NEWTON'S 3RD LAW & NORMAL FORCE

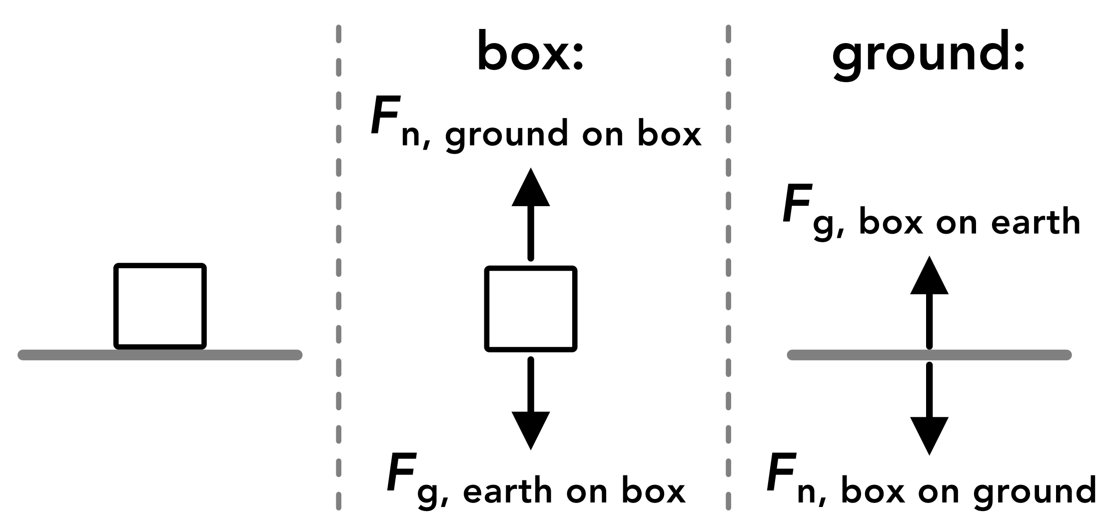
Newton's 3rd Law of Motion & Normal Force

1. A pen is sitting at rest on a desk. If the pen exerts a downwards force on the desk, then according to Newton's 3rd law of motion…
   - A the desk also exerts a downwards force on the ground with an equal magnitude
   - B the pen also exerts an upwards force on itself with equal magnitude
   - C the desk exerts an upwards force on the pen with a greater magnitude because it has a greater mass
   - D the desk exerts an upwards force on the pen with an equal magnitude

2. A car is driving on a road. Which of the following should be included in a free body diagram of the car? (select all that apply)
   - A the car
   - B the force exerted by the car on the road
   - C the road
   - D the force exerted by the road on the car

3. True or false: A pair of equal and opposite forces (described in Newton's 3rd law) only arises when two objects are in contact with each other.
   - A True
   - B False

4. A box is sitting at rest on the ground as shown on the right, along with free body diagrams of the box and the ground. Which of the following are a pair of equal and opposite forces described in Newton's 3rd law? (select all that apply)
   - A $F_{\text{n, ground on box}}$ and $F_{\text{g, earth on box}}$
   - B $F_{\text{n, box on ground}}$ and $F_{\text{n, ground on box}}$
   - C $F_{\text{g, box on earth}}$ and $F_{\text{n, box on ground}}$
   - D $F_{\text{g, box on earth}}$ and $F_{\text{g, earth on box}}$

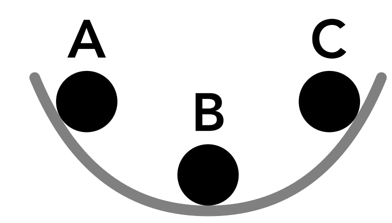


5. A force that is acting on an object may be referred to as a "normal" force because…
   - A it is much more common that other types of forces
   - B all objects experience a normal force
   - C it is perpendicular to the surface that the object is in contact with
   - D it is part of a pair of forces as described in Newton's 3rd law

6. A person is trying to push their car that broke down by applying a 60 N force to the back of the car. The car doesn't move so the person stops and then tries again, exerting a greater force of 80 N on the car, but the car still doesn't move. Which of the following is true?
   - A The car exerts a greater force on the person during the second try
   - B The car exerts the same amount of force on the person both times because it's not moving
   - C The car exerts a smaller force on the person during the second try
   - D The car does not exert a force on the person

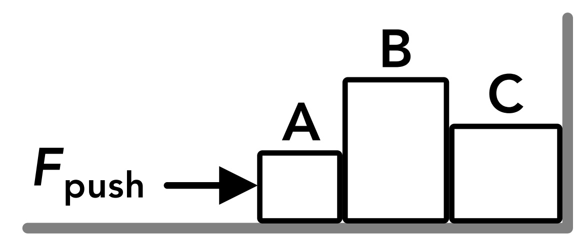
7. A person places a book against a wall and leans on the book so it doesn't fall, but the person does not touch the wall. Which of the following is true? (select all that apply)
   - A The book exerts a normal force on the person
   - B The person exerts a normal force on the book
   - C The wall exerts a normal force on the book
   - D The person exerts a normal force on the wall

8. A ball is rolling along a curved surface as shown on the right. When the ball is at position C, which of the following show the direction of the normal force acting on the ball?



A B C D

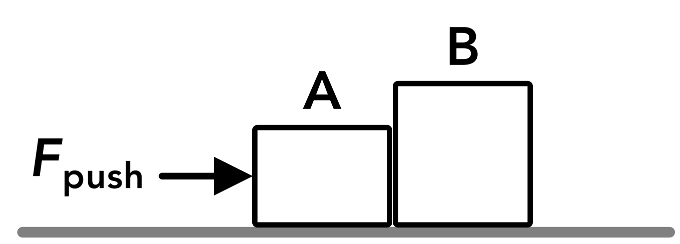
9. Three blocks are on a frictionless surface as shown on the right. A force F_{push} is acting on block A so that the three blocks are in contact, block C is in contact with the wall, and the blocks are at rest. Which of the following describes the relationship between the normal forces acting on the blocks?



   - A $F_{C\ on\ wall} > F_{B\ on\ C} = F_{A\ on\ B}$
   - B $F_{C\ on\ wall} > F_{B\ on\ C} > F_{A\ on\ B}$
   - C $F_{A\ on\ B} > F_{B\ on\ C} > F_{C\ on\ wall}$
   - D $F_{A\ on\ B} = F_{B\ on\ C} = F_{C\ on\ wall}$

10. Person A and person B are standing next to each other at rest on a frictionless surface. Person A pushes person B and they slide away from each other in opposite directions. If person A has a greater mass than person B, who is moving at a greater speed a few seconds after they move apart?
   - A Person A
   - B Person B
   - C They will be moving at the same speed
   - D Cannot be determined

11. Two blocks are sliding on a frictionless surface due to an applied force as shown on the right. The direction of the force on block A by block B is...



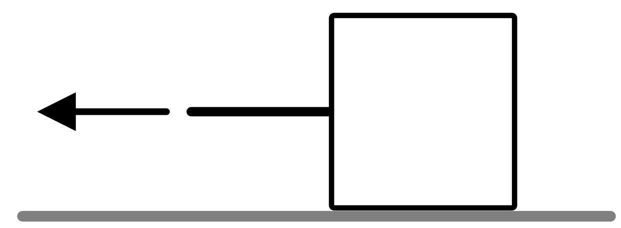
   - A to the right
   - B to the left
   - C upward
   - D downward

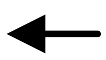
12. An astronaut floating freely in space is holding a wrench. If the astronaut throws the wrench, which of the following is true during the throw?
   - A The force of the astronaut on the wrench is equal to the force of the wrench on the astronaut
   - B The force of the astronaut on the wrench is greater than the force of the wrench on the astronaut
   - C The astronaut exerts a force on the wrench but the wrench does not exert a force on the astronaut
   - D The relationship between the forces cannot be determined without knowing the masses

13. Three books are stacked on top of each other at rest on a table. There is a gravitational force acting downwards on each of the books. Which of the following is true about the magnitudes of the normal forces involved?
    - A All of the normal forces between the books are equal
    - B The force of the top book on the middle book is greater than the force of the bottom book on the table
    - C The force of the middle book on the top book is equal to the force of the top book on the middle book
    - D None of the above

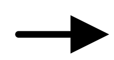
14. When approaching an intersection, car A hits the back of car B (which was stopped before the crash). During the collision...
    - A car B pushes on car A with a greater amount of force than car A pushes on car B, because car B is stopped
    - B car A pushes on car B, but car B does not push on car A
    - C car A pushes on car B with a greater amount of force than car B pushes on car A, because car A is moving
    - D car B pushes on car A with the same amount of force that car A pushes on car B

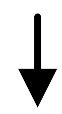
15. A person pulls on a rope attached to a box as shown on the right. Which of the following show the direction of the force acting on the rope by the box?



A 

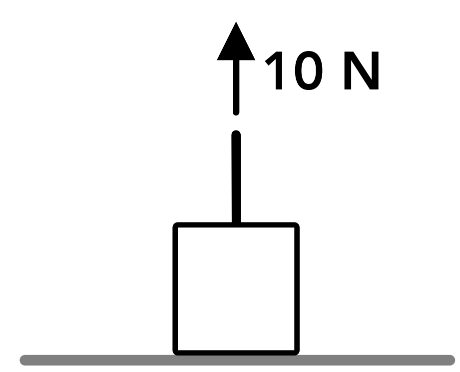
B 

C 

D 

16. A hammer is being used to drive a nail into a wall. The hammer hits the nail with a force of 100 N. If the mass of the hammer is 100 kg and the mass of the nail is 0.1 kg, what is the force of the nail on the hammer?
    - A 0.1 N
    - B 1 N
    - C 10 N
    - D 100 N

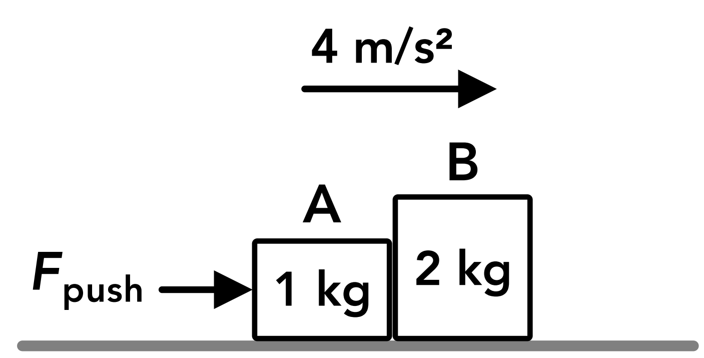
17. A box is sitting on the ground and is then pulled upwards with a force of 10 N as shown on the right. If there is a 14 N gravitational force acting downwards on the box, what is the normal force acting on the box by the ground?



18. A laptop is sitting at rest on a table and a downwards gravitational force of 20 N is acting on the laptop. A person then pushes down on the laptop towards the table, and the normal force acting on the laptop by the table doubles. What is the magnitude of the force applied by the person?

19. A 4,000 kg rocket is floating in space (assume no forces are acting on it) and carrying a 500 kg satellite. The satellite is then pushed away from the rocket, and the rocket experiences an acceleration of 2 m/s^2 for 0.5 seconds. How fast is the satellite moving away from the rocket after it's pushed?

20. Two blocks are sliding on a frictionless surface with an acceleration of 4 m/s^2 due to a force being applied to block A. The two blocks slide while remaining in contact with each other. What is the magnitude of the force being applied to block A, F_{push} ?



Answers

1. D	6. A	11. B	16. D
2. A, D	7. A, B, C	12. A	17. 4 N
3. B, False	8. B	13. C	18. 20 N
4. B, D	9. D	14. D	19. 8 m/s
5. C	10. B	15. C	20. 12 N

Answers - Newton's 3rd Law of Motion & Normal Force

1. **Answer: D**
   According to Newton's 3rd law of motion, if one object (the pen) exerts a force on a second object (the desk) then the second object (the desk) exerts a force on the first object (the pen) with an equal magnitude and in the opposite direction.

2. **Answer: A, D**
   A free body diagram of an object should only include that object and the forces acting on that object. It should not include other objects or any forces exerted by that object on other things.

3. **Answer: B, False**
   Some force pairs arise when two objects are in contact (such as normal forces) but there are also pairs of non-contact forces (such as gravitational forces).

4. **Answer: B, D**
   The pair of equal and opposite forces described in Newton's 3rd law refers to the force exerted on object A by object B, and the force exerted by object B on object A. This pair of forces will always be the same type of force. In this case it's one pair of normal forces $\boldsymbol{F}_n$ and one pair of gravitational forces $\boldsymbol{F}_g$. A pair of forces is split up between the free body diagrams of the two objects because the forces act on different objects.

5. **Answer: C**
   The word "normal" means perpendicular and a normal force always acts perpendicular to the surface that the object is in contact with.

6. **Answer: A**
   The car will always exert a force on the person (when in contact) that is equal in magnitude to the force exerted by the person on the car according to Newton's 3rd law of motion.

7. **Answer: A, B, C**
   A normal force exists between two objects that are in direct contact with each other. The person is in contact with the book and the book is in contact with the wall, but the person is not in contact with the wall.

8. **Answer: B**
   A normal force always acts perpendicular to the surface that the object is in contact with. Options B and D are both perpendicular to the surface at point C. Option B shows the direction of the normal force acting on the ball by the surface, and option D shows the direction of the normal force acting on the surface by the ball.

9. **Answer: D**
The blocks are at rest so the acceleration of each block is zero, the net force acting on each block is zero and the leftward and rightward forces on each block must be equal in magnitude. There is no friction force so the only horizontal forces acting on the blocks are $\boldsymbol{F}_{\text{push}}$ and the horizontal normal forces. $\boldsymbol{F}_{\text{push}} = \boldsymbol{F}_{\text{B on A}}$ (net force on A is zero), $\boldsymbol{F}_{\text{B on A}} = \boldsymbol{F}_{\text{A on B}}$ (Newton's 3rd law), $\boldsymbol{F}_{\text{A on B}} = \boldsymbol{F}_{\text{C on B}}$ (net force on B is zero), $\boldsymbol{F}_{\text{C on B}} = \boldsymbol{F}_{\text{B on C}}$ (Newton's 3rd law), $\boldsymbol{F}_{\text{B on C}} = \boldsymbol{F}_{\text{wall on C}}$ (net force on C is zero), $\boldsymbol{F}_{\text{wall on C}} = \boldsymbol{F}_{\text{C on wall}}$ (Newton's 3rd law).

10. **Answer: B**
When person A pushes on person B, person B also exerts a force on person A according to Newton's 3rd law (this is just a contact force, person B doesn't need to push on person A with their hands). If the force exerted on each person is the same, then the person with a smaller mass (person B) will experience a greater acceleration based on Newton's 2nd law: $\boldsymbol{F} = m\boldsymbol{a}$. If person B experiences a greater acceleration (for the same period of time) they will be moving faster at any time after the force is applied.

11. **Answer: B**
Blocks A and B exert an equal and opposite normal force on each other. The force exerted on block B by block A points to the right and the force exerted on block A by block B points to the left.

12. **Answer: A**
The force of the astronaut on the wrench is equal to the force of the wrench on the astronaut according to Newton's 3rd law.

13. **Answer: C**
The force of the middle book on the top book is equal to the force of the top book on the middle book according to Newton's 3rd law. Each book is at rest so the net force on each book is zero. The downwards gravitational force on the top book is equal to the upwards force of the middle book on the top book. The middle book has two downwards forces: its own gravitational force and the force of the top book on the middle book. The sum of those two forces is equal to the force of the bottom book on the middle book, which is equal to the force of the middle book on the bottom book. Because each book has its own gravitational force, the normal forces between the three books are not equal, and the force of the top book on the middle book is less than the force of the bottom book on the table.

14. **Answer: D**
Both cars exert an equal and opposite force on each other when in contact according to Newton's 3rd law.

15. **Answer: C**
The rope and the box exert equal and opposite forces on each other according to Newton's 3rd law. The rope pulls on the box to the left and the box pulls on the rope to the right.

16. **Answer: D**
The hammer and the nail exert a force on each other with the same magnitude according to Newton's 3rd law, which does not depend on the mass of each object.

17. **Answer: 4 N**
There is a 10 N force acting upwards on the box, a normal force acting upwards on the box (with an unknown magnitude), and a 14 N gravitational force acting downwards on the box. Applying Newton's 2nd law:
$\sum F_y = 10\text{ N} + F_n - 14\text{ N} = ma_y$
The vertical acceleration of the box must be zero. The box can't accelerate downwards. If the box accelerated upwards it would lose contact with the ground, the normal force would be zero and the net force would be 4 N downwards (which is not possible if the acceleration is upwards). If the acceleration is zero:
$10\text{ N} + F_n - 14\text{ N} = m\,(0\text{ m/s}^2) \qquad F_n = 4\text{ N}$

18. **Answer: 20 N**
When the laptop is sitting on the table with no applied force, the upwards normal force is equal to the downwards gravitational force on the laptop if the laptop is not accelerating. The upwards normal force on the laptop when it's being pushed down by the person is twice the first normal force, which can be used to find the force applied by the person F_{push} :
No applied force: $\sum F_y = ma_y$ $\quad F_{n1} - 20 \text{ N} = m\,(0 \text{ m/s}^2)$ $\quad F_{n1} = 20 \text{ N}$
With push force: $\sum F_y = ma_y$ $\quad F_{n2} - 20 \text{ N} - F_{push} = m\,(0 \text{ m/s}^2)$ $\quad F_{push} = F_{n2} - 20 \text{ N} = 40 \text{ N} - 20 \text{ N} = 20 \text{ N}$

19. **Answer: 8 m/s**
When the rocket pushes the satellite, the rocket exerts a force on the satellite and the satellite exerts an equal and opposite force on the rocket. We can find the magnitude of that force on the satellite, then find the acceleration of the satellite, then find its speed after 0.5 seconds (the initial speed relative to the rocket is zero):
Rocket: $\sum F = ma$ $\quad F = (4000 \text{ kg})(2 \text{ m/s}^2)$ $\quad F = 8{,}000 \text{ N}$
Satellite: $\sum F = ma$ $\quad 8{,}000 \text{ N} = (500 \text{ kg})a$ $\quad a = 16 \text{ m/s}^2$
$v_f = v_i + a\Delta t$ $\quad v_f = (0 \text{ m/s}) + (16 \text{ m/s}^2)(0.5 \text{ s})$ $\quad v_f = 8 \text{ m/s}$

20. **Answer: 12 N**
This can be solved in two ways. First, because the two blocks are sliding together on a frictionless surface, the acceleration of both blocks is caused by the applied force on block A. If we treat the two blocks as a sytem, we treat them as one object with a mass of 3 kg. If we apply Newton's 2nd law to this system:
System of two blocks: $\sum F_x = ma_x$ $\quad \sum F_x = F_{push} = (3 \text{ kg})(4 \text{ m/s}^2)$ $\quad F_{push} = 12 \text{ N}$
The second option is to apply Newton's 2nd law to each block separately and solve the set of equations:
Block A: $\sum F_x = ma_x$ $\quad \sum F_x = F_{push} - F_{B\text{ on }A} = (1 \text{ kg})(4 \text{ m/s}^2)$ $\quad F_{push} = 4 \text{ N} + F_{B\text{ on }A}$
Block B: $\sum F_x = ma_x$ $\quad \sum F_x = F_{A\text{ on }B} = (2 \text{ kg})(4 \text{ m/s}^2)$ $\quad F_{A\text{ on }B} = 8 \text{ N}$
Combining equations and Newton's 3rd law: $F_{push} = 4 \text{ N} + F_{B\text{ on }A} = 4 \text{ N} + 8 \text{ N} = 12 \text{ N}$