University Physics I (Phys214) - Lesson Sheet 1

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Chapter 5 - Application of Newton's Laws of Motion

APPLICATION OF NEWTONS LAWS OF MOTION describes why the sifaka, a lemur (old-world monkey) from Madagascar, spreads out its arms and legs in front of itself while making spectacular leaps from tree to tree.

THE STUDENT LEARNING OUTCOME is **SLO2:** Use Newton's law of motion to analyze objects in dynamic equilibrium and undergoing acceleration.

WEEKLY LEARNING OBJECTIVES are to:

- Solve problems about objects in equilibrium;
- Use free-body diagrams, Newton's second law, and the problem-solving approach to solve dynamics problems;
- Work with and distinguish between mass and weight;

HOMEWORK IS DUE on the Friday following the next class period. Please upload homework assignments as a pdf to Google Scholar. You can either scan your assignment or take a picture of your assignment and convert it to a pdf. If you have an iPhone, tap on the 'Share' icon, then share to iBooks to automatically convert the jpg to a pdf.

WEEK ONE PROBLEMS Chapter 5 problems #: 3, 7, 9, 13, 17, 19, 25.

LOOKING FORWARD TO NEXT WEEK we will complete Chapter Five.

FORCES ARE INTERACTIONS, pushes and pulls, between **agents** and **objects**. An object at rest with no net forces on it will stay at rest. An object in motion with no net forces acting on it will continue moving in a straight line at constant speed. [1] Forces are in units called **newtons**. [2] [3]

[1] **Newton's First Law**

[2] 1 newton = 1 N = $1 \frac{kg \times m}{s^2}$

[3] 1 pound (force) = 1 lb = 4.45 N

- Weight is caused by gravity and always points vertically downward. [4] Your sensation of weight [5] is the magnitude of the contact forces supporting an object.
- Spring force is caused by the compression or tension of a spring.
- Tension force is caused by a string or rope pulling on an object. The direction of the tension force is in the direction of the string or rope.
- Normal forceis the force exerted on an object by the surface it is resting on. The normal force is perpendicular to the surface.
- Thrust is the force of air expelled from a jet turbine or rocket that propels an object forward. Thrust is in the direction opposite the direction of which the exhaust gas is expelled.
- Electic and magnetic forces are long-range forces acting on charged particles. [6]

[4] $\vec{w} = mg$

[5] the apparent weight

[6] We will discuss these forces in detail in Physics II.

FORCES CAUSE OBJECTS TO ACCELERATE, to change their velocity. A larger force causes a larger acceleration. The connection between force and motion is described by [7] $\vec{a} = \vec{F_{net}}/m$

[7] **Newton's Second Law**

OBJECTS INTERACT WITH ONE ANOTHER as action/reaction pairs. Every force occurs as one member of an action/reaction pair of forces. [8] The two members of the pair always act on *different* objects. The two members of the action/reaction pair point in *opposite* directions and are *equal* in magnitude

[8] **Newton's Third Law**

FOR EQUILIBRIUM PROBLEMS the net forces equal zero because $\vec{a} = 0$. Objects at rest or moving at constant velocity are at equilibrium.

1. Use a picture
2. Identify what is known and what you are trying to find
3. Draw a free-body diagram
4. Evaluate [9] [10]
5. Assess if result is reasonable

[9] $\Sigma F_x = ma_x = 0$

[10] $\Sigma F_y = ma_y = 0$

FREE BODY DIAGRAMS should be drawn using a ruler to draw figures to scale, and a protractor to draw and measure angles. FBDs should be a minimum of 3-inches by 3-inches. [11] [12]

[11] to make your life easier...

[12] Tactics Box 4.2 discusses how to identify forces using free body diagrams.

In Class Problems

EQUILIBRIUM PROBLEMS FOLLOW THE SAME BASIC FORMAT

In equilibrium, the sums of the x- and y-components of the force are zero.

STRATEGIZE If an object is in equilibrium, the net force acting on it must be zero. We will use this fact to find the forces that keep it in equilibrium.

PREPARE Check that the object is in equilibrium: [13]

- An object at rest is in static equilibrium.
- An object moving at a constant velocity is in dynamic equilibrium.

Draw a free-body diagram to determine which forces you know and which you need to solve for.

SOLVE An object in equilibrium must satisfy Newton's second law

You can find the force components that go into these sums directly from your free-body diagram. From these two equations, [14] [15] solve for the unknown forces in the problem.

ASSESS Check that your result has the correct units, is reasonable, and answers the question.

PROBLEM 1–SYLLABUS Please go to Google Classroom, enroll for the class and print out your syllabus. Go to `https://classroom.google.com/c/MTUyNTI3NDQ0MDBa`. The class code is **kk6aw2y**. [16]

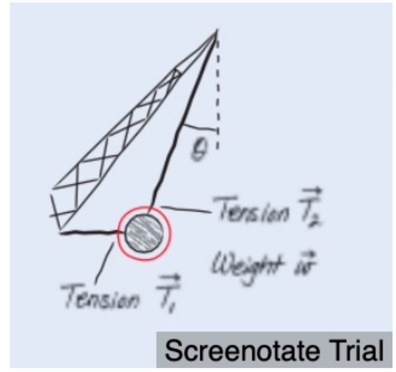
[13] Does $\vec{a} = 0$?

[14] $$\Sigma F_x = m \cdot a_x$$

[15] $$\Sigma F_y = m \cdot a_y$$

[16] You will need to use your OLC email address to access Google Classroom.

PROBLEM 2–EXAMPLE 5.2 A wrecking ball weighing 2500 N hangs from a cable. Prior to swinging, it is pulled back to a 20° angle by a second, horizontal cable. What is the tension in the horizontal cable?



STRATEGIZE Is the object in equilibrium? [17]

[17] $\Sigma F_{net} = 0$

PREPARE Draw a free body diagram of the wrecking ball to identify the forces: tension force 1, tension force 2, and weight.

SOLVE

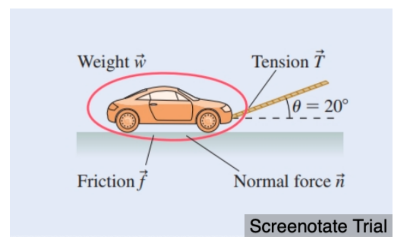
$$\Sigma F_x = m \cdot a_x$$

$$\Sigma F_y = m \cdot a_y$$

ASSESS Does the answer make sense?

PROBLEM 3–EXAMPLE 5.4 A car with a mass of 1500 kg is being towed at a steady speed by a rope held at a 20° angle from the horizontal. A friction force of 320 N opposes the car's motion.

What is the tension in the rope?



STRATEGIZE Is the object in equilibrium? [18] If so, what kind of equlibrium?

[18] $\Sigma F_{net} = 0$

PREPARE Draw a free body diagram of the car to identify the forces: normal force, tension force, weight, and friction forces.

SOLVE

$$\Sigma F_x = m \cdot a_x$$

$$\Sigma F_y = m \cdot a_y$$

ASSESS Does the answer make sense?

FOR DYNAMICS PROBLEMS the net forces do not equal zero because the object is accelerating. $\vec{a} \neq 0$. Find the net forces:

1. Use a picture
2. Identify what is known and what you are trying to find, often the force causing the aceleration [19]
3. Draw a free-body diagram
4. Evaluate, [20] [21]
5. Assess if result is reasonable

PROBLEM 4–EXAMPLE 5.5 A golfer putts a 46 g ball with a speed of 3.0 m/s. Friction exerts a 0.020 N retarding force on the ball, slowing it down. Will her putt reach the hole, 10 m away?

STRATEGIZE Is the object in equilibrium? [22] How to find the acceleration? How to find the net force?

PREPARE Draw a free body diagram of the golf ball to identify the forces: normal force, weight, and friction forces.

SOLVE

$$\Sigma F_x = m \cdot a_x$$

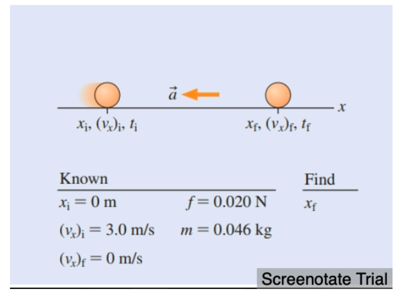
$$\Sigma F_y = m \cdot a_y$$

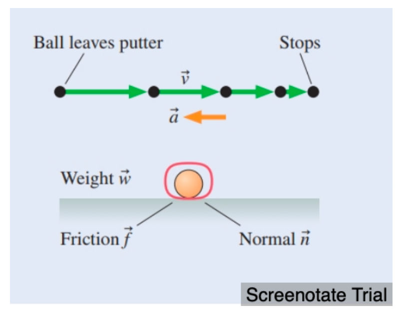
ASSESS Does the answer make sense?

19
$$\vec{a} = \frac{\vec{F}}{m}$$

20
$$\Sigma F_x = m \cdot a_x$$

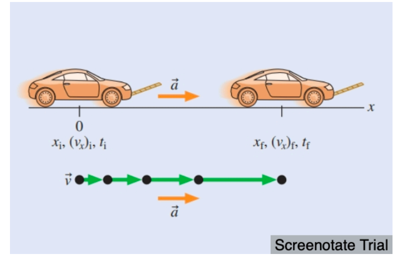
21
$$\Sigma F_y = m \cdot a_y$$

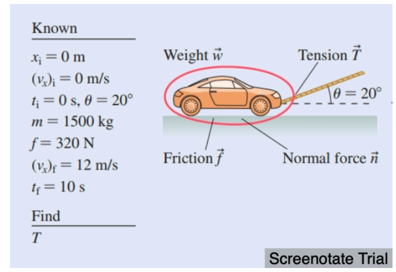




[22] $\Sigma F_{net} = 0$

PROBLEM 5–EXAMPLE 5.6 A car with a mass of 1500 kg is being towed by a rope held at a 20° angle to the horizontal. A friction force of 320 N opposes the car's motion. What is the tension in the rope if the car goes from rest to 12 m/s in 10 s?





STRATEGIZE This problem is almost identical to Example 5.4. The difference is that the car is now accelerating, so it is no longer in equilibrium. How to find the acceleration? How to find the net tension force?

PREPARE Draw a free body diagram of the car to identify the forces: normal force, tension force, weight, friction force, and net force causing the acceleration.

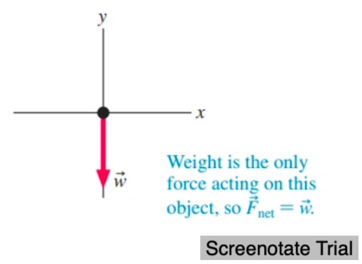
SOLVE

$$\Sigma F_x = m \cdot a_x$$

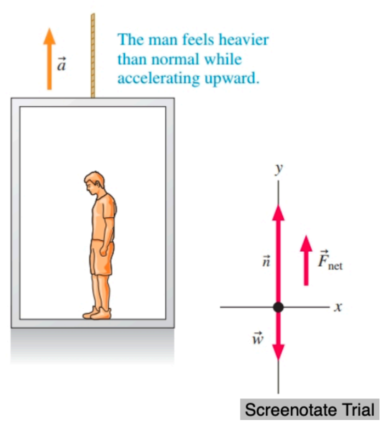
$$\Sigma F_y = m \cdot a_y$$

ASSESS Does the answer make sense?

MASS AND WEIGHT ARE NOT THE SAME THING, but they are related. Newton's second law for a falling object is $\Sigma F_y = -w = -mg$. So, $w = mg$. The magnitude of the weight force, which we call simply "the weight," is directly proportional to the mass, with **g** as the constant of proportionality.



APPARENT WEIGHT IS THE FORCE YOU FEEL. Although, the weight of an object is the force of gravity on that object, gravity is not a force that you can feel or sense directly. Your *sensation* of weight–how heavy you feel–is due to contact forces supporting you. Your sensation of weight when sitting in a chair is due to the normal force exerted on you by the chair in which you are sitting. The chair's surface touches you and activates nerve endings in your skin. You sense the magnitude of this force, and this is your sensation of weight. When you stand, you feel the contact force of the floor pushing against your feet. If you are hanging from a rope, you feel the friction force between the rope and your hands.



AT EQUILIBRIUM YOUR WEIGHT EQUALS YOUR APPARENT WEIGHT. But if you undergo an acceleration, you *feel* heavier or lighter. For instance, you feel "heavy" when an elevator you are riding in suddenly accelerates upward, and you feel lighter than normal as the upward-moving elevator brakes to a halt. Your true weight

$w = mg$ has not changed during these events, but your sensation of your weight has. The apparent weight isn't just a sensation. You can measure it with a scale. When you stand on a bathroom scale, the scale reading is the upward force of the scale on you.

PROBLEM 6–EXAMPLE 5.8 Anjay's mass is 70 kg. He is standing on a scale in an elevator that is moving at 5.0 m/s. As the elevator slows to a stop, the scale reads 750 N. Before it stopped, was the elevator moving up or down? How long did the elevator take to come to rest?

STRATEGIZE What is the scale reading? Apparent weight or true weight? What would the scale read if Anjay's apparent weight is greater than his actual weight?

PREPARE Draw a free body diagram of Anjay to identify the forces: weight, normal force, and net force. Find Anjay's actual weight [23].

SOLVE Is Anjay's weight greater or less than the apparent weight shown on the scale? Use Newton's second law [24] and kinematics [25] and to find the stopping time.

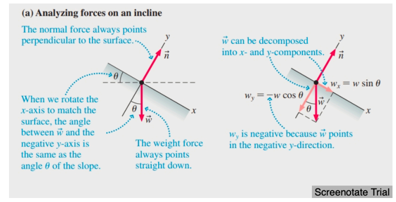
ASSESS Think about your elevator riding experiences. You *feel* heavy as a downward moving elevator comes to a rest.

[23] $w = mg$

[24] $a_y = \frac{w_{app} - w}{m}$

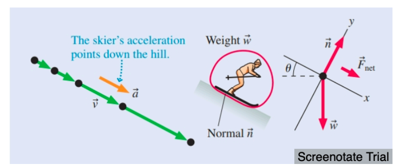
[25] $v_f = v_i + a\Delta t$

AN OBJECT AT REST ON A TABLE IS SUBJECT TO AN UPWARD FORCE due to the table. This force is called the **normal force** because it is always directed normal, or perpendicular, to the surface of contact. The normal force has its origin in the atomic "springs" that make up the surface. The harder the object bears down on the surface, the more these springs are compressed and the harder they push back. Thus the normal force adjusts itself so that the object stays on the surface without penetrating it. This fact is key in solving for the normal force.



AN OBJECT ON A RAMP OR INCLINE are common normal force problems. If friction is ignored, there are only two forces acting on the object: gravity and the normal force. However, we need to carefully work out the components of these two forces in order to solve dynamics problems.

PROBLEM 7–EXAMPLE 5.10 A skier slides down a steep 27° slope. On a slope this steep, friction is much smaller than the other forces acting on the skier and can be ignored. What is the skier's acceleration?



STRATEGIZE Which of Newton's laws can be used to find acceleration?

PREPARE Draw a free body diagram paying close attention to the coordinate system so you can make $\vec{a}_y = 0$ – see the figure above for some ideas.

SOLVE Use Newton's second law in component form to find the skier's acceleration. [26] [27] Also note that **m** cancels in the first equation

ASSESS Our result shows that when $\theta = 0$, so that the slope is horizontal, the skier's acceleration is zero, as it should be. Further, when $\theta = 90$, a vertical slope, thier acceleration is **g**. Also, the mass canceled out, so we didn't need to know the skier's mass if we can neglect friction.

[26]
$$\Sigma F_x = m \cdot a_x = mg \sin\theta$$

[27]
$$\Sigma F_y = m \cdot a_y = 0$$