Gravitational Interactions I

Level: Conceptual / Physics I  
Teacher: Kim

Review the Concept of ‘Force’
- If we apply a force on an object, the object’s speed will change. Or if an object’s speed is changing, there must be a force responsible to do that.
- If an object is moving at a constant speed, but if the object’s is changing its direction, there must be a force responsible to do that.
- A force is not only responsible to change the speed of an object, but it also can change the direction of the object. Ex) recall circular motion

Q1) How can we justify that the force of gravity of Earth is acting on the Moon? Explain your answer by applying Newton’s 1st law!!

Gravitational Fields – Force at distance
- According to Newton’s 3rd law, earth exerts a gravitational force on the moon while the moon exerts a gravitation force on the earth.
- Before, people(including Newton) were bothered by the fact that not only earth is exerting a force on an object that is not physically ‘touching’, but the moon is over 200,000 miles away.
- Eventually, a new concept of force called (force) field has been developed.
- Instead of thinking that of the earth and the moon ‘directly’ exerting a force on each other, “a middle man”, called a gravitational field is responsible for the interaction between them
- The earth exerts a gravitational force field which extends outward in all directions for a great distance
- Anything in the gravitational field will experience a force and gets weaker the farther we go out.
**Newton’s Law of Universal Gravitation**

Newton did **not** discover gravity. What he discovered was that gravity is **universal(!)**.

=> *Everything pulls on everything else that involves only mass and distance*

**Q2** When the planet Uranus approached Jupiter, the great mass of Jupiter caused Uranus to slightly wobble (perturbation'). However, in the eighteenth century, scientists have observed that even though Uranus was far away from Jupiter, there was a point in space where Uranus again showed perturbation. What could this mean?

a) The law of gravity was a little different at far distance in space
b) Actually, there really was a planet near that point. It’s just that scientist did not discover it yet
c) Newton’s law of gravity applies only to certain areas in space; only areas near the Earth

- Formula for Newton’s Law of Gravitation

\[ F_g = G \frac{m_1 m_2}{r^2} \]

- \(m_1, m_2\) is the mass of the object, and \(r\) is the distance between the two **center** of each mass, **not** from the surface
- The gravitational force \(F_g\) between two objects is **directly** related to the mass and **inversely** related to the distance squared between the two objects
- The greater the mass of the object the stronger the \(F_g\), the greater the distance between the two objects the weaker the \(F_g\)
- The force the two masses exerting on each other is always the same
- \(G\) is called the universal gravitational constant, where the value is \(G=6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2\)

*How was the constant ‘G’ discovered?*

**step i)** Suspend a triangular container of very dense mercury flask of a known mass on one arm of a very sensitive balance that is put in equilibrium

**step ii)** Place a 6-ton lead sphere beneath the mercury flask. The lead is massive enough to pull the flask downward.

**step iii)** Add known weights on the hook until balance is restored. Since the system is balanced, it means that the total weight on the hook is equal the gravitational pull \(F_g\) due to the mercury flask and the lead
Q3) The small value of the constant ‘$G$’ means that gravity is a very (strong or weak) force

\[ F_g = G \frac{m_1 m_2}{r^2} \]

Q4) Find the gravitational attractive force between two objects of mass $m_1=4\text{kg}$ and $m_2=2\text{kg}$, separated by a distance of 3m. ($G=6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$)

a) $1.34\times10^{-11}\text{N}$  
   b) $5.93\times10^{-11}\text{N}$  
   c) $7.32\times10^{-11}\text{N}$  
   d) $9.71\times10^{-11}\text{N}$

Q5) Find the gravitational attractive force between two objects of mass $m_1=8\text{kg}$ and $m_2=4\text{kg}$, separated by a distance of 3m. ($G=6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$)

a) $23.7\times10^{-11}\text{N}$  
   b) $12.5\times10^{-11}\text{N}$  
   c) $3.2\times10^{-11}\text{N}$  
   d) $16.91\times10^{-11}\text{N}$

Q6) Find the gravitational attractive force between two objects of mass $m_1=4\text{kg}$ and $m_2=2\text{kg}$, separated by a distance of 6m. ($G=6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$)

a) $9.72\times10^{-11}\text{N}$  
   b) $7.51\times10^{-11}\text{N}$  
   c) $3.25\times10^{-11}\text{N}$  
   d) $1.48\times10^{-11}\text{N}$

Q7) Calculate the force of gravity on a 1kg mass at Earth’s surface.

The mass of the Earth is $m_e=6\times10^{24}\text{kg}$, and its radius is $R_e=6.4\times10^6\text{m}$.

($G=6.67\times10^{-11}\text{N}\cdot\text{m}^2/\text{kg}^2$)

a) 17.4N  
   b) 14.9N  
   c) 12.4N  
   d) 9.8N
\[ F_g = G \frac{m_1 m_2}{r^2} \]

**Q8** Calculate the force of gravity on a 1kg mass if it were 6.4×10^6 m above the Earth’s surface. The mass of the Earth is \( m_e = 6 \times 10^{24} \) kg, and its radius is \( R_e = 6.4 \times 10^6 \) m. \((G=6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)\)

a) 7.42N  

b) 4.96N  

c) 2.44N  

d) 1.12N

**Q9** Calculate the force of gravity between the Earth and the moon. The average distance between the Earth and the moon is \( r = 3.8 \times 10^8 \) m. The mass of the Earth \( m_e = 6 \times 10^{24} \) kg and mass of the moon is \( m_m = 7.4 \times 10^{22} \) kg. \((G=6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)\)

a) \( 7.4 \times 10^{20} \) N  

b) \( 4.1 \times 10^{20} \) N  

c) \( 2.0 \times 10^{20} \) N  

d) \( 1.1 \times 10^{20} \) N

**Q10** A plane is flying at a height of 10000 meters above the surface. If the plane descent down to a height of 5000 meters, how much will \( F_g \) decrease? \((G=6.67 \times 10^{-11} \text{ N} \cdot \text{m}^2/\text{kg}^2)\)

a) \( F_g \) will reduce to one-half  

b) \( F_g \) will triple  

c) Not sure, but \( F_g \) will surely reduce a lot  

d) \( F_g \) will remain pretty much unchanged