at least one of the object is very ______________.

Gravitational potential energy is a potential energy associated with a body ____________and it's ____________above the ground.

What I Can Do

In these activities, you will investigate Newton's Law of Gravitation. You will experimentally investigate the fact that the acceleration of an object due to gravity is independent of its mass.

Materials:

Several objects of different masses and sizes, such as pencils, crumpled piece of paper, coins, plastic bottle cover. Make sure they are not breakable!

Procedure:

Record your observation in a separate sheets of paper

1.You will drop various objects to the floor to see if they will fall at different rates. Record your observation
2. Drop a pencil and crumpled piece of paper. Make a repeatable trial for your observation.Which one fell faster? Explain
3. Drop a coin and plastic bottle cover. Make a repeatable trial for your observation. Which one fell faster? Explain
4. Standing on a chair drop the pencil and coin. Make a repeatable trial for your observation.Which one fell faster? Explain
5. From your observation make a conclusion.

Assessment for this Activity

Points	Description
4	**A**. Learner is able to predict the motion of objects falling to the ground. **B.** Learner is able to make repeatable measurements of falling objects. **C.** Learner able to thoughtfully consider the initial predictions and revise them, if in correct. **D.** Learner is able to correctly conclude that mass has no effect on acceleration
3	Learner achieves the first three objectives above.
2	Learner achieves the first two objectives above.
1	Learner achieve only the first objective.
0	Learner achieves none of the objectives above.

Assessment

Direction.Choose the letter that best represents your answer. Use a separate piece of paper that will serve as your answer sheet.

1. What is the GPE of a chandelier that has a mass of 9.5kg and is 3m high.
A. 279.3
B. 280.3
C. 297.3
D. 273.3

2. What is the mass of an object that is hanging 12.6m above the surface of the earth and has a gravitational potential energy of 2778.3J?

A. 226
B. 224
C. 225
D. 227

3. When a person holds a ball above Earth's surface, the system contains gravitational potential energy. Where is this potential energy stored?
A. in the ball

B. inside Earth

C. in the person holding the ball

D. in the gravitational field between Earth and the ball

4. The moon has a mass of 7.35×10^{22}kg and a radius of 1.74×10^{6} m. What is the gravitational force between the moon and an 85 kg astronaut? (G = 6.673×10^{-11} N•m2 /kg2)
A. 1.4×10^{2} N
B. 1.3×10^{2} N
C. 1.4×10^{4} N
D. 1.3×10^{4}N

5. Which of the following is an expression of gravitational field strength?

A. Gm1m2/r
B. Gm1m2/r^2
C. Gm_E/r
D. GM/r^2

7. Evidence confirms that gravitational mass___________________

A. depends on gravitational field strength

B. varies with location

C. depends on free-fall acceleration

D. equals inertial mass

8. Which of the following is an expression of gravitational potential energy?

A. mgh
B. m/gh
C. h/gh
D. g/mh

9. The mass that determines an object's attraction to another object is determined by its:
A. gravitational mass

B. inertial mass

C. gravitational field strength

D. weight

10. Which of the following equations expresses Newton's law of universal gravitation?
A. $F_g = mv^2t/r$
B. $F_g = m1m2/r$
C. $g = GM_E/r^2$
D. $F_g = Gm1m2/r^2$

Identify the following statement as **True** or **False**.

11. Astronauts on the space station do not weigh anything.
12. The more massive an object is, the more the object will be attracted to earth.
13. The more massive the Earth, the less that another object will be attracted to earth.
14. More massive objects have greater gravitational potential energy.
15. The higher the object is elevated, the greater the gravitational potential energy.

Additional Activities

TRY THIS!

Materials:

1 sheet of graphing paper

1 ruler

Procedure:

Part A.

1. The table below shows the gravitational force between Saturn and some particles in Saturn's ring. All of the particles are the same distance, 180,000 km, from Saturn's center.

Table 1. Mass and Gravitational Force Data

Mass of Ring Particle (kg)	Gravitational Force between Saturn and ring particle (in 10,000 N)
2	23
3	35
4	47
5	58
6	70
7	82
8	93
9	105

2. Use the data in the table to make a graph of the relationship between mass and gravitational force. Label your graph "Gravitational Force and mass".
Hint: *Put the data for mass on the horizontal axis and the data for gravitational force on the vertical axis.*

3. Look at your graphed data, and record in your answering sheet any relationship you notice.

Part B.

1. The table below shows the gravitational force between Saturn and some ring particles that are at different distance from the planet. All of the particles have a mass of 1 kg.

Table 1. Distance and Gravitational Force Data

Distance of 1-kg Ring Particle from Center of Saturn (in 1,000 km)	Gravitational Force between Saturn and 1-kg ring particle (in 10,000 N)
100	38
120	26
130	22
150	17
180	12
200	9
220	8
250	6
280	5

2. Use the data in the table to make a graph of the relationship between distance and gravitational force. Label your graph "Gravitational Force and distance".
Hint: *Put the data for distance on the horizontal axis and the data for gravitational force on the vertical axis.*

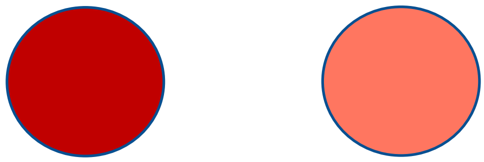
3. Look at your graphed data, and record in your answering sheet any relationship you notice.

Analysis

Use separate answering sheet for the following question

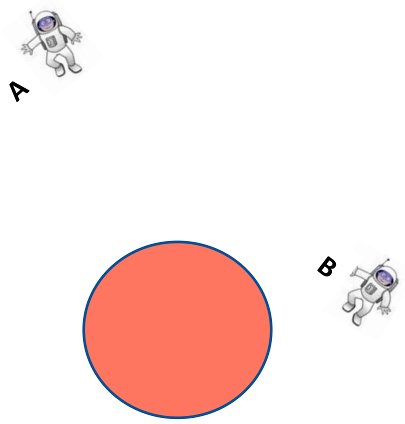
1. Compare your two graphs, Identify and explain any:
    a. similarities
    b. differences

2.Look at the picture of two planets below. The diameter is the same, but Planet B has twice the mass of Planet A. which one would you expect to have a stronger pull of gravity on its surface? Explain



Planet A **Planet B**

3.Look at the picture below of an astronaut at two different distances from a planet. In which position, A or B, would there be a stronger gravitational pull between the astronaut and the planet? Explain



Answer Key

What I Know:

1. A & B
2. B
3. C
4. C
5. D
6. A
7. D
8. A
9. A
10. C
11. C
12. A
13. D
14. A
15. C

What I have learned:

1. Gravity
2. Gravitational Field
3. Isaac Newton
4. Apple
5. Universal gravitation
6. Sun
7. Contact
8. Massive
9. Weight
10. Height

Assessment:

1. A
2. C
3. D
4. A
5. D
6. D
7. A
8. A
9. A
10. D
11. FALSE
12. TRUE
13. FALSE
14. TRUE
15. TRUE

Additional Activities:

- it depends on the learner answer.

What I Can Do:

The score on the assessment is based on the answer of each student

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