

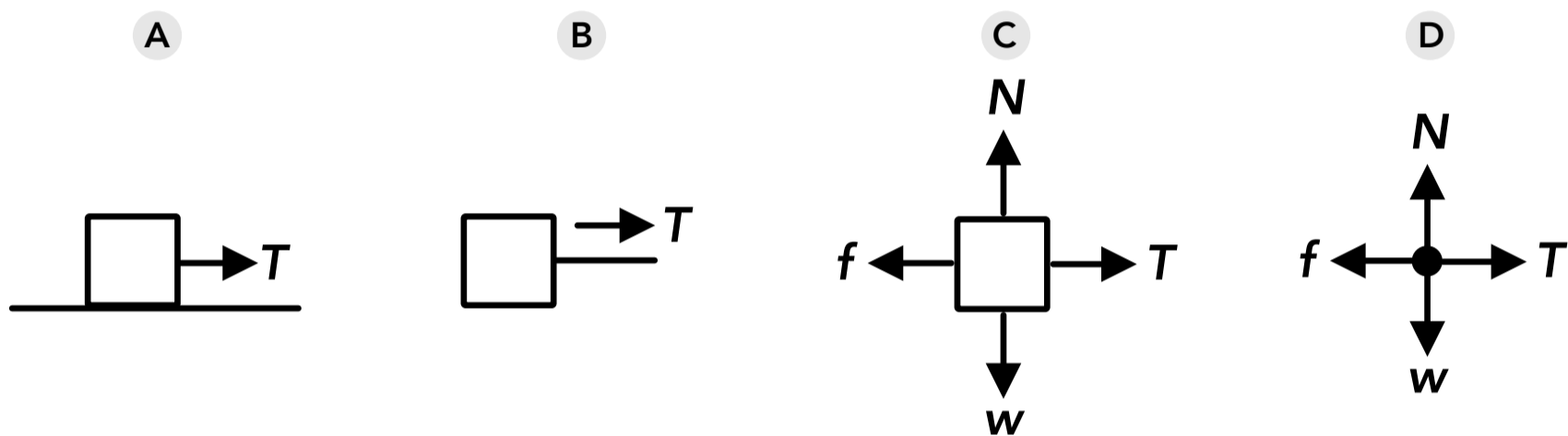
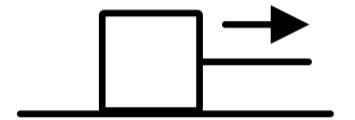
## Newton's 2nd Law of Motion

1. According to Newton's 2nd law of motion, an object's acceleration depends on... (select all that apply)
  - A the mass of the object
  - B the velocity of the object
  - C the net force acting on the object
  - D the energy of the object
2. True or false: If you know the magnitude and direction of every force acting on an object, you can determine the direction that the object is moving.
3. The SI unit for mass is...
  - A N
  - B kg
  - C lb
  - D m
4. An object of mass  $m$  experiences a single force  $F$ . The object's acceleration would be...
  - A  $Fm$
  - B  $m/F$
  - C  $F/m$
  - D 0
5. An object with a mass of 5 kg is accelerating at  $2 \text{ m/s}^2$ . The net force acting on the object must be...
  - A 2 N
  - B 2.5 N
  - C 5 N
  - D 10 N
6. A 25 N net force is acting on an object with a mass of 5 kg. The object's acceleration is...
  - A  $2.5 \text{ m/s}^2$
  - B  $5 \text{ m/s}^2$
  - C  $10 \text{ m/s}^2$
  - D  $25 \text{ m/s}^2$
7. A 6 N force is acting on an object which causes it to accelerate at  $3 \text{ m/s}^2$ . If no other forces are acting on the object, the object's mass must be...
  - A 2 kg
  - B 3 kg
  - C 6 kg
  - D 12 kg

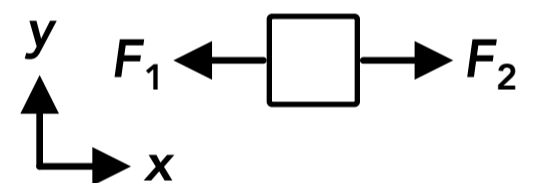
8. A 4 kg object is moving at 6 m/s to the right when it experiences a 12 N force pushing it to the right and a 12 N force pushing it to the left (and no other forces are present). What will happen to the object's speed?
- A It will increase
  - B It will stay the same
  - C It will decrease
  - D Cannot be determined

9. An object with a mass of 2 kg experiences a net force with a magnitude of  $F_1$  and accelerates at  $6 \text{ m/s}^2$ . A second object experiences the same net force and accelerates at  $4 \text{ m/s}^2$ . What is the mass of the second object?
- A 2 kg
  - B 3 kg
  - C 4 kg
  - D 6 kg

10. A box is being pulled to the right by the tension force in a rope. A friction force is acting to the left, the weight force is acting downwards, and a normal force is acting upwards. Which of the following could be a free body diagram of the box? (select all that apply)

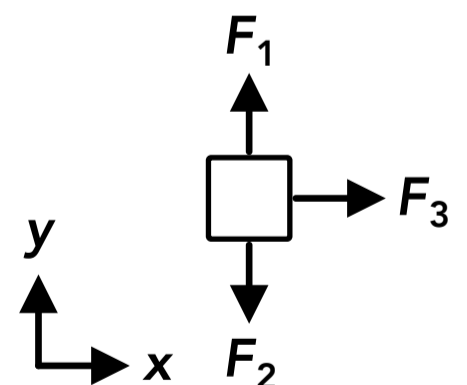


11. A free body diagram of an object is shown on the right. Which of the following describe the net forces acting on the object?



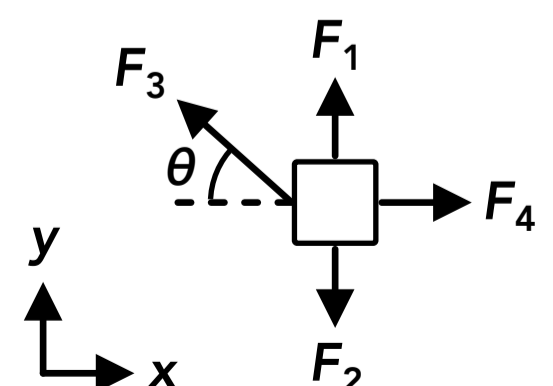
- A  $\sum F_x = F_2 + F_1$  ,  $\sum F_y = 0$
- B  $\sum F_x = F_2 - F_1$  ,  $\sum F_y = 0$
- C  $\sum F_x = F_2$  ,  $\sum F_y = F_1$
- D  $\sum F_x = 0$  ,  $\sum F_y = 0$

12. A free body diagram of an object is shown on the right. Which of the following describe the net forces acting on the object?



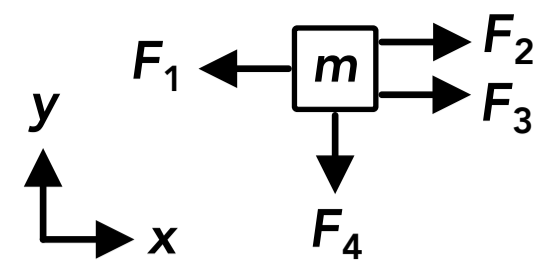
- A  $\sum F_x = F_1 - F_2$  ,  $\sum F_y = F_3$
- B  $\sum F_x = -F_3$  ,  $\sum F_y = F_1 + F_2$
- C  $\sum F_x = F_3$  ,  $\sum F_y = F_1 + F_2$
- D  $\sum F_x = F_3$  ,  $\sum F_y = F_1 - F_2$

13. A free body diagram of an object is shown on the right. Which of the following describe the net forces acting on the object?



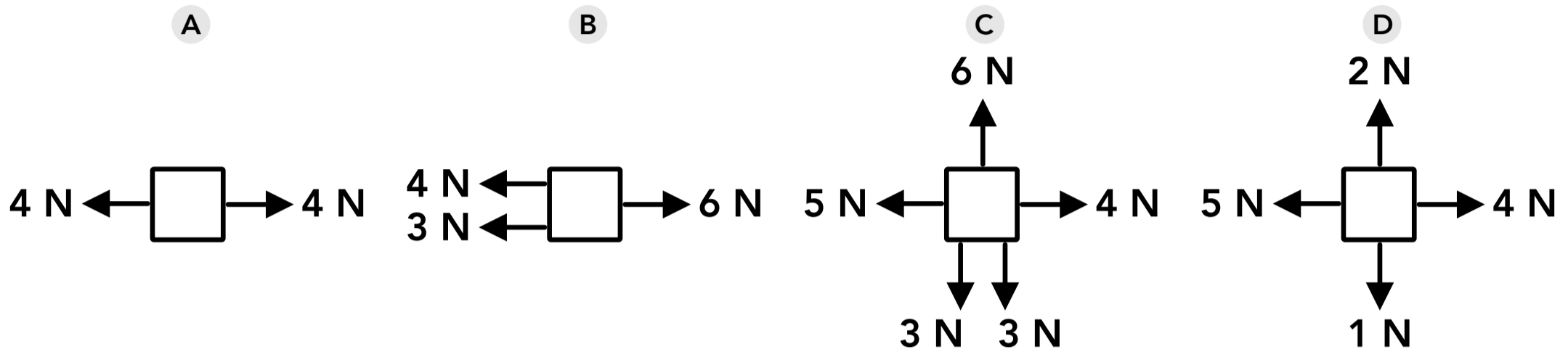
- A  $\sum F_x = F_4 - F_3$  ,  $\sum F_y = F_1 + F_3 - F_2$
- B  $\sum F_x = F_4 - F_3 \sin(\theta)$  ,  $\sum F_y = F_1 + F_3 \cos(\theta) - F_2$
- C  $\sum F_x = F_4 - F_3 \cos(\theta)$  ,  $\sum F_y = F_1 + F_3 \sin(\theta) - F_2$
- D  $\sum F_x = F_4$  ,  $\sum F_y = F_1 + F_3 - F_2$

14. A free body diagram of an object is shown on the right. Which of the following represent Newton's 2nd law applied to this object?

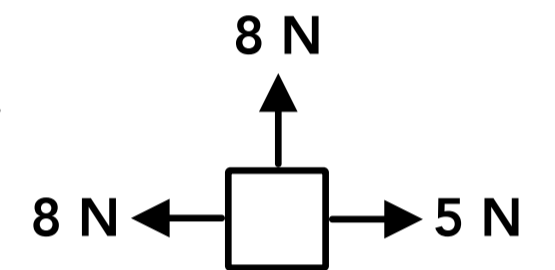


- A  $\sum F_x = F_2 + F_3 - F_1 = ma_x$  ,  $\sum F_y = -F_4 = ma_y$
- B  $\sum F_x = F_2 - F_3 - F_1 = ma_x$  ,  $\sum F_y = -F_4 = ma_y$
- C  $\sum F_x = F_1 + F_2 + F_3 = ma_x$  ,  $\sum F_y = F_4 = ma_y$
- D  $\sum F_x = F_1 - F_2 - F_3 = ma_x$  ,  $\sum F_y = F_4 = ma_y$

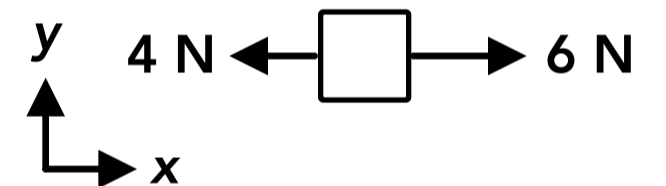
15. An object is accelerating horizontally to the left. Which of the following could be free body diagrams for this object? Note that the vectors are not drawn to scale. (select all that apply)



16. A free body diagram of an object is shown on the right. Which of the following show the direction of the object's acceleration? Note that the vectors are not drawn to scale.

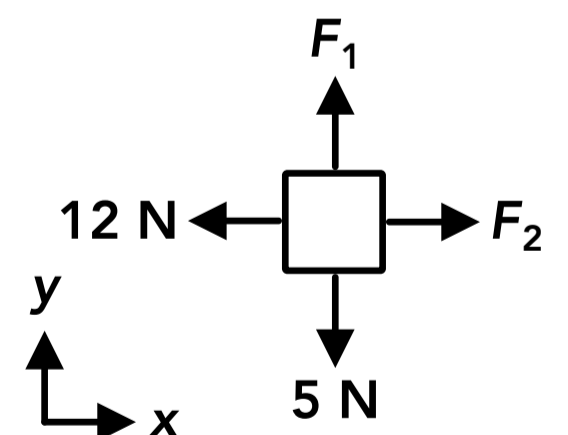


17. A free body diagram of a 4 kg object is shown on the right. What is the magnitude of the object's acceleration?



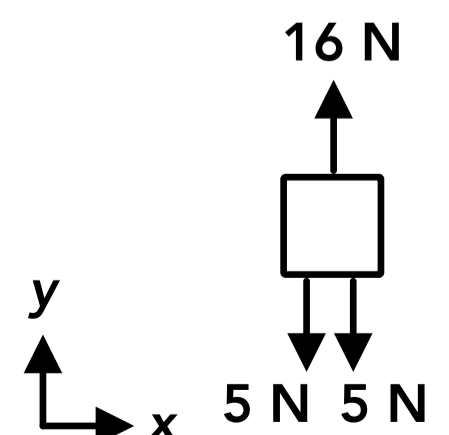
- A  $4 \text{ m/s}^2$
- B  $2 \text{ m/s}^2$
- C  $0.5 \text{ m/s}^2$
- D  $0 \text{ m/s}^2$

18. A free body diagram of a 3 kg object is shown on the right. If  $a_x$  is  $1 \text{ m/s}^2$  and  $a_y$  is  $-1 \text{ m/s}^2$ , what are the magnitudes of  $F_1$  and  $F_2$ ?



- A  $F_1 = 2 \text{ N}$  ,  $F_2 = 15 \text{ N}$
- B  $F_1 = 15 \text{ N}$  ,  $F_2 = 2 \text{ N}$
- C  $F_1 = 8 \text{ N}$  ,  $F_2 = 9 \text{ N}$
- D Cannot be determined

19. A free body diagram of an object is shown on the right. If the object is accelerating at  $3 \text{ m/s}^2$ , what is the mass of the object?



- A 1 kg
- B 2 kg
- C 3 kg
- D 5 kg

20. A free body diagram for an object is shown in Figure 1. What is the magnitude of the object's acceleration?

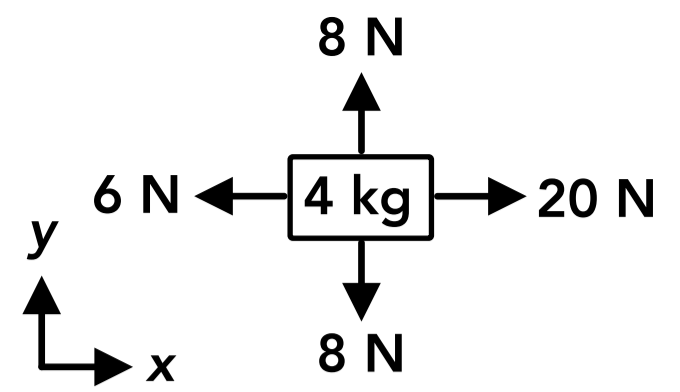
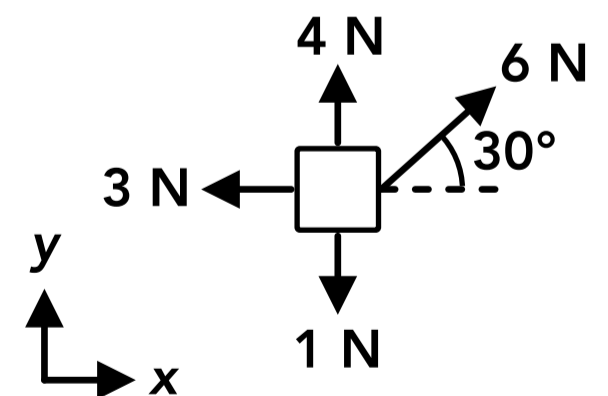


Figure 1

21. If the object in Figure 1 is moving to the right at 4 m/s at  $t = 0$  s, how fast is it moving at  $t = 2$  s?

22. If the object in Figure 1 starts at rest, how far does it move over a period of 3 s?

23. A free body diagram for a 2 kg object is shown on the right. What is the magnitude and direction of the object's acceleration (give the direction as an angle counterclockwise from the positive x axis).



## Answers

- |          |          |          |                          |   |
|----------|----------|----------|--------------------------|---|
| 1. A, C  | 6. B     | 11. B    | 16. D                    | 21. 11 m/s                                  |
| 2. False | 7. A     | 12. D    | 17. C                    | 22. 15.8 m                                  |
| 3. B     | 8. B     | 13. C    | 18. A                    | 23. 3.2 m/s <sup>2</sup> at an angle of 70° |
| 4. C     | 9. B     | 14. A    | 19. B                    |   |
| 5. D     | 10. C, D | 15. B, C | 20. 3.5 m/s <sup>2</sup> |   |

## Answers - Newton's 2nd Law of Motion

1. **Answer: A, C**

Newton's 2nd law is represented by the equation  $\vec{F}_{\text{net}} = m\vec{a}$ , so the acceleration depends on the object's mass and the net force acting on the object.

2. **Answer: False**

If you know the magnitude and direction of every force acting on an object you can determine the magnitude and direction of the net force and the acceleration, but not the direction of the velocity. From kinematics, an acceleration tells you how the velocity is changing over time but you would need to know more information to know the object's velocity at a particular time.

3. **Answer: B**

The SI unit for mass is the kilogram (kg).

4. **Answer: C**

The object's acceleration is given by Newton's 2nd law of motion.

$$F = ma \quad a = F/m$$

5. **Answer: D**

$$F_{\text{net}} = ma = (5 \text{ kg})(2 \text{ m/s}^2) = 10 \text{ N} = 10 \text{ kg}\cdot\text{m/s}^2$$

6. **Answer: B**

$$F_{\text{net}} = ma \quad (25 \text{ N}) = (5 \text{ kg})a \quad a = 5 \text{ m/s}^2$$

7. **Answer: A**

$$F_{\text{net}} = ma \quad (6 \text{ N}) = m(3 \text{ m/s}^2) \quad m = 2 \text{ kg}$$

8. **Answer: B**

Because the two forces are equal in magnitude and acting in opposite directions, the net force acting on the object is zero so the acceleration is also zero. That means the object's speed will not change.

9. **Answer: B**

The magnitude of  $F_1$  can be found from the motion of the first object, which can then be used to find the mass of the second object:

$$\sum F = ma \quad F_1 = (2 \text{ kg})(6 \text{ m/s}^2) \quad F_1 = 12 \text{ N}$$

$$\sum F = ma \quad 12 \text{ N} = m(4 \text{ m/s}^2) \quad m = 3 \text{ kg}$$

10. **Answer: C, D**

A free body diagram of the box shows the box (represented either by a picture of just the box, or a dot which represents the box as a particle) and all of the forces acting on the box. It does not show any other objects.

11. **Answer: B**

$F_2$  acts in the positive  $x$  direction so it has a positive value, and  $F_1$  acts in the negative  $x$  direction so it has a negative value. There are no forces acting in the  $y$  direction.

12. **Answer: D**

$F_3$  acts in the positive  $x$  direction so it has a positive value.  $F_1$  acts in the positive  $y$  direction so it has a positive value, and  $F_2$  acts in the negative  $y$  direction so it has a negative value.

13. **Answer: C**

$F_4$  acts in the positive  $x$  direction so it has a positive value.  $F_1$  acts in the positive  $y$  direction so it has a positive value, and  $F_2$  acts in the negative  $y$  direction so it has a negative value.  $F_3$  acts at an angle so it has force components in the  $x$  and  $y$  directions: the  $x$  component is  $F_3 \cos(\theta)$  which acts in the negative  $x$  direction, and the  $y$  component is  $F_3 \sin(\theta)$  which acts in the positive  $y$  direction.

14. **Answer: A**

$F_2$  and  $F_3$  act in the positive  $x$  direction, and  $F_1$  acts in the negative  $x$  direction.  $F_4$  acts in the negative  $y$  direction. Newton's 2nd law of motion applies to the  $x$  and  $y$  directions:  $\sum F_x = ma_x$ ,  $\sum F_y = ma_y$ .

15. **Answer: B, C**

In options B and C the net horizontal force is to the left and the net vertical force is zero, so the object will accelerate to the left. The object in option A has zero net force and will not accelerate. The object in option D has a net horizontal force to the left and a net vertical force upwards, so the object will accelerate to the left and upwards (not just horizontally to the left).

16. **Answer: D**

The net horizontal force is 3 N to the left and the net vertical force is 8 N up. The net force acting on the object is up and to the left, which is the same direction as the acceleration.

17. **Answer: C**

$$\sum F_x = ma_x \quad \sum F_x = 6 \text{ N} - 4 \text{ N} = 2 \text{ N} = (4 \text{ kg})a_x \quad a_x = 0.5 \text{ m/s}^2$$

18. **Answer: A**

$$\begin{aligned} \sum F_x = ma_x & \quad \sum F_x = F_2 - 12 \text{ N} = (3 \text{ kg})(1 \text{ m/s}^2) & \quad F_2 = 15 \text{ N} \\ \sum F_y = ma_y & \quad \sum F_y = F_1 - 5 \text{ N} = (3 \text{ kg})(-1 \text{ m/s}^2) & \quad F_1 = 2 \text{ N} \end{aligned}$$

19. **Answer: B**

$$\sum F_y = ma_y \quad \sum F_y = 16 \text{ N} - 5 \text{ N} - 5 \text{ N} = m(3 \text{ m/s}^2) \quad m = 2 \text{ kg}$$

20. **Answer: 3.5 m/s<sup>2</sup>**

$$\begin{aligned} \sum F_x = ma_x & \quad \sum F_x = 20 \text{ N} - 6 \text{ N} = (4 \text{ kg})a_x & \quad a_x = 3.5 \text{ m/s}^2 \\ \sum F_y = ma_y & \quad \sum F_y = 8 \text{ N} - 8 \text{ N} = (4 \text{ kg})a_y & \quad a_y = 0 \text{ m/s}^2 \end{aligned}$$

$a = 3.5 \text{ m/s}^2$  (there is no  $y$  component of the acceleration vector)

21. **Answer: 11 m/s**

The acceleration  $a$  is  $3.5 \text{ m/s}^2$  which was found in a previous question.

$$v_f = v_i + a\Delta t \quad v_f = (4 \text{ m/s}) + (3.5 \text{ m/s}^2)(2 \text{ s}) \quad v_f = 11 \text{ m/s}$$

22. **Answer: 15.8 m**

The acceleration  $a$  is  $3.5 \text{ m/s}^2$  which was found in a previous question.

$$x_f = x_i + v_i t + \frac{1}{2}at^2 \quad x_f = (0 \text{ m}) + (0 \text{ m/s})(3 \text{ s}) + \frac{1}{2}(3.5 \text{ m/s}^2)(3 \text{ s})^2 \quad x_f = 15.8 \text{ m}$$

23. **Answer: 3.2 m/s<sup>2</sup> at an angle of 70°**

$$\begin{aligned} \sum F_x = ma_x & \quad \sum F_x = (6 \text{ N})\cos(30^\circ) - 3 \text{ N} = (2 \text{ kg})a_x & \quad a_x = 1.1 \text{ m/s}^2 \\ \sum F_y = ma_y & \quad \sum F_y = 4 \text{ N} + (6 \text{ N})\sin(30^\circ) - 1 \text{ N} = (2 \text{ kg})a_y & \quad a_y = 3 \text{ m/s}^2 \end{aligned}$$

$a_x$  and  $a_y$  are the components of the acceleration vector  $a$ . The magnitude and direction of  $a$  are:

$$a^2 = a_x^2 + a_y^2 \quad a = \sqrt{a_x^2 + a_y^2} \quad a = \sqrt{(1.1 \text{ m/s}^2)^2 + (3 \text{ m/s}^2)^2} = 3.2 \text{ m/s}^2$$

$$\theta = \tan^{-1}\left(\frac{a_y}{a_x}\right) \quad \theta = \tan^{-1}\left(\frac{3 \text{ m/s}^2}{1.1 \text{ m/s}^2}\right) = 70^\circ$$