SI Physics - Full Discipline Demo

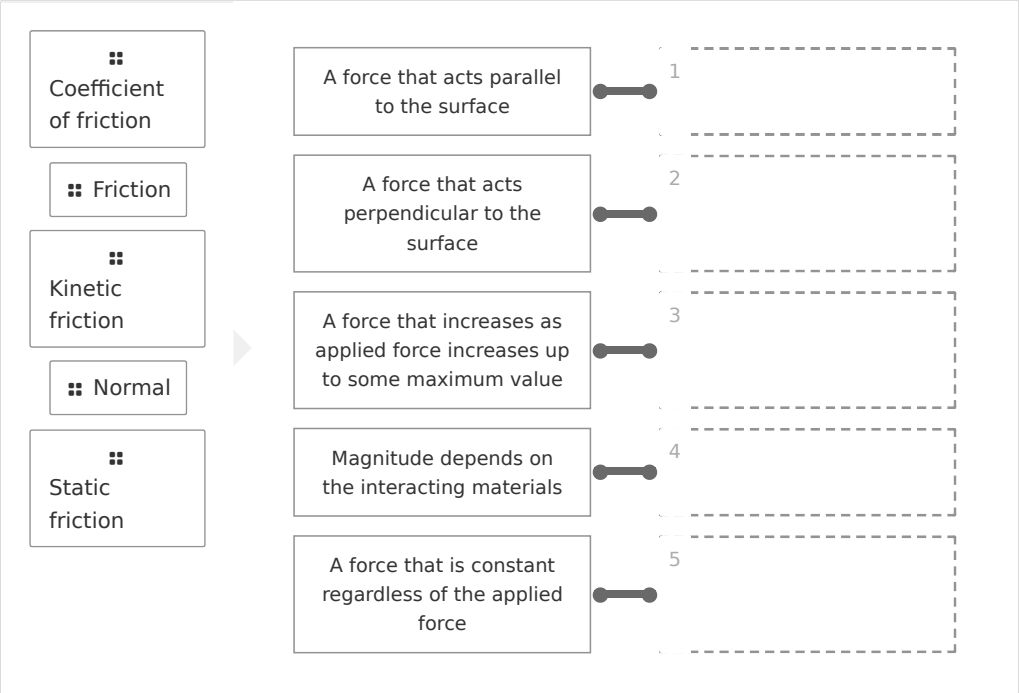
Friction

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Match each term to the best description.

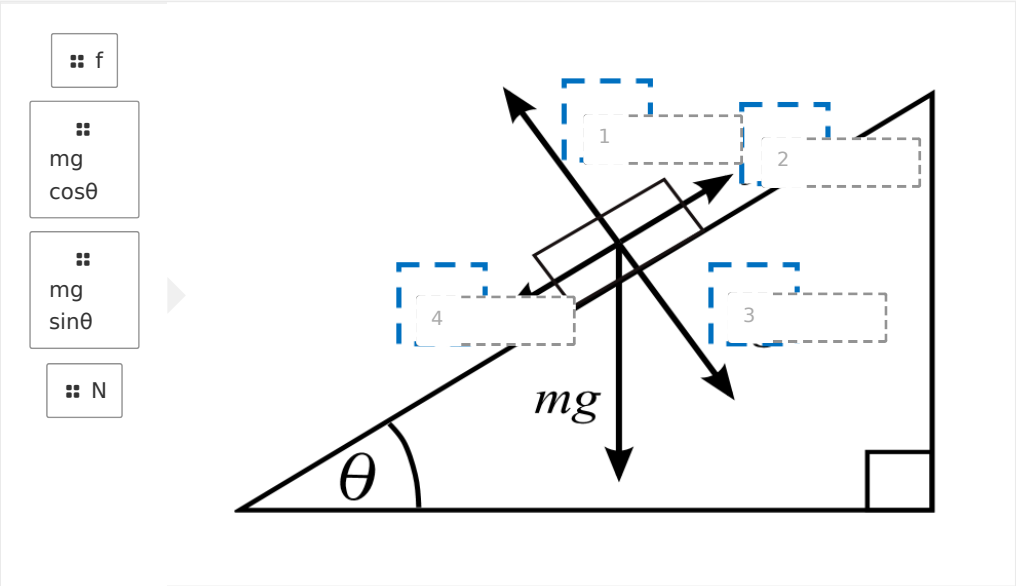


Correct answers:

1 Friction 2 Normal 3 Static friction 4 Coefficient of friction

5 Kinetic friction

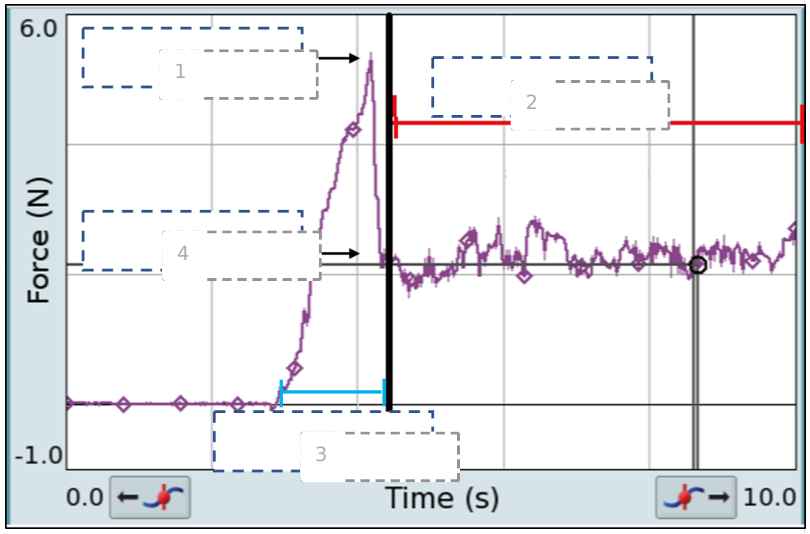
Label the force arrows on the free-body diagram.



Correct answers:

1 N 2 f 3 mg cosθ 4 mg sinθ

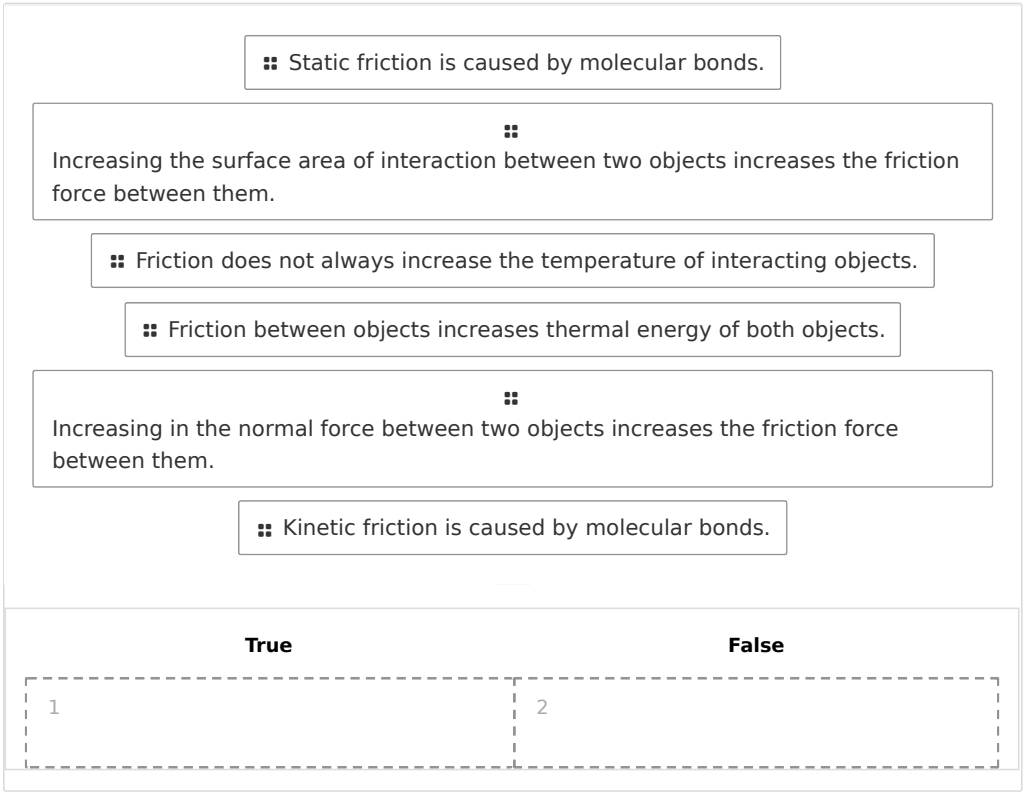
Label the force versus time graph.



Correct answers:

1 μ_s 2 Kinetic friction 3 Static friction 4 μ_k

Categorize each statement as True or False.



Correct answers:

1 Static friction is caused by molecular bonds.

Friction between objects increases thermal energy of both objects.

Increasing in the normal force between two objects increases the friction force between them.

2

Increasing the surface area of interaction between two objects increases the friction force between them.

Friction does not always increase the temperature of interacting objects.

Kinetic friction is caused by molecular bonds.

Exploration

The force of friction always acts parallel to the surface of interaction.

- True ✔
- False

When the objects are moving relative to one another, the speed of the moving object affects the magnitude of what is known as the kinetic friction force.

- True
- False ✔

The force of static friction is always equal to the coefficient of static friction multiplied by the normal force.

- True
- False ✔

The force of kinetic friction for a particular pair of interacting objects is always _____ the force of static friction.

- less than ✔
- greater than
- equal to
- None of the above

Static friction is caused by molecular _____ and kinetic friction is caused by molecular _____.

- attraction; bonds
- attraction; repulsion
- bonds; attraction ✔
- None of the above

The coefficient of static friction is related to the maximum angle of repose by _____.

- $\mu_s = \sin\theta_{max}$
- $\mu_s = \tan\theta_{max}$ ✔
- $\mu_s = \theta_{max}$
- None of the above

The coefficient of kinetic friction is found from the equation: _____.

- $\mu_k = \frac{F_{app}}{F_N}$ ✔
- $\mu_k = \frac{F_N}{F_{app}}$
- $\mu_k = F_{app} \times F_N$
- None of the above

The force of friction is always represented as a horizontal arrow in a free-body diagram.

- True
- False ✔

Exercise 1

Explain the difference between static friction and kinetic friction.

Static friction keeps an object from sliding or moving against a surface while kinetic friction reduces the acceleration of an object sliding against a surface.

Discuss the relationship between friction, normal force, and surface area.

Friction increases as the normal force of an object increases. Friction is not related to surface area.

Compare the static and kinetic friction forces and coefficients determined for the flat wooden friction block and the wooden friction block on its side that were recorded in Data Table 1. What was the relationship of surface area to the force and coefficient of friction between the objects?

Answer based on HOL results. Student responses will correspond to their actual data. The kinetic friction force for the flat friction block and the friction block on its side are the same. The same is true for the coefficient of kinetic friction. The static friction force, and the coefficient of static friction for the flat friction block and the friction block on its side are very similar, but the force and coefficient of static friction were found to be slightly larger for the flat block than for the block on its side. The surface area plays no role in determining the forces or coefficients of friction between two materials.

Compare the forces of static and kinetic friction and the coefficients of static and kinetic friction that were determined for the flat wooden friction block as the weight (and normal force) of the block changed, as recorded in Data Table 2. What was the relationship between the normal force and the forces and coefficients of friction between the two materials?

Answer based on HOL results. Student response will correspond to their actual data. The forces of static and kinetic friction increased as the weight of the friction block increased. The coefficients of static and kinetic friction remained approximately the same for all three weights tried. The normal force is directly proportional to the force of static and kinetic friction. The normal force plays no role in determining the coefficient of static or kinetic friction between two materials.

Do your experimental results support the background statement that the coefficient of kinetic friction is always smaller than the coefficient of static friction for the same two materials? Explain your answer by referencing your data and graphs.

Answer based on HOL results. Student responses will correspond to their actual data and graphs. The coefficient of static friction is always slightly larger than the coefficient of kinetic friction for the same materials. This matches with experimental observations indicating that the greater static friction force must be overcome before the smaller kinetic friction force takes over. This also matches with the theory that static friction is caused by molecular bonds forming between the surfaces of the two interacting objects, while the kinetic friction force is due to much weaker molecular attractions between the two surfaces once the two objects are sliding past one-another.

Compare the average coefficients of static and kinetic friction found for the wooden friction block to the coefficient of static and kinetic friction found from the graph. Do the values match? If not, which method provides a more accurate calculation of the actual coefficient? Explain your choice.

Answer based on HOL results. Student responses will correspond to their actual data and graphs. The values for static and kinetic friction coefficients measured in the two ways do not match. The coefficients from the graphs are smaller than the average calculated coefficients. The graphical method likely provides a more accurate determination of the actual coefficients, because the graphing software uses a least-squares fitting algorithm that better takes into account standard deviation and random errors than a simple average.

Which material among the four you tested has the largest coefficients of static and kinetic friction? Which material has the smallest? Does this make sense? Why or why not?

The sandpaper has the largest coefficient of static and kinetic friction. The glass has the lowest coefficient of static and kinetic friction. This makes sense because the sandpaper is very rough and grips the surface of whatever it touches, while the glass is very smooth and slides past the surface of whatever it touches.

When attempting to determine the coefficient of kinetic friction, why is it necessary to move the block with constant velocity? When attempting to determine the coefficient of static friction, why is it necessary to measure the applied force just before the block moves? Are these two scenarios (constant velocity and almost in motion) the only scenarios when friction is present? Explain your answer.

The constant velocity for the coefficient of kinetic friction measurement is necessary because the kinetic friction force does not increase as the applied force increases. In order to measure the friction force equal to the applied force, the applied force must be perfectly balanced with the friction force (no net force) so there is no acceleration. The measurement for the static friction coefficient must take place just before the block moves because the static friction force increases in proportion to the applied force up until it reaches the maximum value. Kinetic friction is present when objects are accelerating, it is just harder to measure. Static friction is present when there is an applied force attempting to move the object, it is just hard to measure.

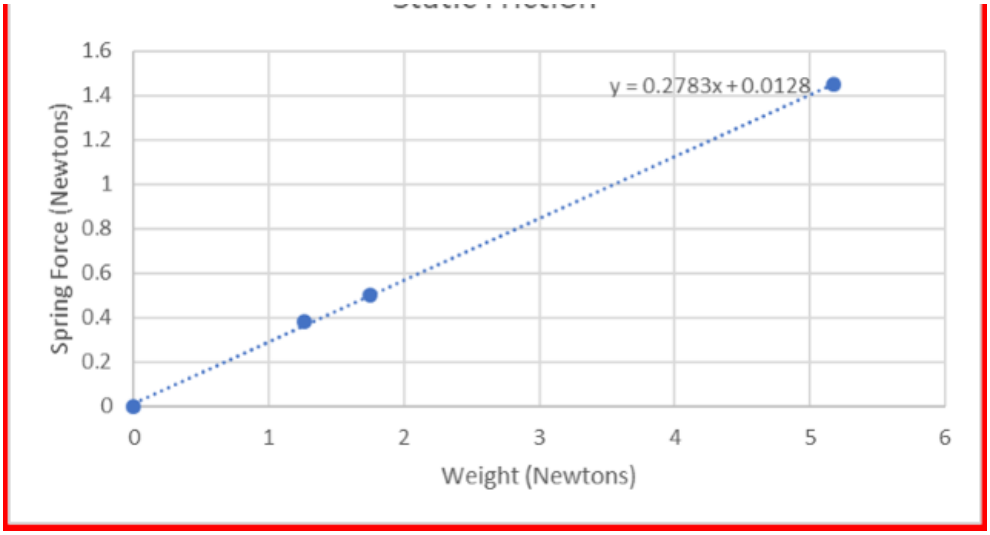
Data Table 1: Friction and Surface Area
(SAMPLE ANSWER BELOW)

Mass28.4g	Weight (N)	F_k Trial 1 (N)	F_k Trial 2 (N)	F_k Trial 3 (N)	Average F_k (N)	μ_k
Flat	5.18	1.20	1.18	1.20	1.19	0.23
Side	5.18	1.20	1.18	1.15	1.18	0.23
	Weight (N)	F_s Trial 1 (N)	F_s Trial 2 (N)	F_s Trial 3 (N)	Average F_s (N)	μ_s
Flat	5.18	1.40	1.50	1.45	1.45	0.28
Side	5.18	1.40	1.30	1.30	1.33	0.26

Data Table 2: Friction and Normal Force
(SAMPLE ANSWER BELOW)

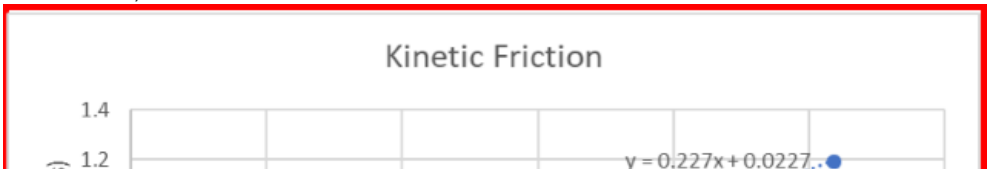
Weight (N)	F_k Trial 1 (N)	F_k Trial 2 (N)	F_k Trial 3 (N)	Average F_k (N)	μ_k calc.	μ_k calc. avg.	μ_k graph
5.18	1.20	1.18	1.20	1.19	0.23		
1.26	0.35	0.33	0.30	0.33	0.26	0.25	0.23
1.75	0.43	0.42	0.45	0.43	0.25		
Weight (N)	F_s Trial 1 (N)	F_s Trial 2 (N)	F_s Trial 3 (N)	Average F_s (N)	μ_s calc.	μ_s calc. avg.	μ_s graph
5.18	1.40	1.50	1.45	1.45	0.28		
1.26	0.40	0.40	0.38	0.39	0.31	0.29	0.28
1.75	0.55	0.49	0.50	0.51	0.29		

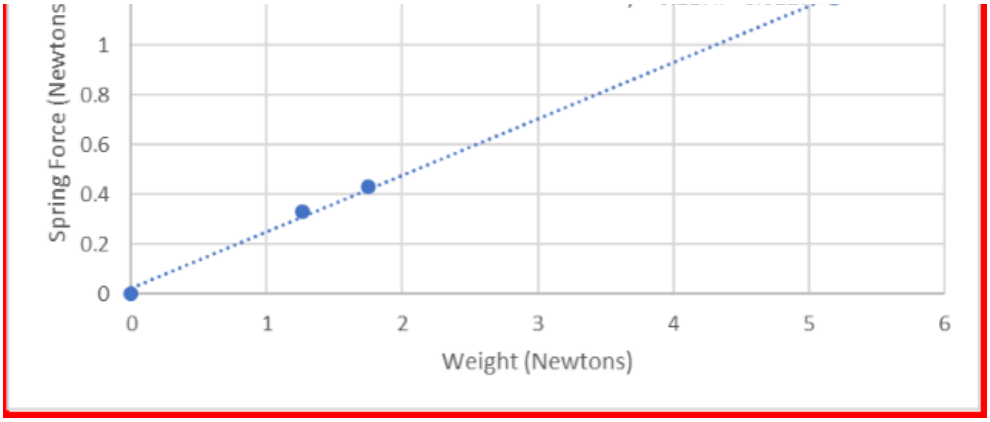
Graph 1: Static Friction
(SAMPLE ANSWER BELOW)



Graph 2: Kinetic Friction

(SAMPLE ANSWER BELOW)





Data Table 3: Friction and Surface Material

(SAMPLE ANSWER BELOW)

Material	Weight (N)	F_k Trial 1 (N)	F_k Trial 2 (N)	F_k Trial 3 (N)	Average F_k (N)	μ_k
Wood	5018	1.20	1.18	1.20	1.19	0.23
Glass	5.34	0.80	0.75	0.70	0.75	0.14
Sandpaper	5.34	2.10	2.00	2.05	2.05	0.38
Paper	5.18	0.95	0.90	0.90	0.92	0.18

	Weight (N)	F_S Trial 1 (N)	F_S Trial 2 (N)	F_S Trial 3 (N)	Average F_S (N)	μ_S
Wood	5.18	1.40	1.50	1.45	1.45	0.28
Glass	5.34	1.10	1.00	1.10	1.07	0.20
Sandpaper	5.34	2.30	2.50	2.40	2.40	0.45
Paper	5.18	1.05	1.20	1.10	1.12	0.22

Data Table 4: Maximum Angle of Repose
(SAMPLE ANSWER BELOW)

Material	θ (°) calc.	θ (°) Trial 1	θ (°) Trial 2	θ (°) Trial 3	θ (°) Average	% Difference
Wood	15.6	16.0	12.0	12.0	13.3	16
Glass	11.3	10.0	8.5	8.0	8.8	25
Sandpaper	24.2	24.5	24.0	24.0	24.2	0
Paper	12.4	11.5	11.9	12.0	11.8	5

Competency Review

The friction force is _____ proportional to the normal force on an object.

- inversely
- directly ✔
- quadradically
- None of the above

The _____ influences the magnitude of the static friction force.

- normal force
- coefficient of static friction
- applied force
- All of the above ✔

The coefficient of static friction for a certain pair of materials is greater than the coefficient of kinetic friction for the same pair of materials.

- True ✔
- False

Smooth surfaces have more points of contact on a molecular level than rough surfaces.

- True
- False ✔

The friction force as represented in a free-body diagram always has the same length as the applied force.

- True
- False ✔

A box of tools rests in the back of a pickup truck. The truck accelerates to the north and the box remains at rest in the truck. The direction of the friction force on the box of tools is _____.

- north ✔
- south
- zero
- None of the Above

A block of mass 10 kg rests on an incline of 20°. The magnitude of the friction force on the block is _____ N.

- 98
- 92
- 34 ✔
- None of the above

If a go-kart's specifications indicate it can climb a slope of 35°, the coefficient of static friction between the go-kart tires and the ramp is _____.

- 0.8
- 0.6
- 0.7 ✔
- None of the above

A block of mass 10 kg is pulled by a 30 N force at a constant velocity along a flat surface. The coefficient of kinetic friction between the block and the surface _____.

- 0.31 ✔
- 0.47
- 0.33
- None of the above

Extension Questions

In the sport of curling, large smooth stones are slid across an ice court to land on a target. Sometimes the stones need to move a bit farther across the ice and other times players want the stones to stop a bit sooner. Suggest a way to increase the kinetic friction between the stone and the ice so that the stone stops more quickly. Next, suggest a way to decrease the kinetic friction between the stone and the ice so that the stone slides farther along the ice before coming to a stop. (SAMPLE ANSWER BELOW)

To increase the kinetic friction, the mass of the stone could be increased, or more pressure could be applied to the stone as it slides to increase the normal force. To decrease the kinetic friction, the ice could be slightly melted in front of the stone to decrease the coefficient of kinetic friction between the ice and the stone. In other words, lubrication could be added to the contact surface between the ice and the stone to decrease the coefficient of kinetic friction.