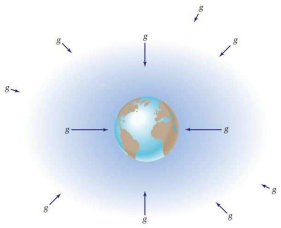
SPH4U UNIVERSITY PHYSICS

ELECTRIC, GRAVITATIONAL, & ... FIELDS

- Gravitational Fields (P.293-296)

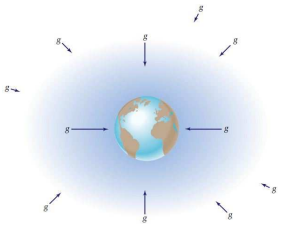
Gravitational Fields

The universal law of gravitation tells us that at any point in space surrounding a massive object, such as Earth, we can calculate the gravitational force on a second object sitting at that point in space.



Gravitational Fields

A vector exists at every point in space surrounding the central object, pointing toward it and depending on the object's mass and the distance from its centre. The ***gravitational field*** *of the central object can be represented by this collection of vectors that are all directed radially inward toward the mass.*



NOTE!

A gravitational field exerts attractive forces on objects with mass.

Gravitational Fields

GRAVITATIONAL FIELD

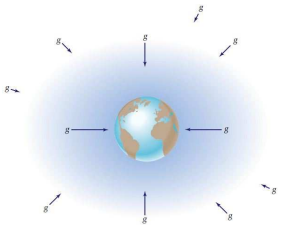
- field of force that exists in a region of space around an object
- is a vector quantity (g)
- exerts an attractive force on objects with a mass
- can be represented by a series of lines directed radially inward toward the mass

NOTE!

*The fundamental concept is that a **field** is a property of space. An object influences the space around it, setting up either a gravitational, electric or magnetic field. The object producing the field is called the "source." This field in turn exerts a force on other objects located within it.*

Gravitational Field Strength

*The strength of the field, or the **gravitational field strength**, is the force of attraction per unit mass of an object placed in a gravitational field. On Earth, the gravitational field strength is ~ 9.8 N/kg. Notice that this has the same magnitude as the acceleration due to gravity on Earth's surface, and thus has the same symbol, g.*



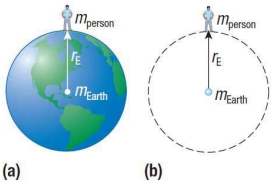
Gravitational Field Strength

For spherical objects, the strength of the gravitational field at a distance from the surface is the same whether the mass actually fills its volume (a) or sits at a point in the centre (b). To calculate the gravitational field strength as a function of a central spherical mass, we combine Newton's second law (F=ma) with the universal law of gravitation.

$$F_g = F_g$$

$$m_{object}g = \frac{Gm_{planet}m_{object}}{r^2}$$

$$g = \frac{Gm_{planet}}{r^2}$$

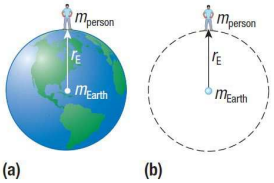


Gravitational Field Strength

NOTE!

This equation holds for any object in a gravitational field. If the object is near any large celestial body with mass m, we can replace the mass of the planet in the equation and generalize it.

$$g = \frac{Gm}{r^2}$$



Gravitational Field Strength

GRAVITATIONAL FIELD STRENGTH

- force of attraction per unit mass (g = 9.8 N/kg on Earth)

$$g = \frac{Gm_p}{r^2}$$

where g is the gravitational field strength at a point in space (N/kg)
G is the universal gravitational constant (6.67×10^{-11} N·m^2/kg^2)
m_p is the mass of the planet/celestial object (kg)
r is the distance between the centres of the masses (m)

NOTE!

An object's acceleration due to gravity does <u>not</u> depend on its own mass.

Universal Gravitation

PRACTICE

1. Calculate the magnitude of the gravitational field strength on the surface of Saturn, assuming that it is perfectly spherical with a radius of 6.03×10^7 m. The mass of Saturn is 5.69×10^{26} kg.

   g = 10.4 N/kg

Universal Gravitation

PRACTICE

2. On the surface of Titan, a moon of Saturn, the gravitational field strength has a magnitude of 1.3 N/kg. Titan's mass is 1.3 x 10^{23} kg. What is Titan's radius?

   r = 2.6 x 10^{6} m

Universal Gravitation

PRACTICE

3. Suppose that an object expanded until its radius doubled, while its mass stayed the same. Determine the effect on it's gravitational field strength.

   ∵ $g \propto 1/r^2$

   ∴ $g_{new} = \frac{1}{4} g_{old}$

Universal Gravitation

PRACTICE

4. Suppose that the mass of a planet doubled but its radius stayed the same. Determine the effect on it's gravitational field strength.

   ∵ $g \propto m$

   ∴ $g_{new} = 2g_{old}$

✔ Check Your Learning

TEXTBOOK

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