USDA National Institute of Food and Agriculture
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FARM PHYSICS

investigating motion, force, and mass

8.PS2.5 Plan and conduct an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

INTRODUCTION

Every time you ride in a car, run to catch a bus, or simply walk down the street, you are experiencing physics in action. Physics is the branch of science that studies matter, energy, forces, and motion, helping us understand why things move the way they do.

These same principles are essential in agriculture. Farmers rely on tractors, combines, and other heavy equipment to plant, cultivate, and harvest crops efficiently. Understanding how forces and mass influence the movement of these machines helps agriculturalists work more safely, save time, and increase productivity.

Have you ever wondered why a tractor carrying a heavy load moves differently than one with an empty trailer? Or why a tractor rolls downhill more easily than across flat ground? The answers lie in understanding how the forces acting on a vehicle and its mass affect its motion.

A **force** is a push or pull that can cause something to start moving, stop moving, speed up, slow down, or change direction. Often, several forces act at the same time. The combined effect of these forces, called the **net force**, determines how an object's motion changes.

Throughout this investigation, you will consider several forces that can affect vehicle motion, including gravitational force and frictional force. An applied force occurs when an outside object or person pushes or pulls an object. In this investigation, you will release the vehicle without pushing it so that the effects of the ramp and mass can be compared more fairly.

- **Applied Force:** A push or pull exerted on an object.
- **Gravitational Force:** The force that pulls objects toward Earth and causes a vehicle to accelerate down a ramp.
- **Frictional Force:** The force that opposes motion between two surfaces, slowing a moving vehicle.

Another important factor is **mass**, which is the amount of matter in an object. As mass increases, more force is generally required to change an object's motion.

In this activity, you will investigate how changing the **ramp angle** and the **mass** of a farm vehicle affects how it moves. You will collect and analyze data, calculate means, and use evidence from your investigation to explain how **net force** and **mass** influence motion.

INVESTIGATION QUESTION

Driving Question
How do ramp angle and vehicle mass affect how far a farm vehicle travels and how long it takes to stop?

BEFORE YOU TEST

Make a Prediction
Which ramp angle do you think will cause the vehicle to travel farther? Why?
How do you think adding magnets will affect the vehicle's travel time and distance?
How many magnets do you think the tractor will need to travel more than 76 cm?

MATERIALS

per group of 4 students	*per student*
• toy farm vehicle • 4 magnet weights • adjustable ramp • timer or stopwatch • measuring tape or meter stick • 4 pieces of tape • permanent marker	• pen or pencil • calculator • student packet

PROCEDURE

Imagine: Your team works for a farm equipment company. A farmer needs to know how a tractor might move on different slopes while carrying different loads. Using the vehicle to represent the tractor, your team will collect data to make a recommendation.

1. Set the ramp to Angle 1. (See picture below.)
2. Start with the empty vehicle, placing the back wheels at the same release point each time at the top of the ramp. Make sure the wheels are centered on the ramp.
3. Release the vehicle without pushing it. Start the timer when the vehicle begins to move.
4. Stop the timer when the vehicle comes to a complete stop.
5. Measure the distance from the bottom of the ramp to where the vehicle comes to a complete stop.
6. Record the time in seconds to the nearest tenth of a second and distance in centimeters in the data table.
7. Repeat until you have three trials for each mass: 0 magnets, 2 magnets, and 4 magnets.
8. Change the ramp to Angle 2. (See picture below.) Repeat all trials starting with an empty vehicle.
9. Calculate the mean time and mean distance for each condition.

1.

2.

DATA COLLECTION: LOW RAMP ANGLE

Table 1 - Angle 1					
Mass Added	Trial	Time (0.1 s)	Distance (cm)	Mean Time (0.1 s)	Mean Distance (cm)
0 magnets	1				
	2				
	3				
2 magnets	1				
	2				
	3				
4 magnets	1				
	2				
	3				

Mean = (Trial 1 + Trial 2 + Trial 3) / 3

Checkpoint
Did your group release the vehicle the same way each time? Explain.

DATA COLLECTION: HIGH RAMP ANGLE

Table 2 - Angle 2					
Mass Added	Trial	Time (0.1 s)	Distance (cm)	Mean Time (0.1 s)	Mean Distance (cm)
0 magnets	1				
	2				
	3				
2 magnets	1				
	2				
	3				
4 magnets	1				
	2				
	3				

Mean = (Trial 1 + Trial 2 + Trial 3) / 3

Checkpoint
Which trial was most different from the others? What might explain the difference?

CLASS DATA SUMMARY

Table 3 - Compare Mean Results				
Ramp Angle	Mass Added	Group Mean Time (0.1 s)	Group Mean Distance (cm)	Pattern Noticed
Angle 1	0 magnets			
Angle 1	2 magnets			
Angle 1	4 magnets			
Angle 2	0 magnets			
Angle 2	2 magnets			
Angle 2	4 magnets			

OPTIONAL GRAPH

Create a bar graph or line graph comparing mean distance for each ramp angle and mass. Label the x-axis, y-axis, and title.

ANALYSIS QUESTIONS

Answer in complete sentences.
Which ramp angle produced the greatest mean distance? Use data from your table.
Which ramp angle produced the shortest mean time? Use data from your table.
How did increasing mass affect the vehicle at the low ramp angle?
How did increasing mass affect the vehicle at the high ramp angle?

What variables were controlled to make the investigation fair?
What sources of error could have affected your results?
How does this investigation show that motion depends on the sum of the forces acting on an object?
How does this investigation show that motion depends on mass?

CLAIM-EVIDENCE-REASONING CONCLUSION

CER
Claim: How do ramp angle and vehicle mass affect how far a farm vehicle travels and how long it takes to stop?
Evidence: What data supports your claim? Include mean time and mean distance.
Reasoning: Explain why your evidence supports your claim using force, net force, gravity, friction, mass, and the evidence from your calculated means.

FARM ENGINEERING RECOMMENDATION

Use your data to make a recommendation to a farmer or equipment designer. Your recommendation should explain how slope and load can affect the motion of farm equipment.

Final Recommendation
What should farmers consider when moving equipment down a slope? Based on your investigation, what advice would you give a farmer transporting heavy equipment down a steep hill?
How could this investigation help make farm work safer or more efficient?

EXIT REFLECTION

Reflection
One thing I learned about force and mass is...
One thing I would change if I repeated this investigation is...