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**IDX G9 Physics S+ STUDY GUIDE ISSUE 5**

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**4.7 +4.8 Solving Problems with Newtons law: Free body diagram...**

1. **Equilibrium Problems**
2. **new terms**

**·Translational equilibrium:**

**·Definition: If the net force on an object is zero, then the object is in translational equilibrium.**

**·Two types:**

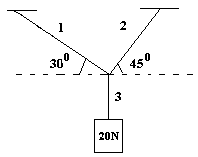
**·Object at rest**

**·Object moving at constant velocity**

**·Formula:**

=0 → &

1. **Practice by examples**

**Eg2. A 20.0 N object hangs at rest from string as shown in the figure. Find the tension force in each string.**

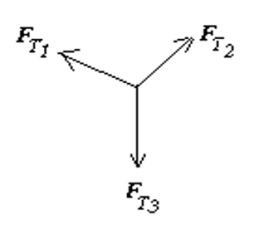
**Step 1:**

**Draw a free body diagram which is integrated by components of the motion**



2

**Step 2:**

**Analyze the relationship between the given data and the target data by equilibrium:**

1

1. =,

= 0,

**2.** = 0,

*,*

*,*

**Step 3:**

**Bring in the given data and get results**

= 20N

*Solve that:*

1. **Friction Problems**

**· Friction:**

**·Definition: Friction is a force that resists the relative motion or tendency of such motion of two surfaces in contact. So, the direction of friction is always towards the opposite of the motion.**

**·Two types which have learned:**

**·static friction () .This type of friction acts on objects when they are at rest and prevents them from starting to move. It must be overcome by an applied force to initiate motion.**

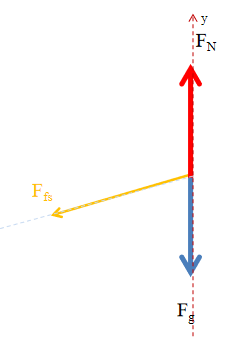
**·kinetic friction(). Also known as dynamic friction, this acts on objects that are already in motion. It opposes the movement and is generally weaker than static friction.**

**·Formula:**

**·=,**

**·=**

**Practice by examples:**

**Eg1. What is the maximum acceleration a car can undergo if the coefficient of static friction between the tires and the ground is 0.80?**

**Step 1:**

**Draw a free body diagram which is integrated by components of the motion**

**Step 2:**

**Analyze the relationship between the given data and the target data by equilibrium:**

*Objects does not move vertically,*

*So ,*

*Object accelerates at a(cceleration) in x direction:*

*=*

*For the maximum a, should be in this situation.*

*=,*

*=*

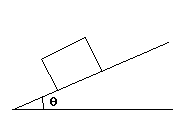
**Step 3:**

**Bring in the given data and get results**

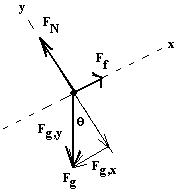
*= = 0.8 \* 9.8m/ = 7.84m/*

1. **Inclined Planes Problem**

**Practice by problems:**

**Eg1. A 5.0 kg box rests on a rough inclined plane, which makes a 30 angle with the floor (shown in the figure). Find the normal force and friction force on the box.**

**Step 1:**

**Draw a free body diagram which is integrated by components of the motion**

**Step 2:**

**Analyze the relationship between the given data and the target data by equilibrium:**

= , so

=, so =

, *mg, mg*

*mg, mg*

**Step 3:**

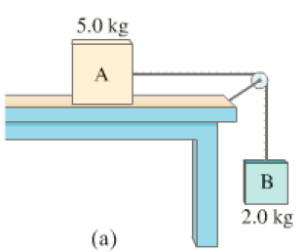
**Bring in the given data and get results**

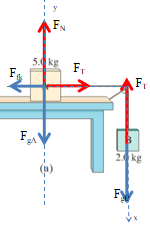
*mg = sin(30) \* 3.0kg \* 9.8 N/kg = 24.5N*

*mg = cos(30) \* 3.0kg \* 9.8N/kg 42.4N*

1. **Connected objects**

**The solution of connected objects is divided by the calculation of the whole object and the calculation of each objects. The following example will show the two solutions:**

***In Fig. 4–32a, two boxes are connected by a cord running over a pulley. The coefficient of kinetic friction between box A and the table is 0.20. We ignore the mass of the cord and pulley and any friction in the pulley. (a) Find the acceleration, a, of the system (assuming the cord doesn’t stretch). (b) Find the tension of the cord.***

***First solution: Divided***

**Step 1:**

**Draw a free body diagram which is integrated by components of the motion**

1

**Step 2:**

2

**Analyze the relationship between the given data and the target data by equilibrium:**

1:=

*,*

*2:*

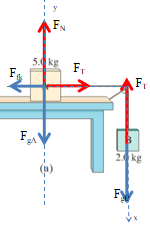
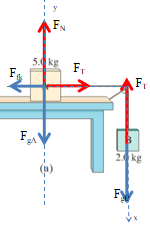
*So,*

*=*

**Step 3:**

**Bring in the given data and get results**

*-=1.4m/*

*=16.8N*

***Second Solution: Whole***

**Step 1:**

**Draw a free body diagram which is integrated by components of the motion**

**Step 2:**

**Analyze the relationship between the given data and the target data by equilibrium:**

*=*

*=*

**Step 3:**

**Bring in the given data and get results**

*-=1.4m/*

*=16.8N*

**8.1 Angular Quantities**

#### ****Angular Position and Displacement****

#### ****Angular Position ()****: The angle an object has rotated relative to a reference line.

#### ****Units****: Radians (rad). Defined as ​, where:

#### = arc length (m)

#### = radius (m)

* **Positive & Negative Convention**:
  + **Counterclockwise** → Positive
  + **Clockwise** → Negative

#### ****Converting Between Degrees and Radians****

* **Conversions**:
* **Formula for conversion**:
  + Degrees → Radians: ​
  + Radians → Degrees: ​​

#### ****Angular Velocity ()****

* **Definition**: The rate of change of angular displacement over time. ​
* **Units**: Radians per second (rad/s).
* **Properties**:
  + **Constant** : Graph of is a straight line.
  + **Changing** : Graph of is curved, and the slope of the tangent at a point gives instantaneous .
* **Direction**: Angular velocity is a **vector**.
  + **Counterclockwise** → Positive
  + **Clockwise** → Negative

#### ****Relationship Between Linear and Angular Quantities****

| **Linear Quantity** | **Angular Quantity** | **Relationship** |
| --- | --- | --- |
| Displacement () | Angular Displacement () |  |
| Velocity () | Angular Velocity () |  |

### ****Check Your Understanding****

### Two points, A and B, are on a rotating disk, with B farther from the center. Which point has a **greater angular velocity**? Which has a **greater linear velocity**? Why?

### Convert 2.5 radians into degrees. Convert 135° into radians.

### The Earth completes one full rotation in **24 hours**. What is its angular velocity in rad/s?

### If a gear with radius 0.2 m is rotating at 10 rad/s, what is the linear velocity of a point on its edge?

**5.1 Kinematics of Uniform Circular Motion**

### ****1. Uniform Circular Motion****

* **Definition**: An object moving in a circular path at a **constant speed** experiences **uniform circular motion**.
* **Velocity Vector**:
  + Always **tangent** to the circle.
  + **Direction changes** continuously, but **magnitude remains constant**.

### ****Centripetal Acceleration****

* **Definition**: Acceleration that points toward the center of a circular path, causing a change in direction.
* **Formula**: 
  + = centripetal acceleration (m/s²)
  + = speed of the object (m/s)
  + = radius of the circular path (m)
  + = time to complete one full revolution (s)
  + = frequency of the object (Hz)

### ****Check Your Understanding****

1. A satellite orbits Earth with a period of **90 minutes** at a radius of **7000 km**. Find its orbital speed.
2. If the radius of a circular path **doubles**, but the speed remains the same, how does the centripetal acceleration change?
3. Two wheels are connected by a belt, with **one wheel twice the radius** of the other. How do their speeds compare?

### ****5.2 Dynamics of Uniform Circular Motion****

### ****1. Centripetal Force****

* **Definition**: The **net force** directed **toward the center** of a circular path that keeps an object moving in uniform circular motion.
* **Not a new force**: It is the **sum** of existing forces that cause circular motion.
* **Formula**:
  + = centripetal force (N)

### ****2. Identifying the Source of Centripetal Force****

* Centripetal force is provided by different forces in various situations:

| **Scenario** | **Centripetal Force Provided By** |
| --- | --- |
| **Ball on a string** | Tension in the string |
| **Car turning on a road** | Static friction between tires and road |
| **Planet orbiting the sun** | Gravitational force |
| **Roller coaster loop** | Normal force and gravity |

### ****3. Effects of Centripetal Force on Motion****

* **If**  → **Uniform circular motion occurs.**
* **If**  → The object moves **outward** (curve is wider).
* **If**  → The object moves **inward** (curve is tighter).

### ****4. Centripetal vs. "Centrifugal" Force****

* **Centripetal force**: **Real force** that keeps an object moving in a circle.
* **"Centrifugal force"**: **Not a real force**—it is the sensation of inertia pushing outward.

### ****5. Motion in Vertical Circles****

* **At the top of a loop**:
  + If , then  **must be at minimum** to stay in a circular path.
  + **Minimum speed**: ​
* **At the bottom of a loop**:
  + Tension is greatest at the bottom due to gravity pulling downward.

### ****Check Your Understanding****

1. A car makes a turn on an icy road and starts sliding outward. Explain why this happens in terms of centripetal force.
2. A **5.0 kg** object is swung in a **1.5 m** radius vertical circle. Find the minimum speed needed at the top to maintain circular motion.
3. A satellite is in orbit around Earth. If its speed doubles while maintaining the same radius, by what factor does the required centripetal force change?