Name _____ Date _____ Period _____

ZornScience
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Inclined Plane Virtual Lab

Physics

Open **activities.zornscience.org/inclined-plane/** and follow each step. The simulation uses g = 9.81 m/s^2. Show your work with units.

Objective

Find how the **ramp angle**, the **surface** and the **mass** affect the forces on a block, the angle where it starts to slide, and its **acceleration**.

NGSS alignment: HS-PS2-1. Analyze data to support the claim that Newton's second law describes the relationship among the net force on an object, its mass, and its acceleration.

Practices and concepts: Analyzing and interpreting data; Using mathematics; Developing and using models; Cause and effect.

Meet the simulation

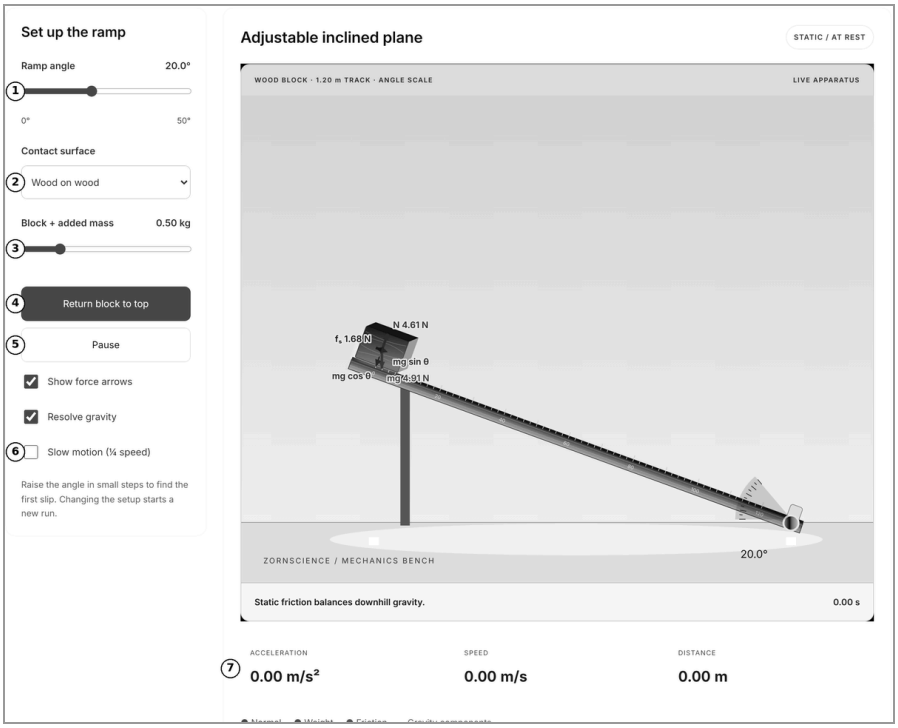


Figure 1. The lab (dark scene inverted for printing).

1. Ramp angle slider, 0° to 50°.
2. Contact surface menu.
3. Block plus added mass.
4. Returns the block to the top.
5. Pauses the motion.
6. Slow motion.
7. Readouts: acceleration, speed, distance (below the scene).

Force arrows show their values in newtons. Dashed arrows (mg sin θ, mg cos θ) are parts of the weight, not extra forces.

Pre-lab

1. What is the difference between **static** friction and **kinetic** friction?

2. A 0.50 kg block sits on a 20° ramp. Calculate its weight, the part of the weight along the ramp (mg sin θ) and the part into the ramp (mg cos θ).

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Part A. Forces on a block at rest

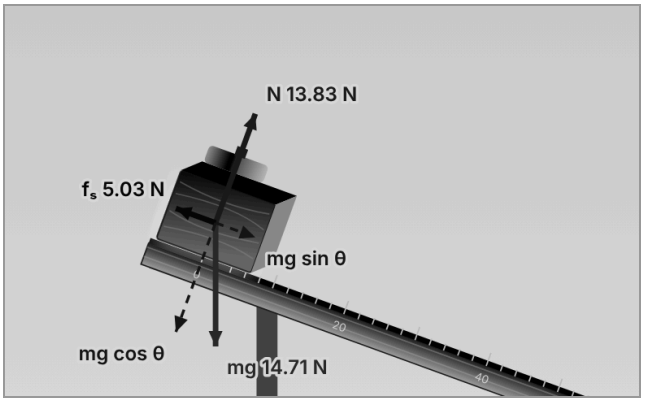


Figure 2. Force arrows on a 1.50 kg block at 20°.

1. Choose **Wood on wood**. Keep **Show force arrows** and **Resolve gravity** checked.
2. Set each mass and angle in the table. The block stays at rest for all of them.
3. Record the values on the N, mg and f_s arrows.

Trial	Mass (kg)	Angle (°)	Weight, mg (N)	Normal force, N (N)	Static friction, f_s (N)
1	0.50	10.0			
2	0.50	15.0			
3	0.50	20.0			
4	1.00	20.0			
5	1.50	20.0			

3. As the angle increases from 10° to 20°, what happens to the normal force and to static friction? Compare f_s in trial 3 with mg sin θ from Pre-lab question 2.

4. Draw a free-body diagram for the block in trial 3. Label each force with its value. Why is the net force zero?

5. Use trials 3 to 5. What happens to all the forces when the mass is tripled from 0.50 kg to 1.50 kg?

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Part B. Find the first slip

1. Set the mass to 0.50 kg and the angle to 10.0°. Choose a surface.
2. Click the angle slider, then press the right arrow key to raise the angle 0.1° at a time. Watch the badge above the scene change from STATIC / AT REST to KINETIC / SLIDING.
3. Record the largest angle where the block stays at rest and the first angle where it slides. Repeat for each surface, then for wood with 1.50 kg.

Surface	Mass (kg)	Largest angle at rest (°)	First slip angle, θ_c (°)	$\mu_s = \tan \theta_c$
Wood on wood	0.50			
Felt on wood	0.50			
Smooth plastic on wood	0.50			
Wood on wood	1.50			

6. Show the calculation of Show the calculation of μ_s for wood on wood with units (or "no units"). Which surfacemu;$_s$ for wood on wood. Does Show the calculation of μ_s for wood on wood with units (or "no units"). Which surfacemu;$_s$ have units? Which surface is the most "grippy"? How do you know?

7. Did tripling the mass change the first slip angle? Explain why, using what you found in question 5.

8. The maximum static friction is $f_{s,max} = \mu_s N$. For the 0.50 kg wood block ($\mu_s = 0.45$), calculate $f_{s,max}$ and the downhill pull mg sin θ at 20° and at 30°. Use them to explain why the block holds at one angle and slides at the other.

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Part C. Sliding down the ramp

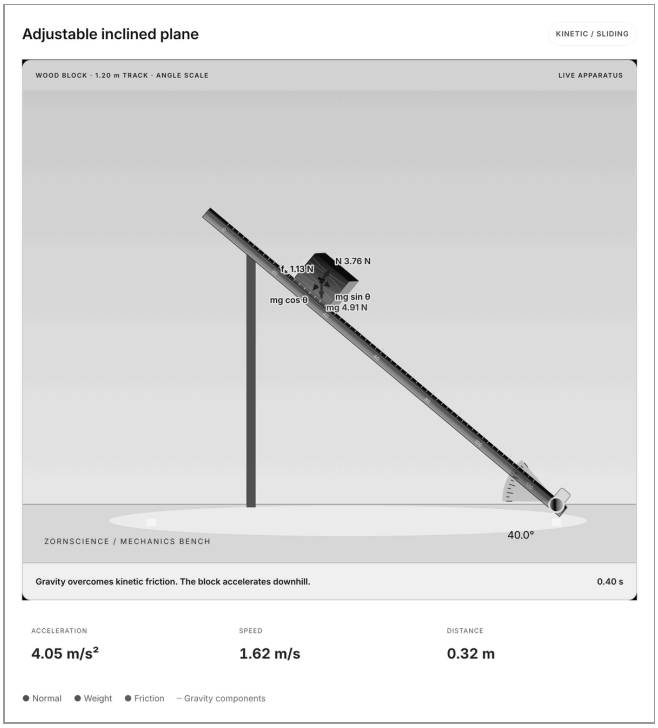


Figure 3. A 0.50 kg wood block sliding at 40°, paused.

1. Choose **Wood on wood**, 0.50 kg. Check **Slow motion**.
2. Set each angle below. The block starts sliding right away. Record the **acceleration** readout.
3. Trials 11 to 13: set the angle to 40.0° and change the surface or mass.

Trial	Surface, mass	Angle (°)	a (m/s^2)
6	Wood, 0.50 kg	30.0	
7	Wood, 0.50 kg	35.0	
8	Wood, 0.50 kg	40.0	
9	Wood, 0.50 kg	45.0	
10	Wood, 0.50 kg	50.0	
11	Felt, 0.50 kg	40.0	
12	Plastic, 0.50 kg	40.0	
13	Wood, 1.50 kg	40.0	

9. Describe how acceleration depends on the angle (trials 6 to 10), on the surface (trials 8, 11, 12) and on the mass (trials 8 and 13).

10. Use trial 8 to find the kinetic friction coefficient: $\mu_k = (g \sin\theta - a) / (g \cos\theta)$. Show your setup.

11. Open **Explore the physics** under the scene to check your μ_s and μ_k for wood. Real wood blocks give different results each trial. Name one reason.

Conclusion

12. Write a claim that answers the objective. Support it with specific numbers from Parts B and C, then explain your reasoning with Newton's second law.

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