Grade 12 Physics

SPH4U

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Contents

Chapter 2

Unit 1B

2.1 Fictitious Forces and Apparent Weight

2.1.1 Fictitious Forces

Fictitious forces are also called apparent forces or perceived forces

Explanation: When the object is viewed from a non-intertial F.O.R, we created fictitious force to explain the motion and behavior

The fictitious forces will always act in the direction opposite to the direction of acceleration of the frame of reference.

The magnitude of each fictitious force can be calculated by:

$$F_{fict} = m|\vec{a_{F.O.R}}|$$

Perceived acceleration could be represented by $\vec{a_{per}}$

Note: The object's actual acceleration would be measured relative to an inertia FOR

2.1.2 Apparent Weight

Technically, this would be the sum of the normal force and the force of friction that a surface exerts on an object.

2.1.3 Some of the formulas

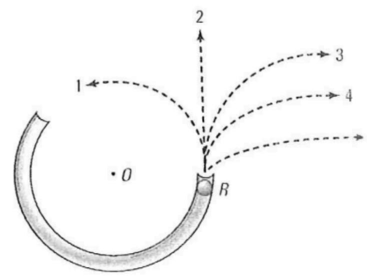
$$\sum \vec{F} = m\vec{a_{per}}$$

2.2 Lecture 2.5

2.2.1 Uniform Circular Motion

Direction: The velocity of an object at any point along a circle has a direction that is tangential to the circle

Question: If an object is attached to a string, swung in a circular motion and then the string is released, which of the five paths shown here will the object take?
ANS: Path 2



2.2.2 Centripetal acceleration

From the Newton second law, we understand that An object will accelerate in the same direction as the net force.

If the centripetal force is directed toward the centre of the circle, then what direction is the acceleration in? ANS: Toward the circle

In other words, the acceleration will always perpendicular to the velocity of the object.

2.2.3 Formulas

Formula 1:

$$\vec{a_c} = \frac{4\pi^2 R}{T^2}$$

$$\vec{a_c} = 4\pi^2 R f^2$$

$$\vec{a_c} = \frac{V^2}{R}$$

$\vec{a_c}$ is the acceleration of the object in $\frac{m}{s^2}$
R is the radius of the circular path that the object is moving around (in m)
T is the period of the object's motion
v is the speed of the object in (m/s)

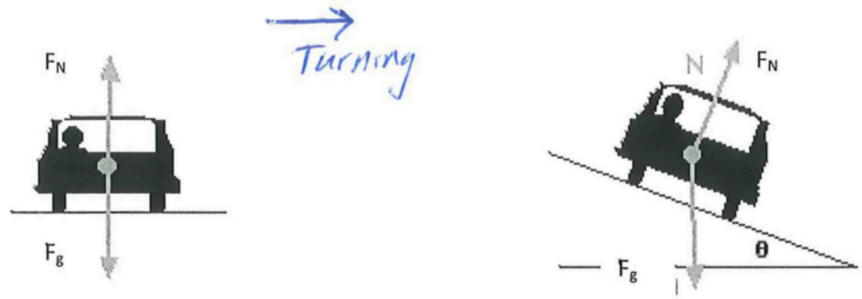
For clockwise:

direction of acceleration = direction of velocity + 90 degree

else:

direction of acceleration = direction of velocity - 90 degree

2.3 Motion of a car on Banked Turn



Unbanked Turn Banked Turn

2.3.1 Forces

For unbanked Turn, Static friction contribute to the centripetal force
For Banked Turn, both static friction and normal force contribute to the centripetal force

2.3.2 Critical Speed

Definition 2.3.1. *Critical speed the minimum speed needed at which a vehicle can travel around a curve, baked road without relying on static friction*

The formula for critical speed is defined as:

$$v = \sqrt{R * tan\theta * g}$$

v = Critical Speed
R = The radius of the banked turn
g = The acceleration by Gravity

Above the critical speed, the car wants to go up. At this case, friction must act down the bank to prevent sliding outward

Below the critical speed, the car wants to go down. At this case, friction must act up the bank to prevent sliding inward

2.4 Universal Gravitation, Gravitational field

2.4.1 Force of Gravity

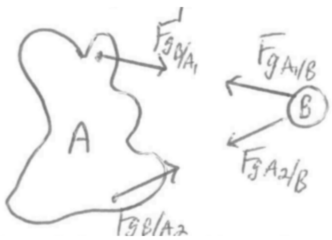
The formula for the **Force of Gravity** acting between two objects is:

$$Fg = \frac{G * m_1 * m_2}{R^2}$$

Fg = the magnitude of the force of gravity that m_1 exerts on m_2 and m_2 exerts on m_1
G = Universal Gravitational Constant
m_1 = the mass of one of the objects (in kg)
m_2 = the mass of the other object (in kg)
R is the distance separating the objects' center of mass in (m)

Remainder: **Altitude** refers to the distance between the Earth's surface and the object!

In reality, every particle in A exerts a force of gravity on every particle in B. If the objects (A and B) are relatively close together and large (relative to their separation distance) then these forces are not parallel.



*As the distance separating the two objects increases, the forces become closer to parallel

The **formula works** best for two objects who seperation distance is very large relative to their sizes, or when both object are perfect sphere

The **formula works well** for a very, very large sphere (whose mass is uniformly distributed through out) and a relatively small object on its surface

You can not use this formula when one object is inside of another object!

2.4.2 Gravational Fields

Definition 2.4.1. *A **force field** is a region surrounding an object in which the object is capable of exerting a force on another object*

A Gravational field is a region surrounding an object in which the object is capable of exerting a force of gravity on another object.

2.4.3 Differences between strength of gravity and acceleration

Acceleration due to gravity:

Units: $\frac{m}{s^2}$
What does it imply?: When an object is in free fall, it will accelerate at that rate
When is it true: Only when Fg is the only force on the object

Gravitational field strength:

Units: $\frac{N}{kg}$
What does it imply?: When an object is in free fall, it will accelerate at that rate
When is it true: Gravity is exertings a force of $|\vec{g}|$ Newtons for each Kg of mass

Specific types of field strengths are additive. The net gravitational field strength at a location is the sum of all the individual strengths of gravitational fields at that location OR $\sum \vec{g} = \vec{g_1} + \vec{g_2}$

When you need to calculate magnitude of Gravational field from that object M exerts on m:

$$Fg_{M/m} = \frac{GMm}{R^2} \tag{2.1}$$

$$Fg_{M/m} = mg \tag{2.2}$$

Add 2.1 and 2.2

$$g = \frac{GM}{R^2} \tag{2.3}$$

g is the magnitude of the grav field strength of M, at a specific location (in N/kg)
R is the distance that the location is from M's centre of mass(in m)
G is the universal gravitational constant ($G = 6.67 * 10^{-11} \frac{Nm^2}{Kg^2}$)

2.5 Satellites

A satellite is an object that orbits around another object

There are **natural** satellites and **artifical** object

- The moon is a **natural** satellite of the Earth
- The international space station (ISS) is an **artifical** object

2.5.1 Netwon's Cannon

His idea was: *if a cannon is placed on the top of a very tall mountain, and if you could ignore air resistance. The cannon shoots a cannonball horizontal*

At the idea speed: the distance the cannonball has fall **equals** the distance that the Earth has **turned away**

If $v < v_{idea}$, the distance between the ball and Earth's surface will **decrease**

If $v > v_{idea}$, the distance between the ball and Earth's surface will **increase**

The cannon must has a constant speed and travel in the perfect circular path

2.5.2 Geosynchronous

They have the same orbital period as the **rotational speed** of the object they are on the ground

The period is around **24 hrs**

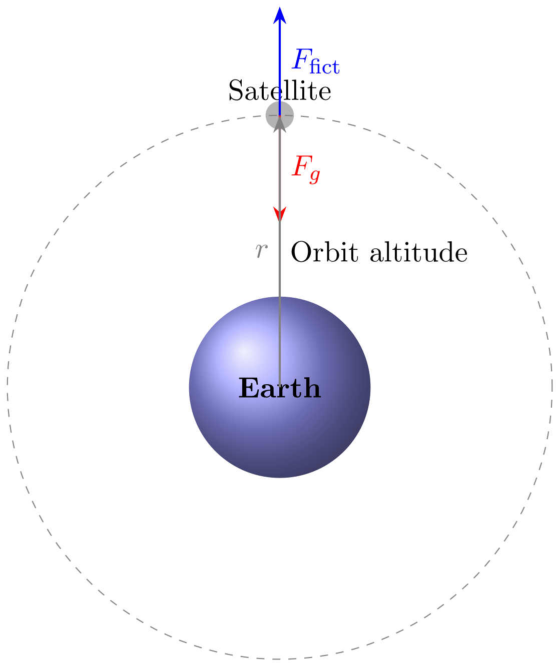
There is a special type of geosynchronous is called **Geostationary**

- "Hang above" a location on Earth's **Equator**
- They orbit in the same **direction** that the Earth rotates

2.5.3 Formulas related to satellite

We will derive each formulas in this handout:

To start off, let's draw the FBD for the satellite



Down is negative

Let's derive the formula for satellite:

$$\sum \vec{F} = m * \vec{a_{per}}$$
$$F_g - F_{fict} = 0$$
$$mg - m * |F_{FOR}| = 0$$
$$mg = ma_c$$
$$a_c = \frac{Gm}{R^2}$$

Sub in $a_c = \frac{V^2}{R}$:

$$\frac{v^2}{R} = \frac{Gm}{R^2}$$
$$v = \sqrt{\frac{Gm}{R}}$$

v = orbital speed
m = mass of the object in (kg)

Sub in $a_c = \frac{4\pi^2 R}{T^2}$

$$\frac{4\pi^2 R}{T^2} = \frac{Gm}{R}$$
$$T^2 = \frac{4\pi^2 R^3}{Gm}$$
$$T = \sqrt{\frac{4\pi^2 R^3}{Gm}}$$

2.6 Rotating Frame of Reference

2.6.1 Little problem

When a person is standing (on Earth) there are two forces acting on them:

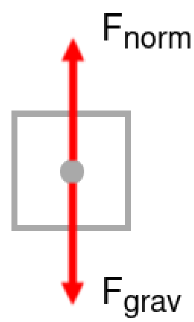


Figure 2.1: Normal force and Gravity

The normal force acting on the person is pushing force, thus a force of **compresion**. An object that has a compression force must be able to **withstand this force** or it will collapse. (See 2.6.1)

In the caes of a person, their muscles and their bones must be able to withstand this force, thus you **muskule-skeletal system develops** to withstand this force

When a person is in orbit around a planet, there is only the force of gravity acting on them! They are in **constant state of free fall**

FBD for a person orbiting a planet:

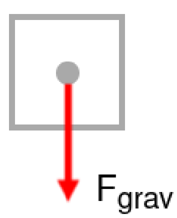


Figure 2.2: Force of Gravity

The person is missing the **normal force** (the compressive force) that they are used to feeling. Without the compressive force, the person's musculo=skeletal system starts to undergo **atrophication**

To solve this problem, we need to make sure that both two forces are acting on the person. The forces must be in **opposite direction** and one force must be a **compression force**

Solution 1

The spaceship is **accelerating** uniformly, in a straight line.

But, there are two problems:

1. Run out of fuel
2. As an object speed up, its **mass increases**. If mass increases, to maintain the acceleration the netforce would also increase

Solution 2

Get a very very large hallow ring and make it spin

For an internal F.O.R, there will be both **Force of Normal** and **Force of Gravity** acting on it

From an internal F.O.R:

$$\sum \vec{F} = m\vec{a_{per}}$$
$$F_N - F_{fict} = 0$$
$$F_N = F_{fict}$$
$$F_N = m * |a_{F.O.R}|$$
$$F_N = ma_c$$

We can calculate the v of the people:

$$F_N = ma_c$$
$$mg = ma_c$$
$$g = a_c$$
$$g = \frac{v^2}{R}$$
$$v = \sqrt{gR}$$

So, in the spaceship rotating question, we can always assume:

$$F_N = F_g$$

We can also using

$$a_c = \frac{4\pi^2 R}{T^2}$$

To sub in

$$g = \frac{4\pi^2 R}{T^2}$$
$$T = \sqrt{\frac{4\pi^2 R}{g}}$$

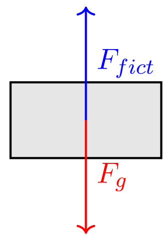
or

$$f = \sqrt{\frac{g}{4\pi^2 R}}$$

2.6.2 Perceived Acceleration in a Rotating Frame of Reference

When a person is stand on the equator, there are a_c to affect the ball

The **perceived** acceleration should be calculated like this:



Now, let's calculate the $\vec{a_{per}}$

$$\sum \vec{F} = m\vec{a_{per}} \tag{2.4}$$
$$F_N - F_{fict} = ma_{per} \tag{2.5}$$
$$mg - m\left|a_{F.O.R}\right| = ma_{per} \tag{2.6}$$
$$a_{per} = g - a_c \tag{2.7}$$

Note

You can always assume Earth's surface to be an inertial F.O.R unless:

- You need to be **extremely accurate**
- The question states **at the equator**