When in Rome

Task 2: Heavy Lifting

Investigation 8: Inclined Plane

Purpose:

To determine the force required to pull a block up an inclined plane.

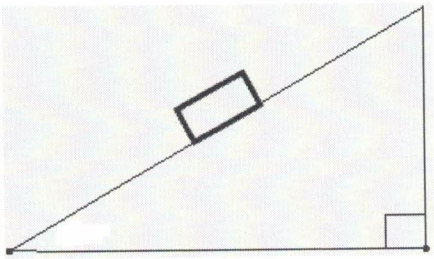
Materials:

- Brick
- Spring Scale
- Whiteboard (or ramp)
- Meter Stick

Investigation

1. Using the spring scale and mass, accurately determine the coefficient of kinetic friction between the mass and the white side of the whiteboard. (This should be done on a horizontal surface. Remember the formula for the force of friction on a horizontal surface.)

2. Draw an FBD that shows the forces acting on a mass that is sliding up an incline at a constant velocity. (In order to slide up the ramp something needs to pull on it.)



3. What forces are acting perpendicular to the plane?

4. What forces are acting parallel to the plane?

5. What two forces would the pull force have to overcome in order to move the brick at a constant speed up the ramp?

When in Rome

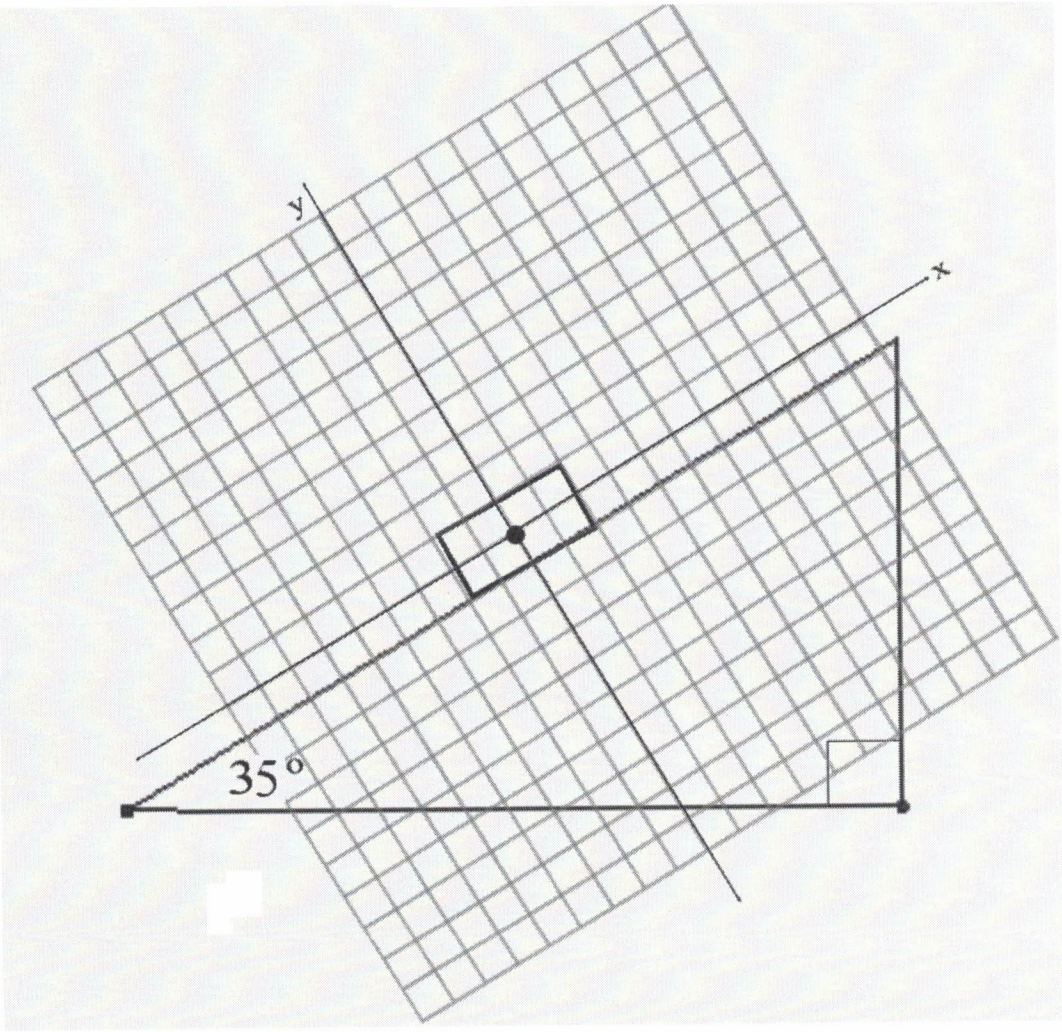
Task 2: Heavy Lifting

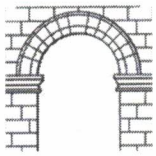
Investigation 8: Inclined Plane

Now that we have identified the forces acting on the block and sketched the directions these forces act on the block, let's find a relationship between these forces.

Suppose the incline is at an angle of 35°.

6. On the diagram on the below, draw a vector (to scale) to represent the weight and label it F_G.
   Let
   1 Newton ↔1 cm.





When in Rome

Task 2: Heavy Lifting

Investigation 8: Inclined Plane

Let's define a coordinate system so that the origin is at the center of the block (at the dot), the y-axis is perpendicular to the ramp and the x-axis is parallel to the ramp.

7. Draw and label the components of F_G using dashed arrows (USE PENCIL). Arrange F_{Gx} and F_{Gy} tip-to-tail, so the vector F_G and its components form a right triangle with a 90° angle where the components meet. Let's call this the "vector triangle".

8. What force(s) cancels out F_{Gy}? Draw and label the force(s) in the diagram, with lengths drawn correctly compared with F_{GY}.

9. What force(s) cancels out F_{Gx}?
   Applying Newton's 2nd Law and knowing the size of F_{Gx} and kinetic friction, how big should the pull up the ramp be so that block travels at a constant speed?

   Draw and label the above forces in the above diagram, with lengths drawn to scale.

10. The ramp has an incline of 35°. Using a protractor, measure the angles of the vector triangle. Is there an angle with the same measure? If so, where is it? Label the angle in the triangle.

Note: For any ramp that has an incline of θ, the angle between F_G and F_{Gy} is also θ.

When in Rome

Task 2: Heavy Lifting

Investigation 8: Inclined Plane

It would be tedious if we needed to draw a free-body diagram to scale every time. Let's use trigonometry to calculate the components of F_G that we can then use to calculate the size of the pull necessary to make the block move up the ramp at a constant speed.

11. Suppose the ramp has an incline angle θ instead of 35 °. Using trigonometry with the vector triangle, write an equation for each of the components of F_G in terms of θ (show work below):

F_{GY} = _____ F_{GX} = _____

12. Write an equation for the normal force and an equation for the size of the pull in terms of F_{GY}, F_{GX}, kinetic fiction and θ .

F_N = _____ F_{pull} = _____

13. Using the equation for question #12, determine how much force is required to pull the brick up a ramp at a constant speed. Assume the ramp is at an angle of 20 degrees to the horizontal.

TEACHER CHECK #1

When in Rome

Task 2: Heavy Lifting

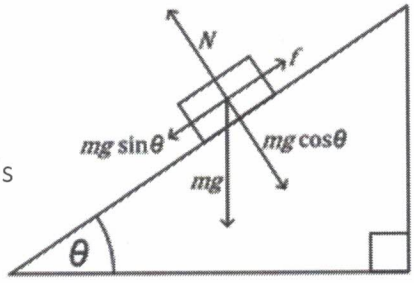
Investigation 8: Inclined Plane

14. Test your predictions. Set up the ramp at an angle of 20 degrees. Using a spring scale, pull the brick up the ramp at a constant speed. Take the average of three trials. Please do not measure the angle with a protractor; instead find the angle using trigonometry.

Trial 1	Trial 2	Trial 3	Average

15. How accurate was your calculated value? What could be some sources of error?

Conclusion Questions:



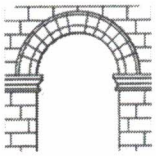
1. On a horizontal plane, the _____force always equals the _____.

2. Lets think about an extreme case when the block is placed on a 90-degree incline. What would the value of the normal force be in this scenario?

3. As the angle of the ramp is increased, the normal force increases / decreases / remains the same and the friction force increases / decreases / remains the same.

4. As the angle of the ramp is increased, the force of gravity down the ramp increases / decreases / remains the same.

5. Consider a very low (zero) friction, 5.0 kg skateboard on a ramp at an angle of 15° to the horizontal. What would be the net force that would cause acceleration when the skateboard is allowed to move? _____ N



When in Rome

Task 2: Heavy Lifting

Investigation 8: Inclined Plane

6. What would be the skateboard's acceleration down the plane? _____ m/s^2

7. Now consider the same no-friction 5.0 kg skateboard on the same 15° ramp. If a 45kg teenager jumps on, what would be her acceleration down the ramp? _____ m/s^2

TEACHER CHECK #2