FRICTION

Friction

1. A block is sliding across a rough table. Which of the following statements is true? (select all that apply)
   - A There is a friction force exerted on the table by the block, in the opposite direction as the block's velocity
   - B There is a friction force exerted on the block by the table, in the opposite direction as the block's velocity
   - C There is a friction force exerted on the block by the table, in the direction of the block's velocity
   - D There is a friction force exerted on the table by the block, in the direction of the block's velocity

2. A book is placed desk and one end of the desk is lifted so that the desk surface is inclined, but the book remains at rest and does not slide. There must be...
   - A a static friction force acting on the book which is perpendicular to the desk surface
   - B a kinetic friction force acting on the book which is parallel to the desk surface
   - C a static friction force acting on the book which is parallel to the desk surface
   - D a kinetic friction force acting on the book which is perpendicular to the desk surface

3. The SI unit for the coefficient of friction is...
   - A N
   - B N·kg
   - C N/kg
   - D It does not have a unit

4. A ball is rolling without slipping on rough ground with an initial velocity. Over a period of time the ball slows down and comes to rest. Which type of friction force(s) was involved while the ball was slowing down? (select all that apply)
   - A Static friction
   - B Kinetic friction
   - C Rolling friction
   - D No friction forces were involved

5. A person gathers together a stack of loose sheets of paper, places the stack against the wall and pushes on them with a force that is directly perpendicular to the wall. If they push hard enough, none of the sheets fall down. What is preventing the sheets of paper from falling?
   - A An upwards vertical component of the applied pushing force which acts on all of the sheets
   - B Static friction forces between the person's hand, each of the sheets and the wall
   - C A normal force acting on the sheets from the person's hand and from the wall
   - D Kinetic friction forces between the person's hand, each of the sheets and the wall which prevents motion

6. A person is trying to push a heavy box across a rough floor. The magnitude of the force they have to apply to the box to get it moving (from rest) depends on which of the following? (select all that apply)
   - A The coefficient of kinetic friction between the box and the floor
   - B The mass of the box
   - C The coefficient of static friction between the box and the floor
   - D The gravitational acceleration g

7. A block is sliding across a rough surface and it slows down due to friction. While the block is slowing down, the magnitude of the friction force…
   - A is increasing
   - B is decreasing
   - C remains the same
   - D its change cannot be determined

8. Two people push on opposite sides of a large box. One person pushes on the box to the left with a force of 20 N and the other person pushes on the box to the right with a force of 30 N. If the box remains at rest, what is the direction of the friction force exerted on the box from the floor?
   - A Left
   - B Right
   - C Down
   - D Up

9. Three blocks are sliding across a rough surface at the same speed. Block A has a mass of 8 kg, block B has a mass of 12 kg, and block C has a mass of 10 kg. How do the magnitudes of the friction forces on each block compare (assuming they all have the same coefficient of friction)?
   - A $f_A = f_B = f_C$
   - B $f_A < f_B < f_C$
   - C $f_B < f_C < f_A$
   - D $f_A < f_C < f_B$

10. A 12 N horizontal force acts on a 3 kg block which remains at rest on a rough surface. The coefficient of static friction between the block and the surface is 0.5. What is the magnitude of the friction force acting on the block?
    - A 12 N
    - B 2.7 N
    - C 14.7 N
    - D 26.7 N

11. A small block and a large block are sliding across a rough surface. The blocks have the same mass but the bottom of the large block has twice the surface area as the bottom of the small block. The coefficient of friction for each block is the same. If the friction force acting on the small block is f, what is the friction force on the large block?
    - A $2f$
    - B $f/2$
    - C f
    - D $f/4$

12. Block A and block B have the same mass but different coefficients of kinetic friction with the rough surface that they're sitting on. The blocks are each given a push so that they are released with the same initial velocity. Block A comes to rest in 3 seconds and block B comes to rest in 2 seconds. How do the coefficients of friction for each block compare?
    - A $\mu_A > \mu_B$
    - B $\mu_A < \mu_B$
    - C $\mu_A = \mu_B$
    - D cannot be determined

13. A box is sitting on a rough floor. A person then pushes horizontally on the box with a force of 20 N but the box does not move. A second person then comes and sits on top of the box. The first person pushes on the box again with a force of 20 N. How does the friction force on the box compare between the first time it's pushed (no person sitting on it) and the second time it's pushed (with a person sitting on it)?

- A The magnitude of the friction force was the same both times
- B The magnitude of the friction force was greater when a person was sitting on the box
- C The magnitude of the friction force was less when a person was sitting on the box
- D Cannot be determined

14. A block of mass m is sliding across a rough surface. There is a coefficient of kinetic friction μ_k between the block and the surface. Which of the following represents the acceleration of the block?

- A $\mu_k mg$
- B mg
- C $\mu_k g/m$
- D $\mu_k g$

15. A block is sitting on a rough surface when a horizontal pushing force is applied to the block. The relationship between the friction force and the pushing force on the block is shown in the graph in Figure 1. If the pushing force is 10 N, which of the following is true?

- A The block will slide
- B The block will remain at rest
- C The block will remain at rest for some time and then slide
- D The motion of the block cannot be determined

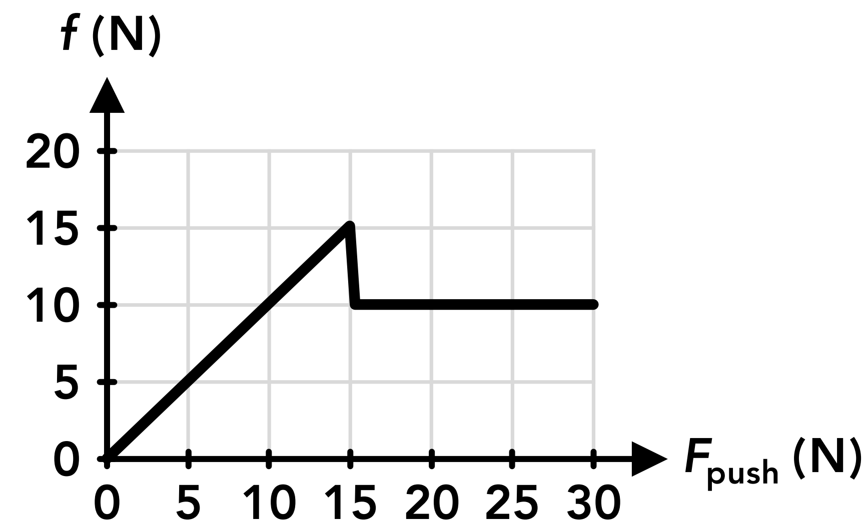
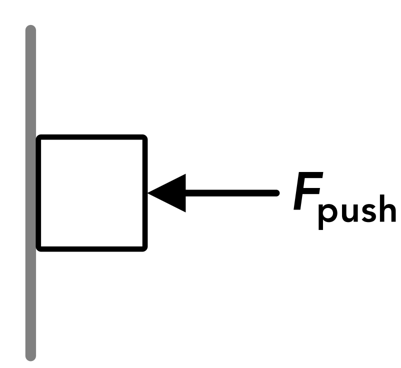


Figure 1

16. A block is sitting on a rough surface when a horizontal pushing force is applied to the block. The relationship between the friction force and the pushing force on the block is shown in the graph in Figure 1. If the applied pushing force is 20 N, the acceleration of the block depends on which of the following? (select all that apply)

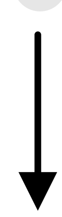
- A The mass of the block
- B The coefficient of static friction between the block and the surface
- C The coefficient of kinetic friction between the block and the surface
- D The acceleration due to gravity g

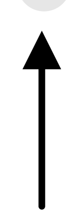
17. A block is held in place against a wall by a pushing force as shown on the right. Which of the following shows the direction of friction force acting on the block from the wall?



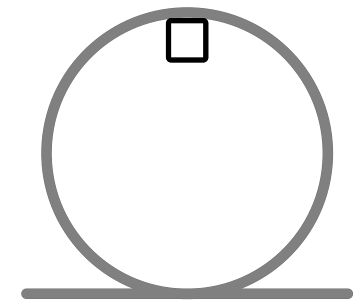
A 

B 

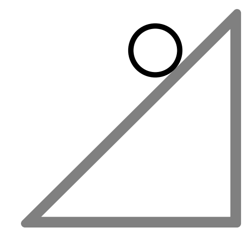
C 

D 

18. A block is sliding counterclockwise around the inside of a vertical circular track as shown on the right. If the track surface is not frictionless, which of the following shows the direction of the friction force acting on the block when it's at the top of the circle?

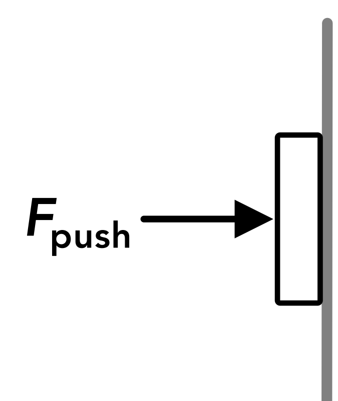


19. A ball is rolling down an incline with a rough surface as shown on the right. Which of the following shows the direction of the rolling friction force acting on the ball?

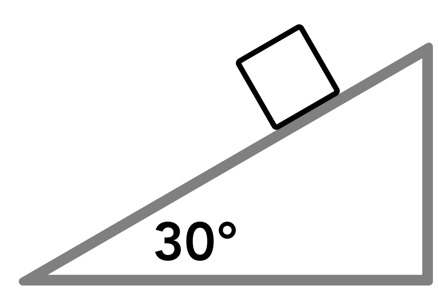


20. A 15 kg block is sitting on a rough surface. The coefficient of static friction between the block and the surface is 0.5 and the coefficient of kinetic friction is 0.3. A 90 N force is applied to the block, horizontal to the surface. What is the magnitude of the friction force acting on the block?

21. A book is placed against a rough wall and a horizontal pushing force is applied to the book as shown on the right. Through experimentation it is determined that the minimum pushing force required to prevent the book from falling is 40 N. If the coefficient of static friction between the book and the wall is 0.6, what is the mass of the book?



22. A 25 kg block is sitting at rest on a rough surface of an incline as shown on the right. What is the magnitude of the friction force acting on the block?



23. A 5 kg block is on a rough surface when a horizontal pulling force is applied to the block. The graph in Figure 2 shows the relationship between the friction force acting on the block vs the applied pulling force. What is the coefficient of static friction between the block and the surface?

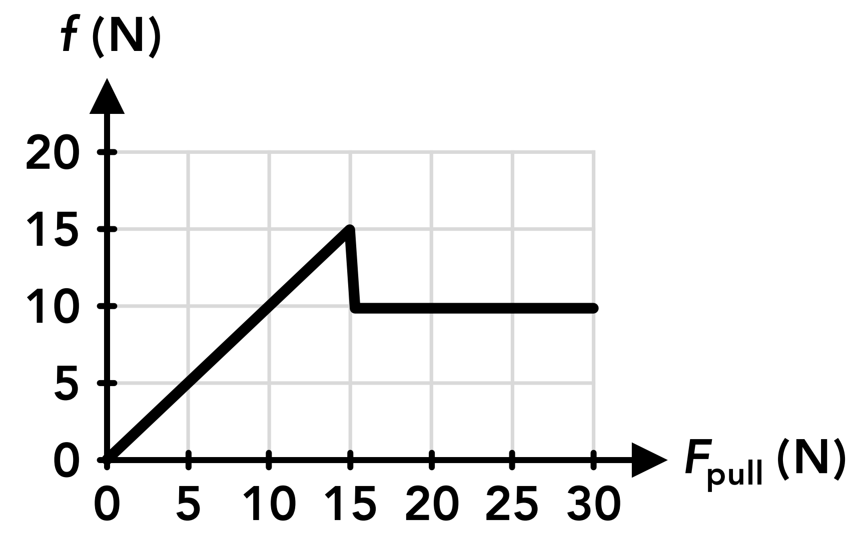


Figure 2

24. Using the same scenario and graph in Figure 2, what is the coefficient of kinetic friction between the block and the surface?

25. Using the same scenario and graph in Figure 2, what is the acceleration of the block if the pulling force on the block is 20 N?

Answers

1. B, D	6. B, C, D	11. C	16. A, C, D	21. 2.4 kg
2. C	7. C	12. B	17. D	22. 122.5 N
3. D	8. A	13. A	18. B	23. 0.3
4. A, C	9. D	14. D	19. A	24. 0.2
5. B	10. A	15. B	20. 44.1 N	25. 2 m/s²

Answers - Friction

1. **Answer: B, D**
   The block and the table exert equal and opposite forces on each other (a pair of forces from Newton's 3rd law of motion). The friction force acting on the block (caused by the table) must be acting in the direction which opposes the block's motion, and the friction force acting on the table (caused by the block) must be pointing in the other direction.

2. **Answer: C**
   A component of the gravitational force acting on the book would cause it to slide down. Since the book is at rest there must be a static friction force acting on it to prevent its motion. Any friction force always acts parallel to the surface that an object is in contact with.

3. **Answer: D**
   The coefficient of friction μ is unitless.

4. **Answer: A, C**
   When an object is rolling without slipping there is a static friction force between the ground and the point on the object that is momentarily in contact with the ground which is preventing it from slipping. Since the ball is rolling there is rolling friction causing it to slow down but there is no kinetic friction involved. There would be kinetic friction, also called "sliding friction", if the ball was sliding or slipping instead of rolling.

5. **Answer: B**
   There is a downwards gravitational force acting on each sheet of paper, so there must also be an upwards force acting on each sheet of paper, which is a static friction force (between their hand and the first sheet, between all of the middle sheets, and between the last sheet and the wall). There are normal forces between their hand each sheet and the wall but those forces are all horizontal (perpendicular to the wall) and have no vertical component that could oppose the downwards gravitational force.

6. **Answer: B, C, D**
   While the box is at rest and the person is applying a force, a static friction force is preventing the box from moving. The maximum static friction force between the box and the floor is $f_{s\ max} = \mu_s F_n$, and the person will have to apply a greater force than that. The maximum static friction force depends on the coefficent of static friction and the normal force, which depends on the weight of the box, $F_g = mg$.

7. **Answer: C**
   While the block is moving the friction force acting on it is kinetic friction, which only depends on the coefficient of kinetic friction and the normal force between the block and the surface. The friction force does not depend on the velocity of the block.

8. **Answer: A**
   The box remains at rest so the net horizontal force on the box must be zero. Therefore there must be a 10 N friction force acting on the box to the left (the total force in each direction is 30 N).

9. **Answer: D**
   The friction forces acting on the blocks are kinetic friction which depends on the coefficient of kinetic friction and the normal force between the block and the surface, which depends on the weight, which depends on the mass.

10. **Answer: A**
    The equation $f_{s\ max} = \mu_s F_n$ gives us the maximum possible static friction force, not necessarily the actual static friction force, which depends on the other forces acting along the same direction. The maximum static friction force for the block is 14.7 N but since the 12 N force is less than that the block remains at rest and the actual static friction force is equal in magnitude to the applied 12 N force. The net horizontal force on the block is zero.

11. **Answer: C**
    The kinetic friction force only depends on the coefficient of kinetic friction and the normal force between the block and the surface. The normal force only depends on the mass of the block and the acceleration due to gravity g, it does not depend on the contact surface area.

12. **Answer: B**
    If the blocks start with the same velocity, block B has a greater acceleration because it's velocity changes to zero in less time. The friction force (which is the net force causing the acceleration) on block B must be greater than the friction force on block A. The blocks have the same mass so the normal force acting on each block is the same, so the coefficient of friction for block B must be greater.

13. **Answer: A**
    The maximum possible static friction force depends on the normal force between the box and the floor which did increase when the second person was sitting on the box. But in both scenarios the box did not move so the static friction force was equal to the applied 20 N force.

14. **Answer: D**
    The net horizontal force on the block is the kinetic friction.
    $\sum F = ma \qquad f_k = ma \qquad \mu_k mg = ma \qquad \mu_k g = a$

15. **Answer: B**
    From the graph, the maximum static friction force is 15 N. The applied 10 N force is less than the maximum static friction force so the block remains at rest with a static friction force acting on it.

16. **Answer: A, C, D**
    From the graph, the applied pushing force of 20 N is greater than the maximum static friction force of 15 N so the block will slide and accelerate, and a kinetic friction force acts on the block. The kinetic friction force depends on the coefficient of kinetic friction and the weight of the block, which depends on the mass of the block and the acceleration due to gravity. The acceleration of the block also depends on the mass of the block.

17. **Answer: D**
    The block is held in place so it's not moving and the net vertical force acting on it is zero. There is a downwards gravitational force on the block so the friction force on the block must be acting upwards.

18. **Answer: B**
    The block is traveling counterclockwise around the circle so its velocity points to the left at the position shown, which means the kinetic friction force acting on the block points to the right.

19. **Answer: A**
    The ball is rolling down the incline so its velocity points down and to the left. The direction of the rolling friction force is in the opposite direction as its velocity, so it points up and to the right.

20. **Answer: 44.1 N**
The maximum possible static friction force which can act on the block is:
$f_{s\ max} = \mu_s F_n = (0.5)(15\text{ kg})g = 73.5\text{ N}$
The 90 N applied force is greater than the maximum possible static friction force so the block begins to move and the friction force acting on it is a kinetic friction force:
$f_k = \mu_k F_n = (0.3)(15\text{ kg})g = 44.1\text{ N}$

21. **Answer: 2.4 kg**
The magnitude of the applied pushing force is equal to the magnitude of the normal force between the book and the wall (since the net horizontal force on the book is zero if it's not moving). There is a static friction force acting upwards on the book from the wall which is always equal in magnitude to the gravitational force acting downwards on the book if the book is not moving. The maximum possible static friction force must occur when the applied force is exactly 40 N. If the applied force is less than 40 N, the gravitational force is greater than the maximum static friction force. If the applied force is more than 40 N, the static friction force is still equal to the gravitational force.
$\sum F_y = ma_y \quad f_s - F_g = m(0) \quad f_s = F_g \quad \mu_s F_n = mg \quad (0.6)(40\text{ N}) = mg \quad m = 2.4\text{ kg}$

22. **Answer: 122.5 N**
The block is at rest so the net force on the block is zero. The static friction force acting up the incline (parallel to the incline) must be equal to the component of the gravitational force on the block that is acting down the incline (parallel to the incline). Using the 30° angle between the incline and the horizontal:
Parallel to the incline: $\sum F = ma \quad f_s - F_{g\parallel} = m(0) \quad f_s = F_{g\parallel} = F_g\sin(30°) = (25\text{ kg})g\sin(30°) = 122.5\text{ N}$

23. **Answer: 0.3**
From the graph, the maximum static friction force is 15 N (the peak of the initial diagonal line).
$f_{s\ max} = \mu_s F_n \quad 15\text{ N} = \mu_s(5\text{ kg})g \quad \mu_s = 0.3$

24. **Answer: 0.2**
From the graph, the kinetic friction force is 10 N (the flat line after the static friction force).
$f_k = \mu_k F_n \quad 10\text{ N} = \mu_k(5\text{ kg})g \quad \mu_k = 0.2$

25. **Answer: 2 m/s²**
From the graph, if the pulling force is 20 N then the friction force on the block is 10 N and the block will slide. The friction force acts in the opposite direction as the pulling force, so the net horizontal force on the block is:
$\sum F_x = ma_x \quad (20\text{ N}) - (10\text{ N}) = (5\text{ kg})a_x \quad a_x = 2\text{ m/s}^2$