***Force and Newton’s Laws Study Guide*** 11/16/16 ***Name\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_***

***Hour\_\_\_\_\_***

**Forces**

A force is a \_\_\_\_\_\_\_\_\_\_\_ or a \_\_\_\_\_\_\_\_\_\_. Forces can come from direct contact between two objects, or from other sources such as magnets or gravity. Force from direct contact is actually electromagnetic repulsion between the valence electrons in the atoms on the two surfaces. There are also nuclear forces between *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*and *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*in the nucleus of an atom. The strong force holds them together, while the weak force is involved in complicated nuclear reactions.

Some forces have special names. A pulling force, like in a rope, is called *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*.

A pushing force from a rocket or an engine is called *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.*

The force of gravity is called *\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_*. The force of air resistance is called \_\_\_\_\_\_\_\_.

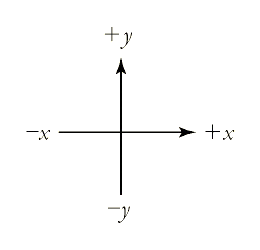
**Free Body Diagrams**

A Free Body Diagram shows all of the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ acting on a single body, or object. The object is drawn as a simple rectangle or circle. Each force is drawn as a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ pointing from the center of the body, in the direction of the force. Larger forces are drawn as \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ vectors.

**Practice 1:** Draw a free body diagram for a sled being pulled to the right by a rope which is 30 degrees above horizontal. The sled has four forces on it: gravity pulls down with a force of 50 Newtons, the rope pulls diagonally with a force of 40N, the ground pushes up with a force of 30 N, and friction pulls back with a force of 35N. Draw vectors to scale, with a scale of 1cm = 10 Newtons

**Net Force**

“Net” is the term for the final result after all positives and negatives are added. When you have positive salary on your paycheck, and then taxes are subtracted, you are left with net pay. The net force is usually what matters in motion problems.

 When there are forces in more than one direction, **choose one direction to be positive and the other negative**. (whichever directions you like) Then add the positive forces and subtract the negative forces to calculate the net force. Forces, velocities, displacements, and accelerations will have the same directions defined as positive and negative. You can define whatever direction you want as “positive” along each axis, but you have to stick with that definition for all of the variables, for the whole problem.

**Balanced and Unbalanced Forces**

When two forces are the same size (strength) but act in opposite directions, they are balanced, and they cancel each other out, adding to zero net force. When two or more forces end up not canceling each other, they are called unbalanced forces, and these are what cause changes in motion.

**Practice 2: Calculate the net force for the following situations. It will help to make a diagram.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **F1** | **F2** | **F3** | **Net Force** |
| 1 | 24 N, right | 53 N, right | 17N, right |  |
| 2 | 35 N, up | 19N, down | 16N, down |  |
| 3 | 14 pounds, east | 18 pounds, west | 52 pounds, west |  |

When forces are not all parallel (acting along the same axis), you need to use the Pythagorean Theorem to calculate the magnitude, and usually use inverse tangent to calculate the angle. State the direction clearly.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 4 | 18 N, up | 9N, up | 49N, right |  |
| 5 | 75.0 N at 90° | 190. N at 180° | 160. N at 270° |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | **x** | **y** | **Polar** |
| **F1** |  |  |  |
| **F2** |  |  |  |
| **F3** |  |  |  |
| **Total** |  |  |  |

**It may help to make a table with x and y components for each vector.**

**Newton’s First Law: (The Law of Inertia)**

An object at rest will ­­­­­­­­­­­­­­­­­­­­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, unless acted upon by an unbalanced \_\_\_\_\_\_\_\_\_\_\_. An object in motion will remain in motion, traveling in a \_\_\_\_\_\_\_\_\_\_\_\_\_\_ line at constant ­­­­­­\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, unless acted upon by an unbalanced force.

In other words, **objects don’t change their motion unless a force causes them to do so**.

**Inertia** is the tendency to keep doing whatever you’re already doing. The more ­­­­­\_\_\_\_\_\_\_\_\_ something has, the more inertia it has, and the harder it is to change its motion. (speed it up, slow it down, or turn it). If you pile a cart full of bags of cement, you will find it difficult to get the cart moving, and then once it is moving, you will find it difficult to change its velocity. This is because the cement has a lot of mass, so it has a lot of inertia.

Automakers work to use lightweight materials like aluminum and carbon fiber, especially in sports cars, because \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_.

**Newton’s Second Law:**

The amount an object accelerates depends on its \_\_\_\_\_\_\_\_\_ and on the net \_\_\_\_\_\_\_\_ acting on it.

 The bigger the force, the \_\_\_\_\_\_\_\_\_\_ it accelerates. The bigger the mass, the *\_\_\_\_\_\_\_* it accelerates.

*Force = mass • acceleration*

formula!

*Newton = kilogram • m/s2*

units!

**Practice 3: Calculate the missing values for the following:**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **mass** | **acceleration** | **Net Force** |
| 1 | 2.0 kg |  | 6.0N |
| 2 | 15 kg | 3.0 m/s2 |  |
| 3 |  | 6.0 m/s2 | 3.0N |
| 4 | 87.2kg | 9.81m/s2 |  |

**Note: the formula for *weight* is this same formula as Newton’s Second Law!**

**We just give the terms special names!**

*Force = mass • acceleration*

*Force of gravity = mass • acceleration of gravity*

*Weight = mass • g [g on earth = 9.81 m/s2]*

**♫♫ “Weight is the force of gravity, so we measure it in Newtons…” ♫♫**

**\*\* A volume of one liter of water has a mass of one kilogram. It’s how the kilogram was defined.\*\***

A mass of one kilogram on earth has a force of gravity of 9.81N (2.20 pounds) pulling on it. If that 1 kg mass is taken to the moon, where gravity is only 1.62 m/s2, it will only have a weight of 1.62N (0.36 lb).

**One pound equals 4.45N. One Newton equals .225 pounds.**

[If a metric scale says you weigh 578N, don’t flip out – that’s only (578N)(.225 lb/N) = 130 pounds.]

**Practice 4: Calculate the missing values for the following. WRITE THE UNITS.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **mass** | **acceleration of gravity**  **(“g”)** | **Force of gravity in Newtons**  **(“weight”)** | **Force of gravity in pounds (lb)** |
| 1 | 4.0 kg  (gallon of milk) | 9.81 m/s2 |  |  |
| 2 | 4.0 kg  (gallon of milk) | 1.62 m/s2  (gravity on the moon) |  |  |
| 3 |  | 9.81 m/s2 | 356N |  |
| 4 |  | 9.81 m/s2 |  | 3250 lb  (small car) |
| 5 | 11.4 kg  (25-lb barbell) |  | 283N  (weight on Jupiter) |  |

**Newton’s Third Law:**

An object can not push or pull another object without *being* pushed or pulled. If A pushes B, B pushes A back, with exactly the same amount of force. If C pulls D, D pulls C back with the same amount of force, in exactly the opposite direction.

“For every action force there is an \_\_\_\_\_\_\_\_ and \_\_\_\_\_\_\_\_\_\_ reaction force.”

Remember, when you want to do a “pushup”, you are really pushing down on the floor, and the floor is pushing back up on you, with an equal and opposite force. When you push a car forward, you get pushed back, so hopefully friction acting on your feet keeps you from slipping.

**Practice 5: Write the reaction force for each of the following.**

|  |  |  |
| --- | --- | --- |
|  | **Action force** | **Reaction force** |
| ex | Bill pushes wall east with F=26 lb | Wall pushes Bill west with force of 26 pounds. |
| 1 | Oar pushes water west with 80N |  |
| 2 | Feet push down on ground with force of 1240 N |  |
| 3 | Alicia pulls down on rope with force of 168 pounds |  |
| 4 | Dog pulls north on toy with F=26lb |  |

**Everyday Forces:**

Weight is the force of gravity.Applied force is just another name for pushing or pulling on something, like with your hands.Friction is a force which acts between objects moving relative to one another. It always acts to resist sliding. It slows down a box sliding across the floor, but also keeps your tires from sliding, so you can accelerate your car. A few types of friction are static, sliding, rolling, and fluid friction, which includes air resistance, or “drag”.

Static and sliding (kinetic) friction depend on the normal force, which is the force perpendicular to the surfaces which squeezes the surfaces together. It also depends on the materials, which between them have a \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ of \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, abbreviated “mu” (greek letter μ).

The force of friction equals mu times the normal force. Ff= μFN μ = Ff / FN

What are the units for μ? Explain.\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

A higher coefficient of friction (like rubber shoes on gym floor) will give more traction than a lower μ, like socks on a gym floor.

Pulling diagonally upwards on an object reduces the normal force, reducing the frictional force and making it easier to slide something across the floor.

The normal force can be caused by anything, from a person pushing their hands together while rubbing them to warm them up, to gravity holding a desk to the floor while you try to drag it, to the magnetic force holding a clip to the whiteboard, hopefully with enough friction force to keep it from sliding down.

A key concept is that if an object is on level ground, not accelerating up or down, then the vertical forces on the object must add to \_\_\_\_\_\_\_\_\_\_\_\_\_, because the forces are \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. If the force of gravity is pulling down on the object, then the normal force from the ground must push \_\_\_\_\_ on the object, with a force equal to the object’s \_\_\_\_\_\_\_\_\_\_\_\_\_\_.

The two categories of friction between surfaces are *static*, which is when objects are stuck together, and\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_, when the objects are sliding while touching.

**Practice 6:**

**A 23.0 kg box is sitting on the floor. A woman uses a metric scale attached to a rope to pull the box sideways. She pulls harder and harder, until she reaches a force of 105 N, at which time the box gets “unstuck” and starts to slide.**

1. Draw a free body diagram showing the four forces on the box when it is not moving.
2. Label the forces with their names and values, at the point when she pulls with maximum force.
3. Knowing the frictional force and the normal force, calculate the coefficient of friction for when the box was not moving. μstatic = **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**
4. Once the box starts sliding, she measures that it takes only 85N of force to keep the box sliding at a constant velocity**.** Knowing that frictional force, calculate the coefficient of friction for when the box was moving. μkinetic = **\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_**

***Force and Newton’s Laws Study Guide*** 2/7/15 ***Name\_\_\_KEY\_\_\_\_\_\_\_\_\_\_\_ Date \_\_\_\_\_\_\_\_***

***Hour\_\_\_\_\_***

**Forces**

A force is a \_\_\_\_push\_\_\_ or a \_\_\_pull\_\_. Forces can come from direct contact between two objects, or from other sources such as magnets or gravity. Force from direct contact is actually electromagnetic repulsion between the valence electrons in the atoms on the two surfaces. There are also nuclear forces between *\_*electrons*\_\_*and protons*\_*. The strong force holds them together, while the weak force is involved in complicated nuclear reactions.

Some forces have special names. A pulling force, like in a rope, is called *\_\_*tension*\_*.

A pushing force from a rocket or an engine is called *\_\_*thrust*\_\_.*

The force of gravity is called *\_*weight*\_\_\_*. The force of air resistance is called \_drag\_\_\_.

**Free Body Diagrams**

A Free Body Diagram shows all of the \_\_\_forces\_\_ acting on a single body, or object. The object is drawn as a simple rectangle or circle. Each force is drawn as a \_\_\_vector\_\_\_ pointing from the center of the body, in the direction of the force. Larger forces are drawn as \_\_longer\_\_\_ vectors.

**Practice 1:** Draw a free body diagram for a sled being pulled by a rope which is 30 degrees above horizontal. The sled has four forces on it: gravity pulls down with a force of 50 Newtons, the rope pulls diagonally with a force of 40N, the ground pushes up with a force of 30 N, and friction pulls back with a force of 35N. Draw vectors to scale, with a scale of 1cm = 10 Newtons

T=40N

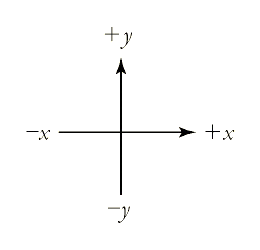
FN = +30N

Ff = -35N

FG = -50N

**Net Force**

“Net” is the term for the final result after all positives and negatives are added. When you have positive salary on your paycheck, and then taxes are subtracted, you are left with net pay. The net force is usually what matters in motion problems.

 When there are forces in more than one direction, **choose one direction to be positive and the other negative**. (whichever directions you like) Then add the positive forces and subtract the negative forces to calculate the net force. Forces, velocities, displacements, and accelerations will have the same directions defined as positive and negative. You can define whatever direction you want as “positive” along each axis, but you have to stick with that definition for all of the variables, for the whole problem.

**Balanced and Unbalanced Forces**

When two forces are the same size (strength) but act in opposite directions, they are balanced, and they cancel each other out, adding to zero net force. When two or more forces end up not canceling each other, they are called unbalanced forces, and these are what cause changes in motion.

**Practice 2: Calculate the net force for the following situations:**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **F1** | **F2** | **F3** | **Net Force** |
| 1 | 24 N, right | 53 N, right | 17N, right | **94N, right** |
| 2 | 35 N, up | 19N, down | 16N, down | **0N (balanced forces)** |
| 3 | 14 pounds, east | 18 pounds, west | 52 pounds, west | **56 pounds, west** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| 4 | 18 N, up | 9N, up | 49N, right | **56 N, 61° right of vertical or**  **29° above right** |
| 5 | 75.0 N at 90° | 190. N at 180° | 160. N at 270° | **208 N @ 204°** |

**Newton’s First Law: (The Law of Inertia)**

An object at rest will ­­­­­­­­­­­­­­­­­­­­­­­­­\_\_remain at rest\_, unless acted upon by an unbalanced \_force\_. An object in motion will remain in motion, traveling in a \_straight\_ line at constant ­­­­­­\_\_speed\_\_\_, unless acted upon by an unbalanced force.

In other words, **objects don’t change their motion unless a force causes them to do so**.

**Inertia** is the tendency to keep doing whatever you’re already doing. The more ­­­­­\_\_\_\_\_\_\_\_\_ something has, the more inertia it has, and the harder it is to change its motion. (speed it up, slow it down, or turn it). If you pile a cart full of bags of cement, you will find it difficult to get the cart moving, and then once it is moving, you will find it difficult to change its velocity. This is because the cement has a lot of mass, so it has a lot of inertia.

Automakers work to use lightweight materials like aluminum and carbon fiber, especially in sports cars, because it is easier to accelerate (speed up, slow down, or turn) a car which has little mass, and therefore little inertia.

**Newton’s Second Law:**

The amount an object accelerates depends on its \_\_mass\_ and on the net \_force\_ acting on it.

 The bigger the force, the \_more\_ it accelerates. The bigger the mass, the *\_*less*\_* it accelerates.

*Force = mass • acceleration*

formula!

*Newton = kilogram • m/s2*

units!

**Practice 3: Calculate the missing values for the following:**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **mass** | **acceleration** | **Net Force** |
| 1 | 2.0 kg | **3.0 m/s2** | 6.0N |
| 2 | 15 kg | 3.0 m/s2 | **45 N** |
| 3 | **0.5 kg** | 6.0 m/s2 | 3.0N |
| 4 | 87.2kg | 9.81m/s2 | **855 N** |

**Note: the formula for *weight* is this same formula as Newton’s Second Law!**

**We just give the terms special names!**

*Force = mass • acceleration*

*Force of gravity = mass • acceleration of gravity*

*Weight = mass • g [g on earth = 9.81 m/s2]*

**♫♫ “Weight is the force of gravity, so we measure it in Newtons…” ♫♫**

**\*\* A volume of one liter of water has a mass of one kilogram. It’s how the kilogram was defined.\*\***

A mass of one kilogram on earth has a force of gravity of 9.81N (2.21 pounds) pulling on it. If that 1 kg mass is taken to the moon, where gravity is only 1.62 m/s2, it will only have a weight of 1.62N (0.36 lb).

**One pound equals 4.45N. One Newton equals .225 pounds.**

[If a metric scale says you weigh 578N, don’t flip out – that’s only (578N)(.225 lb/N) = 130 pounds.]

**Practice 4: Calculate the missing values for the following. WRITE THE UNITS.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **mass** | **acceleration of gravity**  **(“g”)** | **Force of gravity in Newtons**  **(“weight”)** | **Force of gravity in pounds (lb)** |
| 1 | 4.0 kg  (gallon of milk) | 9.81 m/s2 | **39 N** | **8.8 lb** |
| 2 | 4.0 kg  (gallon of milk) | 1.62 m/s2  (gravity on the moon) | **6.5 N** | **1.5 lb** |
| 3 | **36.3 kg** | 9.81 m/s2 | 356N | **80 lb** |
| 4 | **1470 kg** | 9.81 m/s2 | **145,000 N** | 3250 lb  (small car) |
| 5 | 11.4 kg  (25-lb barbell) | **24.8 m/s2** | 283N  (weight on Jupiter) | **63.6 pounds** |

**Newton’s Third Law:**

An object can not push or pull another object without *being* pushed or pulled. If A pushes B, B pushes A back, with exactly the same amount of force. If C pulls D, D pulls C back with the same amount of force, in exactly the opposite direction.

“For every action force there is an \_equal\_ and \_opposite\_ reaction force.”

Remember, when you want to do a “pushup”, you are really pushing down on the floor, and the floor is pushing back up on you, with an equal and opposite force. When you push a car forward, you get pushed back, so hopefully friction acting on your feet keeps you from slipping.

**Practice 5: Write the reaction force for each of the following.**

|  |  |  |
| --- | --- | --- |
|  | **Action force** | **Reaction force** |
| ex | Bill pushes wall east with F=26 lb | Wall pushes Bill west with force of 26 pounds. |
| 1 | Oar pushes water west with 80N | **Water pushes oar east with force of 80 Newtons** |
| 2 | Feet push down on ground with force of 1240 N | **Ground pushes up on feet with force of 1240 Newtons.** |
| 3 | Alicia pulls down on rope with force of 168 pounds | **Rope pulls up on Alicia with force of 168 pounds** |
| 4 | Dog pulls north on toy with F=26lb | **Toy pulls dog north with force of 26 pounds** |

**Everyday Forces:**

Weight is the force of gravity.Applied force is just another name for pushing or pulling on something, like with your hands.Friction is a force which acts between objects moving relative to one another. It always acts to resist sliding. It slows down a box sliding across the floor, but also keeps your tires from sliding, so you can accelerate your car. A few types of friction are static, sliding, rolling, and fluid friction, which includes air resistance, or “drag”.

Static and sliding (kinetic) friction depend on the normal force, which is the force perpendicular to the surfaces which squeezes the surfaces together. It also depends on the materials, which between them have a \_\_**coefficient** of \_\_**friction**\_, abbreviated “mu” (greek letter μ).

The force of friction equals mu times the normal force. Ff= μFN μ = Ff / FN

What are the units for μ? Explain.\_**The coefficient of friction has no units, because it is a ratio of forces. The units for force cancel out when you divide**.\_\_

A higher coefficient of friction (like rubber shoes on gym floor) will give more traction than a lower μ, like socks on a gym floor.

Pulling diagonally upwards on an object reduces the normal force, reducing the frictional force and making it easier to slide something across the floor.

The normal force can be caused by anything, from a person pushing their hands together while rubbing them to warm them up, to gravity holding a desk to the floor while you try to drag it, to the magnetic force holding a clip to the whiteboard, hopefully with enough friction force to keep it from sliding down.

A key concept is that if an object is on level ground, not accelerating up or down, then the vertical forces on the object must add to \_**zero**, because the forces are \_\_**balanced**\_\_. If the force of gravity is pulling down on the object, then the normal force from the ground must push \_**up**\_ on the object, with a force equal to the object’s \_**weight**\_.

The two categories of friction between surfaces are *static*, which is when objects are stuck together, and\_\_**kinetic**\_\_, when the objects are sliding while touching.

**Practice 6:**

**A 23.0 kg box is sitting on the floor. A woman uses a metric scale attached to a rope to pull the box sideways. She pulls harder and harder, until she reaches a force of 105 N, at which time the box gets “unstuck” and starts to slide.**

1. Draw a free body diagram showing the four forces on the box when it is not moving.
2. Label the forces with their names and values, at the point when she pulls with maximum force.
3. Knowing the frictional force and the normal force, calculate the coefficient of friction for when the box was not moving. μstatic = **105N ÷ 226N = 0.464**
4. Once the box starts sliding, she measures that it takes only 85N of force to keep the box sliding at a constant velocity**.** Knowing that frictional force, calculate the coefficient of friction for when the box was moving. μkinetic = **85N ÷ 226N = 0.376**

T=105N

FN = +226 N

Ff = -105N

FG = m∙g

= -226 N