

Exercise walk-through

3.1.1.1

Forces step by step

A-Level Physics

Forces step by step

Name: _____ Class: _____ Date: _____

Total: 71 marks

KEY WORDS resultant force • weight • normal contact force

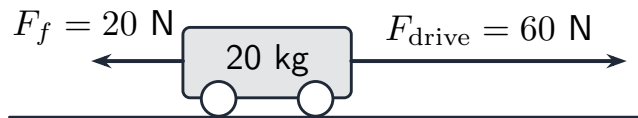
1 Key knowledge and worked examples

On Earth, use $g = 9.81 \text{ m s}^{-2}$. For constant mass: $F_{\text{res}} = ma$; weight: $F_W = mg$.
Constant velocity means zero resultant force.

Exercise 2.1 (a)

2.1 A 20 kg delivery robot moves right on a level floor. Its driving force F_{drive} is 60 N right; resistance F_f is 20 N left.

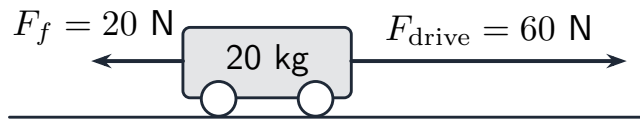
(a) Choose right positive. Find the **resultant force** using $F_{\text{res}} = F_{\text{drive}} - F_f$, then find $a = F_{\text{res}}/m$. [2]



Exercise 2.1 (a)

2.1 A 20 kg delivery robot moves right on a level floor. Its driving force F_{drive} is 60 N right; resistance F_f is 20 N left.

(a) Choose right positive. Find the **resultant force** using $F_{\text{res}} = F_{\text{drive}} - F_f$, then find $a = F_{\text{res}}/m$. [2]



(a) Opposing forces subtract.

$$F_{\text{res}} = F_{\text{drive}} - F_f = 60 \text{ N} - 20 \text{ N} = 40 \text{ N}$$

$$a = \frac{F_{\text{res}}}{m} = \frac{40 \text{ N}}{20 \text{ kg}} = 2.0 \text{ m s}^{-2} \text{ right}$$

Exercise 2.1 (b)

2.1 A 20 kg delivery robot moves right on a level floor. Its driving force F_{drive} is 60 N right; resistance F_f is 20 N left.

(b) The motor switches off while the robot still moves right. Resistance stays 20 N. Find the new acceleration and state how the speed changes. [2]

Exercise 2.1 (b)

2.1 A 20 kg delivery robot moves right on a level floor. Its driving force F_{drive} is 60 N right; resistance F_f is 20 N left.

(b) The motor switches off while the robot still moves right. Resistance stays 20 N. Find the new acceleration and state how the speed changes. [2]

(b) The only horizontal force is now leftwards.

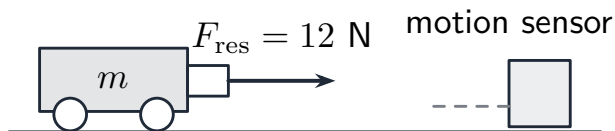
$$a = \frac{-F_f}{m} = \frac{-20 \text{ N}}{20 \text{ kg}} = -1.0 \text{ m s}^{-2}$$

Acceleration is leftwards, opposite the velocity, so the robot slows down.

Exercise 2.2 (a)

2.2 A student uses a horizontal force sensor and a motion sensor to measure the mass of a cart. The measured resultant force is 12 N and its acceleration is 3.0 m s^{-2} .

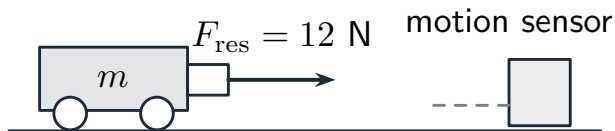
(a) Rearrange $F_{\text{res}} = ma$ to calculate the cart's mass. [2]



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(a) Rearrange $F_{\text{res}} = ma$ to calculate the cart's mass. [2]



(a) Mass measures resistance to acceleration.

$$m = \frac{F_{\text{res}}}{a} = \frac{12 \text{ N}}{3.0 \text{ m s}^{-2}} = 4.0 \text{ kg}$$

Exercise 2.2 (b)

2.2 A student uses a horizontal force sensor and a motion sensor to measure the mass of a cart. The measured resultant force is 12 N and its acceleration is 3.0 m s^{-2} .

(b) A load is added. The same resultant force now produces an acceleration of 1.5 m s^{-2} . Calculate the mass of the added load. [2]

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(b) First find the total mass, then subtract the empty cart.

$$m_{\text{total}} = \frac{F_{\text{res}}}{a} = \frac{12 \text{ N}}{1.5 \text{ m s}^{-2}} = 8.0 \text{ kg}$$

$$m_{\text{load}} = m_{\text{total}} - m = 8.0 \text{ kg} - 4.0 \text{ kg} = 4.0 \text{ kg}$$

Exercise 2.3 (a)

2.3 Two probes rest on different moons. Probe A has mass 200 g and weight 0.60 N. Probe B has mass 0.50 kg and weight 800 mN.

(a) Convert A's mass to kg and B's weight to N.

[2]

Exercise 2.3 (a)

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(a) Convert A's mass to kg and B's weight to N. [2]

(a) $200 \text{ g} = 0.200 \text{ kg}$; $800 \text{ mN} = 0.800 \text{ N}$.

Exercise 2.3 (b)

2.3 Two probes rest on different moons. Probe A has mass 200 g and weight 0.60 N. Probe B has mass 0.50 kg and weight 800 mN.

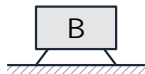
(b) Use the weight equation to find g for each probe. Which moon has the weaker gravitational field? [2]

$$F_W = 0.60 \text{ N}$$



200 g

$$F_W = 800 \text{ mN}$$



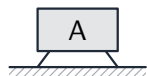
0.50 kg

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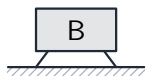
(b) Use the weight equation to find g for each probe. Which moon has the weaker gravitational field? [2]

$$F_W = 0.60 \text{ N}$$



200 g

$$F_W = 800 \text{ mN}$$



0.50 kg

(b) Compare weight per unit mass.

$$g_A = \frac{F_{W,A}}{m_A} = \frac{0.60 \text{ N}}{0.200 \text{ kg}} = 3.0 \text{ N kg}^{-1}$$

$$g_B = \frac{F_{W,B}}{m_B} = \frac{0.800 \text{ N}}{0.50 \text{ kg}} = 1.6 \text{ N kg}^{-1}$$

B's moon has the weaker field. B

Exercise 2.3 (c)

2.3 Two probes rest on different moons. Probe A has mass 200 g and weight 0.60 N. Probe B has mass 0.50 kg and weight 800 mN.

(c) A student says: “B does not accelerate, so it has no weight.” Explain the error. [1]

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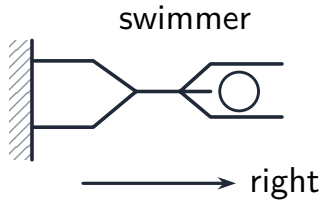
(c) A student says: “B does not accelerate, so it has no weight.” Explain the error. [1]

(c) Zero acceleration means zero resultant force, not zero weight. The upward surface force balances the weight.

Exercise 2.4 (a)

2.4 A swimmer pushes left on the wall of a pool with a force of 240 N. The wall is fixed to the ground.

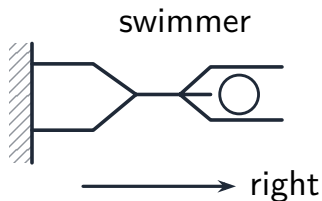
(a) State the size and direction of the force of the wall on the swimmer. [2]



Exercise 2.4 (a)

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(a) State the size and direction of the force of the wall on the swimmer. [2]



(a) 240 N to the right, by Newton's third law.

Exercise 2.4 (b)

2.4 A swimmer pushes left on the wall of a pool with a force of 240 N. The wall is fixed to the ground.

(b) A student says: “These equal and opposite forces cancel, so the swimmer cannot accelerate.” Explain the error. [1]

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2.4 A swimmer pushes left on the wall of a pool with a force of 240 N. The wall is fixed to the ground.

(b) A student says: “These equal and opposite forces cancel, so the swimmer cannot accelerate.” Explain the error. [1]

(b) The forces act on different objects: one on the swimmer and one on the wall.

Exercise 2.4 (c)

2.4 A swimmer pushes left on the wall of a pool with a force of 240 N. The wall is fixed to the ground.

(c) Which pairs with the swimmer's weight: the water's force on the swimmer or the swimmer's pull on Earth? State the object it acts on. [1]

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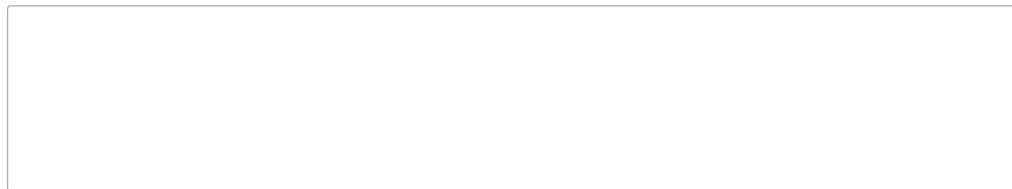
(c) Which pairs with the swimmer's weight: the water's force on the swimmer or the swimmer's pull on Earth? State the object it acts on. [1]

(c) The swimmer's gravitational pull on Earth, acting on Earth. The water force acts on the swimmer and is a different interaction.

Exercise 2.5 (a)

2.5 A drone of mass 2.0 kg moves vertically downwards at constant speed. Its rotors exert an upward thrust F_{thrust} . Ignore air resistance.

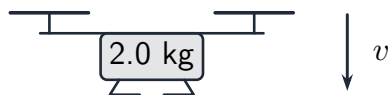
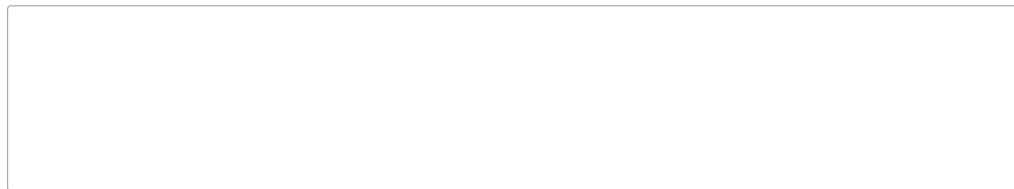
(a) Represent the drone by a dot. Draw and label its two forces during steady descent. Show their relative sizes with your arrows. [2]



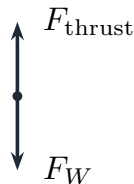
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(a) Force diagram : correct forces and directions; equal arrow lengths.



Exercise 2.5 (b)

2.5 A drone of mass 2.0 kg moves vertically downwards at constant speed. Its rotors exert an upward thrust F_{thrust} . Ignore air resistance.

(b) The thrust falls to 15.62 N. Choose a positive direction, write a force equation and calculate the acceleration, including its direction. [2]

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(b) The thrust falls to 15.62 N. Choose a positive direction, write a force equation and calculate the acceleration, including its direction. [2]

(b) Choose down positive. Calculate weight, then subtract thrust to find the resultant.

$$F_W = mg = 2.0 \text{ kg} \times 9.81 \text{ m s}^{-2} = 19.62 \text{ N}$$

$$F_W - F_{\text{thrust}} = ma$$

$$a = \frac{mg - F_{\text{thrust}}}{m} = \frac{19.62 \text{ N} - 15.62 \text{ N}}{2.0 \text{ kg}} = 2.0 \text{ m s}^{-2} \text{ down}$$

Exercise 2.5 (c)

2.5 A drone of mass 2.0 kg moves vertically downwards at constant speed. Its rotors exert an upward thrust F_{thrust} . Ignore air resistance.

(c) Is the drone now speeding up or slowing down? Explain using the directions of velocity and acceleration. [1]

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(c) It speeds up: velocity and acceleration both point downwards.

Exercise 2.6 (a)

2.6 A cleaner pushes a 10 kg floor-cleaning machine with a 40 N force at 30° below horizontal. Resistance is 14.6 N. The machine stays on the floor.

(a) Find the forward component using $F_{P,x} = F_P \cos 30^\circ$. [1]

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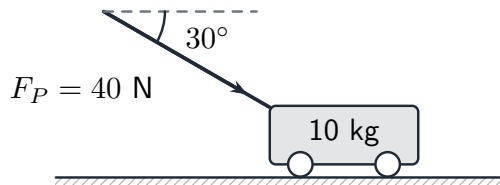
(a) Resolve the push horizontally.

$$F_{P,x} = F_P \cos \theta = 40 \text{ N} \cos 30^\circ = 34.6 \text{ N}$$

Exercise 2.6 (b)

2.6 A cleaner pushes a 10 kg floor-cleaning machine with a 40 N force at 30° below horizontal. Resistance is 14.6 N. The machine stays on the floor.

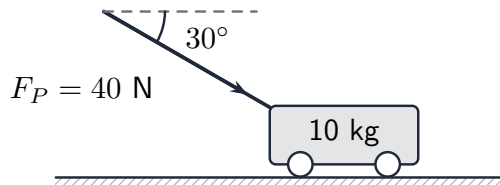
(b) Find the downward component of the push. Write a vertical force equation and calculate the **normal contact force** from the floor. [2]



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(b) Find the downward component of the push. Write a vertical force equation and calculate the **normal contact force** from the floor. [2]



(b) The floor supports both the weight and the downward component.

$$F_N - F_W - F_{P,y} = 0$$

$$F_{P,y} = F_P \sin \theta = 40 \text{ N} \sin 30^\circ = 20.0 \text{ N}$$

$$F_N = mg + F_{P,y} = 10 \text{ kg} \times 9.81 \text{ m s}^{-2} + 20.0 \text{ N} = 118.1 \text{ N}$$

Exercise 2.6 (c)

2.6 A cleaner pushes a 10 kg floor-cleaning machine with a 40 N force at 30° below horizontal. Resistance is 14.6 N. The machine stays on the floor.

(c) Write a horizontal force equation and calculate the machine's acceleration. [2]

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(c) Write a horizontal force equation and calculate the machine's acceleration. [2]

(c) Subtract resistance from the horizontal component.

$$F_{P,x} - F_f = ma$$

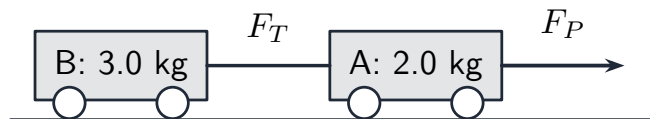
$$F_{\text{res}} = F_P \cos \theta - F_f = 40 \text{ N} \cos 30^\circ - 14.6 \text{ N} = 20.0 \text{ N}$$

$$a = \frac{F_P \cos \theta - F_f}{m} = \frac{40 \text{ N} \cos 30^\circ - 14.6 \text{ N}}{10 \text{ kg}} = 2.00 \text{ m s}^{-2} \text{ forwards}$$

Exercise 2.7 (a)

2.7 Two carts are connected by a light, taut string. A motor pulls cart A right. Both accelerate at 1.2 m s^{-2} . Resistances are 0.6 N on A and 1.4 N on B.

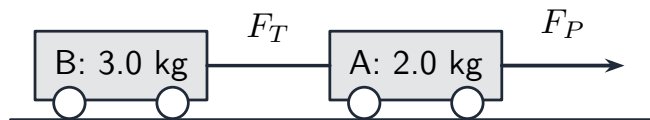
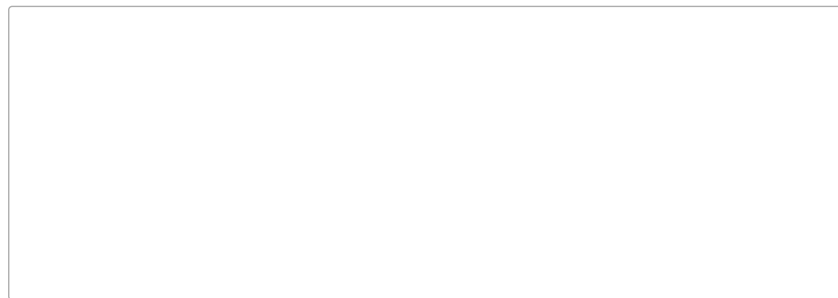
(a) Draw and label all forces on B alone. Write its horizontal force equation and calculate the tension F_T . [3]



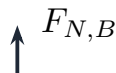
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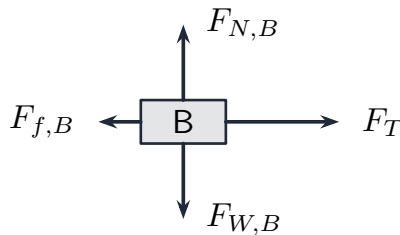


(a) Force diagram :



Full solution 2.7 (a)

(a) Force diagram :



Tension must overcome B's resistance and accelerate B.

B

B

$$F_T - F_{f,B} = m_B a$$

$$F_T = m_B a + F_{f,B} = 3.0 \text{ kg} \times 1.2 \text{ m s}^{-2} + 1.4 \text{ N} = 5.0 \text{ N}$$

Exercise 2.7 (b)

2.7 Two carts are connected by a light, taut string. A motor pulls cart A right. Both accelerate at 1.2 m s^{-2} . Resistances are 0.6 N on A and 1.4 N on B.

(b) Calculate the motor's pulling force F_P . Show which mass and forces you use. [2]

Exercise 2.7 (b)

2.7 Two carts are connected by a light, taut string. A motor pulls cart A right. Both accelerate at 1.2 m s^{-2} . Resistances are 0.6 N on A and 1.4 N on B.

(b) Calculate the motor's pulling force F_P . Show which mass and forces you use. [2]

(b) Use both masses; the string tension is internal.

$$F_P = (m_A + m_B)a + F_{f,A} + F_{f,B}$$

$$F_P = (2.0 + 3.0) \text{ kg} \times 1.2 \text{ m s}^{-2} + 2.0 \text{ N} = 8.0 \text{ N}$$

Exercise 2.7 (c)

2.7 Two carts are connected by a light, taut string. A motor pulls cart A right. Both accelerate at 1.2 m s^{-2} . Resistances are 0.6 N on A and 1.4 N on B.

(c) Is $F_T = F_P$? Does the string pull B harder than B pulls the string? Explain both answers. [2]

Exercise 2.7 (c)

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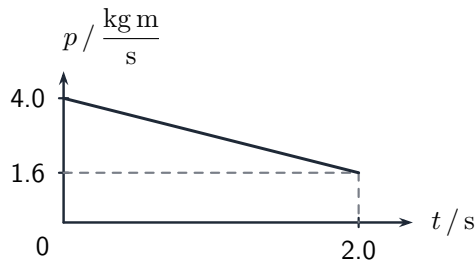
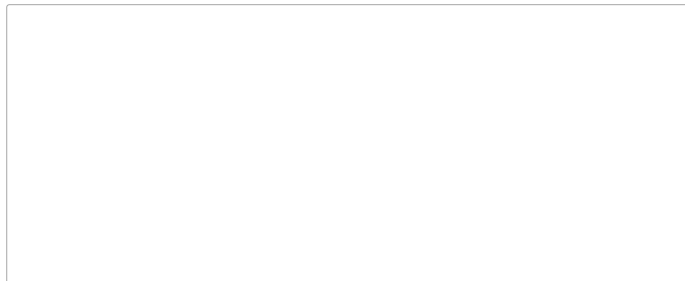
(c) No: $F_T = 5.0 \text{ N} < F_P = 8.0 \text{ N}$. The motor also accelerates A against resistance.
A

B and the string exert equal and opposite forces on each other, even during acceleration:
Newton's third law. B B ,

Exercise 2.8 (a)

2.8 A 0.80 kg glider moves right. A braking pad supplies the only horizontal force. Its **momentum** $p = mv$ changes as shown; right is positive.

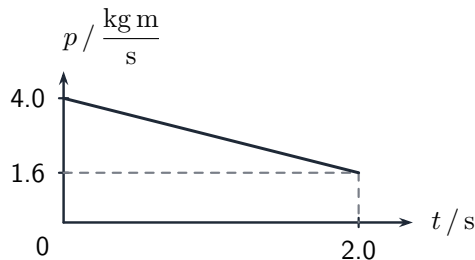
(a) The gradient of a momentum-time graph gives the resultant force. Read the change in momentum and use $F_{\text{res}} = \Delta p / \Delta t$ to calculate this force, including its direction. [2]



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(a) The gradient of a momentum-time graph gives the resultant force. Read the change in momentum and use $F_{\text{res}} = \Delta p / \Delta t$ to calculate this force, including its direction. [2]



(a) Read the two endpoint momenta. The slope is negative, so the force is leftwards.

$$\Delta p = p_{\text{final}} - p_{\text{initial}} = (1.6 - 4.0) \text{ kg m s}^{-1} = -2.4 \text{ kg m s}^{-1}$$

$$F_{\text{res}} = \frac{\Delta p}{\Delta t} = \frac{-2.4 \text{ kg m s}^{-1}}{2.0 \text{ s}} = -1.2 \text{ N}$$

Exercise 2.8 (b)

2.8 A 0.80 kg glider moves right. A braking pad supplies the only horizontal force. Its **momentum** $p = mv$ changes as shown; right is positive.

(b) Calculate the initial and final speeds from the graph. Hence calculate the distance travelled in the 2.0 s. [3]

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(b) Calculate the initial and final speeds from the graph. Hence calculate the distance travelled in the 2.0 s. [3]

(b) Divide momentum by mass to find velocity.

$$u = \frac{p_{\text{initial}}}{m} = \frac{4.0 \text{ kg m s}^{-1}}{0.80 \text{ kg}} = 5.0 \text{ m s}^{-1}$$

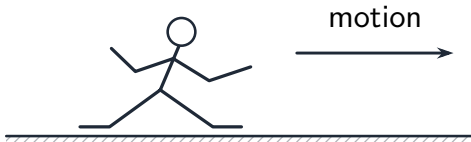
$$v = \frac{p_{\text{final}}}{m} = \frac{1.6 \text{ kg m s}^{-1}}{0.80 \text{ kg}} = 2.0 \text{ m s}^{-1}$$

Constant mass and graph gradient mean constant acceleration. Use average velocity.

$$s = \frac{u + v}{2} t = \frac{(5.0 + 2.0) \text{ m s}^{-1}}{2} \times 2.0 \text{ s} = 7.0 \text{ m}$$

Exercise 3.1 (a)

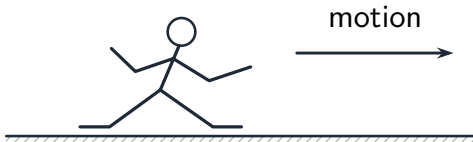
3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



(a) Calculate her acceleration, the average horizontal resultant force, and the average forward force of the ground on her. [3]

Exercise 3.1 (a)

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(a) Calculate her acceleration, the average horizontal resultant force, and the average forward force of the ground on her. [3]

(a) Find acceleration from the change of velocity, then use the resultant force.

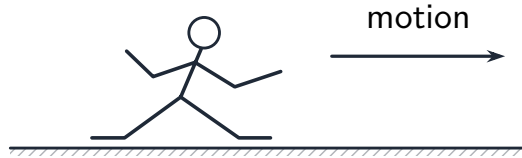
$$a = \frac{v - u}{\Delta t} = \frac{(8.0 - 4.0) \text{ m s}^{-1}}{2.0 \text{ s}} = 2.0 \text{ m s}^{-2}$$

$$F_{\text{res}} = ma = 60 \text{ kg} \times 2.0 \text{ m s}^{-2} = 120 \text{ N}$$

$$F_{\text{drive}} = ma + F_D = 120 \text{ N} + 30 \text{ N} = 150 \text{ N}$$

Exercise 3.1 (b)

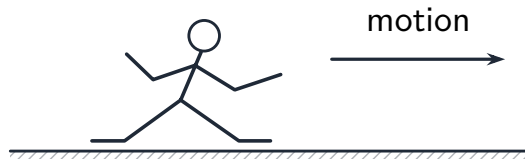
3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



(b) State the size and direction of the force she exerts on the ground horizontally. Name the law used. [2]

Exercise 3.1 (b)

3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.

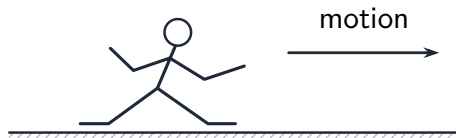


(b) State the size and direction of the force she exerts on the ground horizontally. Name the law used. [2]

(b) 150 N backwards on the ground, by Newton's third law.

Exercise 3.1 (c)

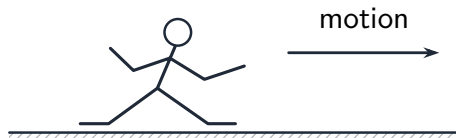
3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



(c) Sketch her velocity-time graph for these 2.0 s. Label both axes and the start and end values. [2]

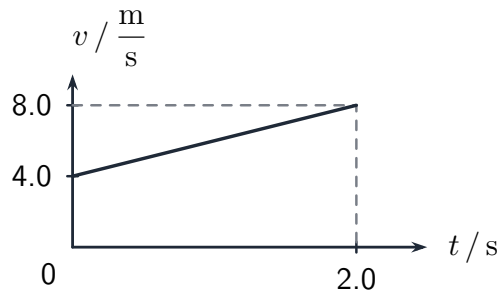
Exercise 3.1 (c)

3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



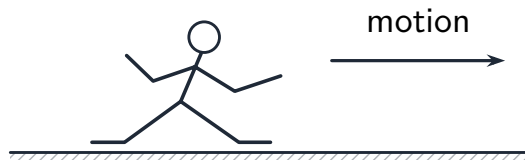
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(c) Velocity-time graph - :



Exercise 3.1 (d)

3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.

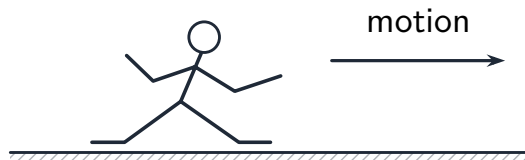


(d) Calculate the distance she travels during these 2.0 s.

[2]

Exercise 3.1 (d)

3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



(d) Calculate the distance she travels during these 2.0 s. [2]

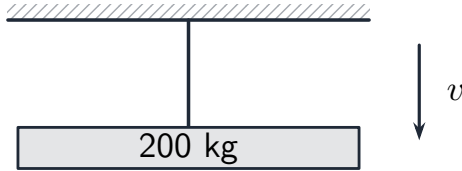
(d) Use average velocity because the acceleration is constant.

$$s = \frac{u + v}{2}t = \frac{(4.0 + 8.0) \text{ m s}^{-1}}{2} \times 2.0 \text{ s} = 12 \text{ m}$$

Equivalently use $s = ut + \frac{1}{2}at^2$.

Exercise 3.2 (a)

3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.

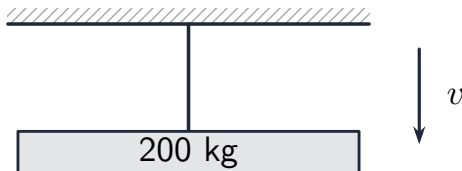


(a) Draw and label the forces on the beam.

[2]

Exercise 3.2 (a)

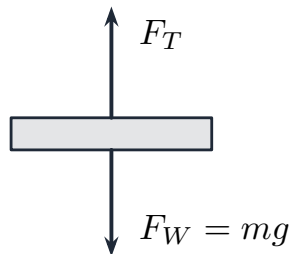
3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



(a) Draw and label the forces on the beam.

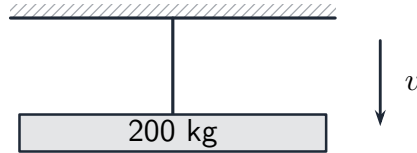
[2]

(a) Upward tension and downward weight.



Exercise 3.2 (b)

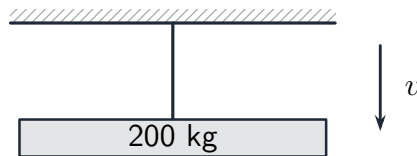
3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



(b) Calculate the acceleration, giving its direction, and the cable tension during the slowing-down stage. [3]

Exercise 3.2 (b)

3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



(b) Calculate the acceleration, giving its direction, and the cable tension during the slowing-down stage. [3]

(b) Choose up positive. The initial velocity is negative, and becomes zero.

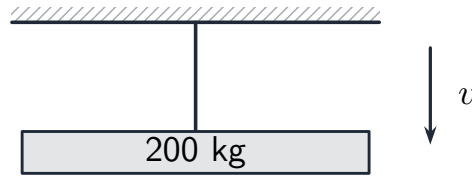
$$a = \frac{v - u}{\Delta t} = \frac{[0 - (-1.2)] \text{ m s}^{-1}}{3.0 \text{ s}} = 0.40 \text{ m s}^{-2} \text{ up}$$

$$F_T - mg = ma \quad \Rightarrow \quad F_T = m(g + a)$$

$$F_T = m(g + a) = 200 \text{ kg} \times (9.81 + 0.40) \text{ m s}^{-2} = 2042 \text{ N}$$

Exercise 3.2 (c)

3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.

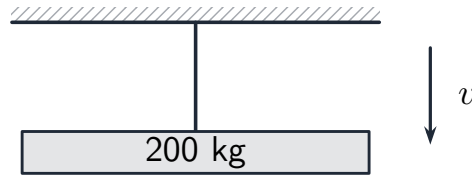


(c) State the force of the beam on the cable, including direction.

[1]

Exercise 3.2 (c)

3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.

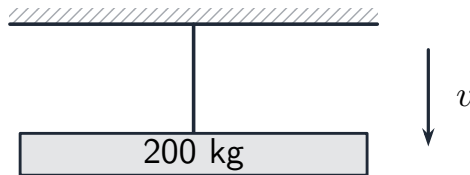


(c) State the force of the beam on the cable, including direction. [1]

(c) 2042 N downwards on the cable. The third-law pair remains equal during acceleration.
2042 N

Exercise 3.2 (d)

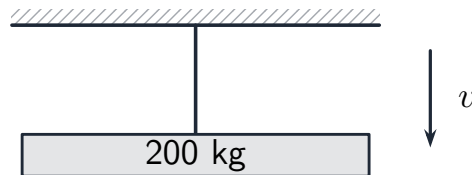
3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



(d) The cable can sustain a maximum tension of 3000 N. Calculate the greatest mass it can raise with an upward acceleration of 0.40 m s^{-2} . [2]

Exercise 3.2 (d)

3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



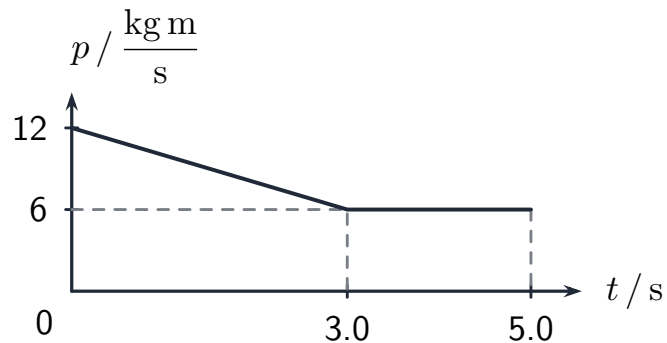
(d) The cable can sustain a maximum tension of 3000 N. Calculate the greatest mass it can raise with an upward acceleration of 0.40 m s^{-2} . [2]

(d) Use the tension limit in the same force equation.

$$m_{\max} = \frac{F_{T,\max}}{g + a} = \frac{3000 \text{ N}}{(9.81 + 0.40) \text{ m s}^{-2}} = 294 \text{ kg}$$

Exercise 3.3 (a)

3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.

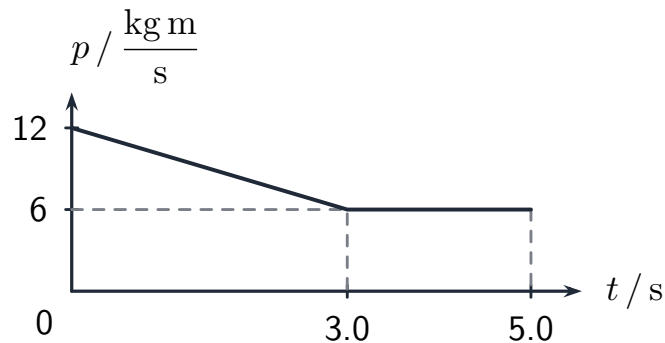


(a) State Newton's second law in terms of momentum.

[1]

Exercise 3.3 (a)

3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.

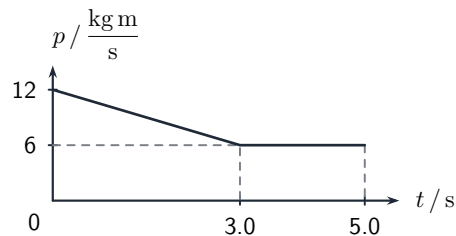


(a) State Newton's second law in terms of momentum. [1]

(a) Resultant force equals the rate of change of momentum, in the direction of that change.

Exercise 3.3 (b)

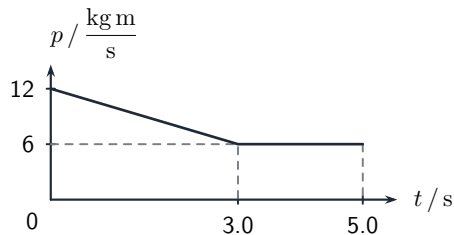
3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.



(b) Determine the resultant force, including direction, and the driving force at $t = 1.0$ s. [2]

Exercise 3.3 (b)

3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.



(b) Determine the resultant force, including direction, and the driving force at $t = 1.0$ s. [2]

(b) Choose right positive. Use the negative gradient.

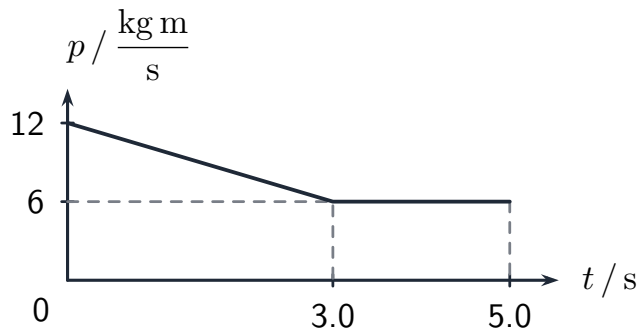
$$F_{\text{res}} = \frac{\Delta p}{\Delta t} = \frac{(6 - 12) \text{ kg m s}^{-1}}{3.0 \text{ s}} = -2.0 \text{ N}$$

The resultant is 2.0 N leftwards.

$$\begin{aligned} F_{\text{drive}} - F_f &= F_{\text{res}} \quad \Rightarrow \quad F_{\text{drive}} = F_f + F_{\text{res}} \\ F_{\text{drive}} &= F_f + F_{\text{res}} = 3.0 \text{ N} + (-2.0 \text{ N}) = 1.0 \text{ N} \end{aligned}$$

Exercise 3.3 (c)

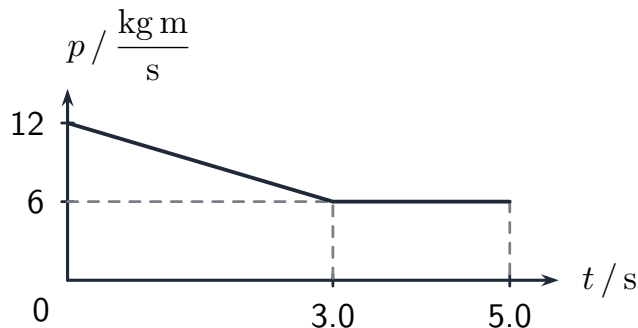
3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.



(c) Sketch F_{drive} against time from 0 to 5.0 s. Label the force values and the time at which F_{drive} changes. [3]

Exercise 3.3 (c)

3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.



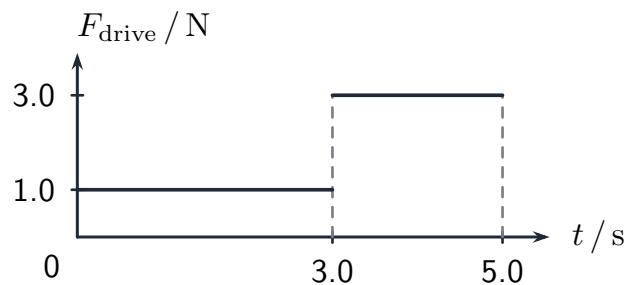
(c) Sketch F_{drive} against time from 0 to 5.0 s. Label the force values and the time at which F_{drive} changes. [3]

(c) Constant momentum means zero resultant force: driving force equals resistance.

Full solution 3.3 (c)

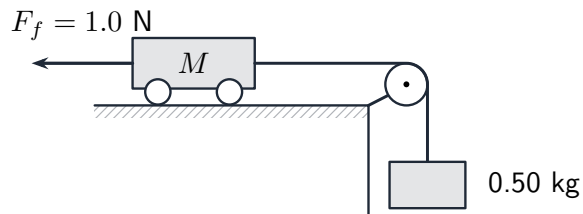
(c) Constant momentum means zero resultant force: driving force equals resistance.

$$F_{\text{drive}} = F_f = 3.0 \text{ N}$$



Exercise 3.4 (a)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .

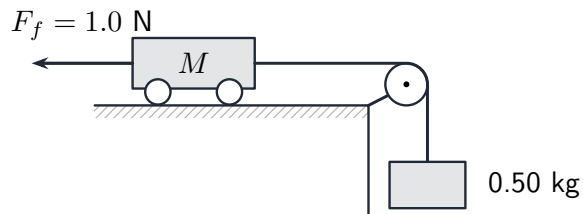


(a) Draw a labelled force diagram for each body.

[2]

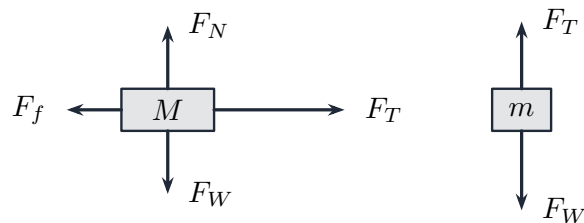
Exercise 3.4 (a)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



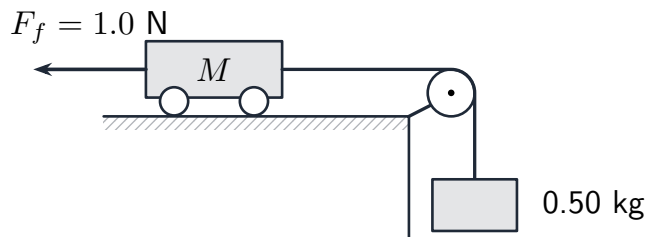
(a) Draw a labelled force diagram for each body. [2]

(a) Force diagrams :



Exercise 3.4 (b)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .

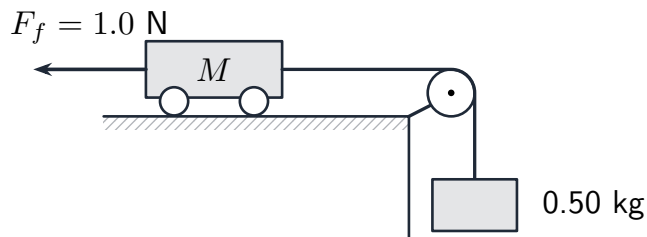


(b) Calculate the string tension.

[2]

Exercise 3.4 (b)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



(b) Calculate the string tension.

[2]

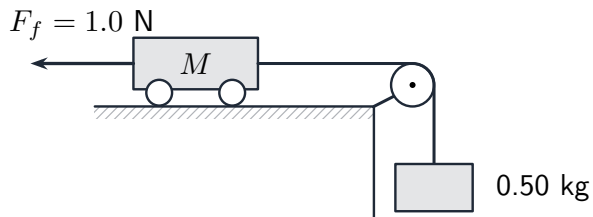
(b) Start with the known hanging mass, choosing down positive.

$$mg - F_T = ma \quad \Rightarrow \quad F_T = m(g - a)$$

$$F_T = m(g - a) = 0.50 \text{ kg} \times (9.81 - 1.50) \text{ m s}^{-2} = 4.155 \text{ N}$$

Exercise 3.4 (c)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .

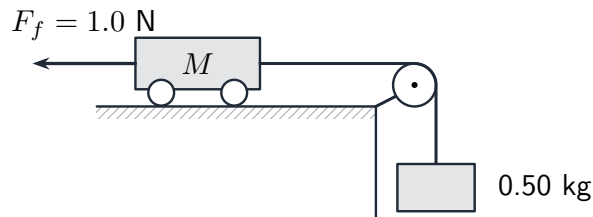


(c) Use the motion of the cart to determine M .

[2]

Exercise 3.4 (c)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



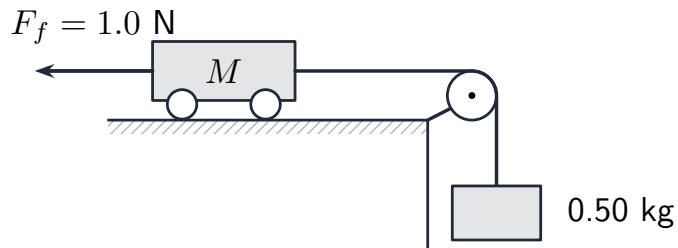
(c) Use the motion of the cart to determine M . [2]

(c) For the cart, tension minus resistance is the resultant.

$$F_T - F_f = Ma \quad \Rightarrow \quad M = \frac{F_T - F_f}{a}$$
$$M = \frac{F_T - F_f}{a} = \frac{4.155 \text{ N} - 1.0 \text{ N}}{1.50 \text{ m s}^{-2}} = 2.10 \text{ kg}$$

Exercise 3.4 (d)

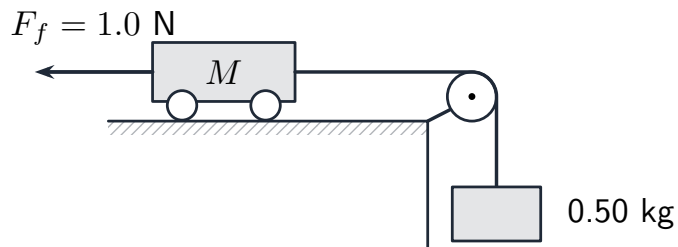
3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



(d) Replace the hanging mass with 0.80 kg. The cart and resistance are unchanged. Calculate the new acceleration. [3]

Exercise 3.4 (d)

3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



(d) Replace the hanging mass with 0.80 kg . The cart and resistance are unchanged. Calculate the new acceleration. [3]

(d) Both the driving weight and total mass change. Add the two force equations to eliminate the new tension.

Full solution 3.4 (d)

(d) Both the driving weight and total mass change. Add the two force equations to eliminate the new tension.

$$F'_T - F_f = Ma', \quad m'g - F'_T = m'a'$$

$$a' = \frac{m'g - F_f}{M + m'}$$

$$a' = \frac{m'g - F_f}{M + m'} = \frac{0.80 \text{ kg} \times 9.81 \text{ m s}^{-2} - 1.0 \text{ N}}{(2.10333 + 0.80) \text{ kg}} = 2.36 \text{ m s}^{-2}$$

The cart accelerates right and the hanging mass down.