

Exercise walk-through

3.1.1.1

Forces step by step

A-Level Physics

3.1.1.1 Forces step by step

Name: _____ Class: _____ Date: _____

Total: 69 marks

KEY WORDS resultant force • weight • normal contact force

1 Key knowledge and worked examples

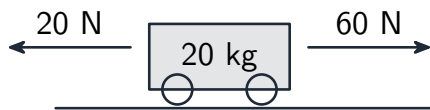
Use $g = 9.81 \text{ m s}^{-2}$. For constant mass: $F_{\text{res}} = ma$; weight: $F_W = mg$. Constant velocity

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.

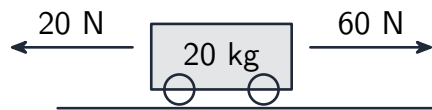
(a) Choose right positive. Find the **resultant force** using $F_{\text{res}} = F_{\text{drive}} - F_f$, then find $a = F_{\text{res}}/m$. [2]



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.

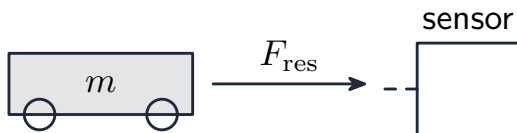
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Exercise 2.2 (a)

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} .

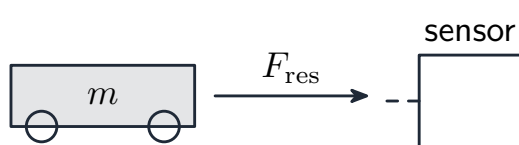
(a) Rearrange $F_{\text{res}} = ma$ to calculate the cart's mass. [2]



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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]



(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) 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]

(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]

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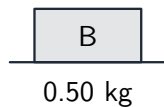
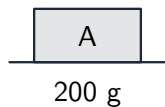
(a) Convert A's mass to kg and B's weight to N. [2]

(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.

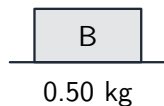
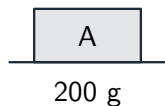
(b) Use $g = F_W/m$ for each probe. Which moon has the weaker gravitational field? [2]



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 $g = F_W/m$ for each probe. Which moon has the weaker gravitational field? [2]



(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) B has weight but does not accelerate. Explain how this is possible. [1]

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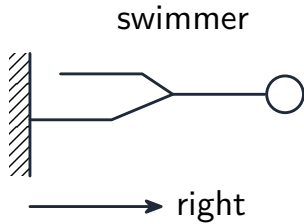
(c) The upward surface force balances the weight, so the resultant is zero.

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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.

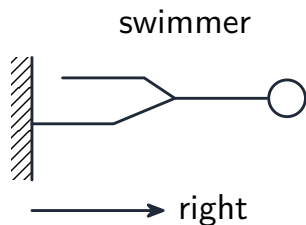
(a) State the size and direction of the force of the wall on the swimmer. [2]



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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.

(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. ,

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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]

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]

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

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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) Name the third-law partner of Earth's gravitational force on the swimmer. State which object this partner acts on. [1]

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(c) Name the third-law partner of Earth's gravitational force on the swimmer. State which object this partner acts on. [1]

(c) The swimmer's gravitational pull on Earth, acting on Earth.

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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) Calculate the drone's weight.

[1]

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) Calculate the drone's weight. [1]

(a) Weight is the gravitational force. ◦

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

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) State F_{thrust} during the steady descent and explain your answer. [1]

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(b) State F_{thrust} during the steady descent and explain your answer. [1]

(b) $F_{\text{thrust}} = 19.62 \text{ N}$. Constant velocity means zero acceleration and balanced forces.

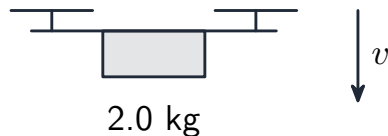
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Exercise 2.5 (c)

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.

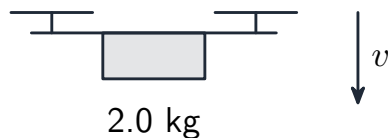
(c) The thrust falls to 15.62 N. Choose down positive and use $mg - F_{\text{thrust}} = ma$ to calculate the acceleration. [2]



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) The thrust falls to 15.62 N. Choose down positive and use $mg - F_{\text{thrust}} = ma$ to calculate the acceleration. [2]



(c) Down is positive, so subtract the upward thrust. , .

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

Exercise 2.5 (d)

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.

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

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

(d) 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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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]

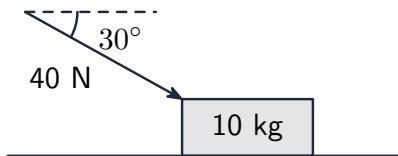
(a) Resolve the push horizontally. ◦

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

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.

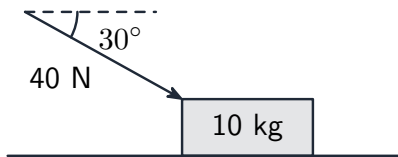
(b) The downward component is $F_{P,y} = F_P \sin 30^\circ$. Use vertical balance to calculate the **normal contact force** from the floor. [2]



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(b) The downward component is $F_{P,y} = F_P \sin 30^\circ$. Use vertical balance to calculate the **normal contact force** from the floor. [2]



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

◦

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

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

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) Calculate the machine's horizontal acceleration.

[2]

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) Calculate the machine's horizontal acceleration. [2]

(c) Subtract resistance from the horizontal component. ◦

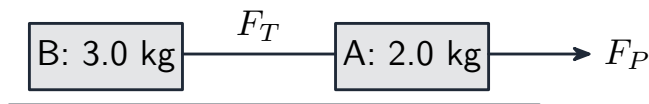
$$F_{\text{res}} = F_P \cos \theta - F_f = 40 \text{ N} \cos 30^\circ - 14.6 \text{ N} = 20.0 \text{ N}$$

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

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.

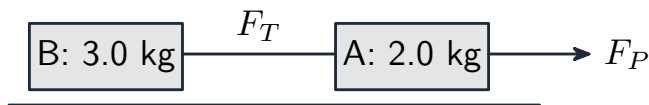
(a) Consider B alone. Use $F_T - 1.4 \text{ N} = m_B a$ to find the string tension F_T . [2]



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(a) Consider B alone. Use $F_T - 1.4 \text{ N} = m_B a$ to find the string tension F_T . [2]



(a) Tension must overcome B's resistance and accelerate B. B ,
B .

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

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) Consider both carts together. Their total resistance is 2.0 N. Calculate the motor's pulling force F_P . [2]

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(b) Consider both carts together. Their total resistance is 2.0 N . Calculate the motor's pulling force F_P . [2]

(b) The motor accelerates the total mass. Internal string forces cancel for the whole system. ; , °

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

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

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) The string breaks while both carts move right. Explain how B's speed then changes.[1]

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(c) The string breaks while both carts move right. Explain how B's speed then changes.[1]

(c) B slows down because resistance acts left, opposite its rightward velocity. B

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Exercise 2.8 (a)

2.8 An air-track glider of mass 0.80 kg moves right. A braking pad reduces its speed uniformly from 5.0 m s^{-1} to 2.0 m s^{-1} in 2.0 s . The pad supplies the only horizontal force.

(a) Define **momentum** .

[1]

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(a) Define **momentum** . [1]

(a) Momentum is the product of mass and velocity. .

Exercise 2.8 (b)

2.8 An air-track glider of mass 0.80 kg moves right. A braking pad reduces its speed uniformly from 5.0 m s^{-1} to 2.0 m s^{-1} in 2.0 s . The pad supplies the only horizontal force.

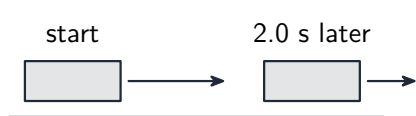
(b) Choose right positive. Use $p = mv$, then $F_{\text{res}} = (p_{\text{final}} - p_{\text{initial}})/\Delta t$, to calculate the resultant force. [2]



Exercise 2.8 (b)

2.8 An air-track glider of mass 0.80 kg moves right. A braking pad reduces its speed uniformly from 5.0 m s^{-1} to 2.0 m s^{-1} in 2.0 s . The pad supplies the only horizontal force.

(b) Choose right positive. Use $p = mv$, then $F_{\text{res}} = (p_{\text{final}} - p_{\text{initial}})/\Delta t$, to calculate the resultant force. [2]



(b) The momentum change is final minus initial.

$$\Delta p = m(v - u) = 0.80 \text{ kg} \times (2.0 - 5.0) \text{ m s}^{-1} = -2.4 \text{ kg m s}^{-1}$$

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

Exercise 2.8 (c)

2.8 An air-track glider of mass 0.80 kg moves right. A braking pad reduces its speed uniformly from 5.0 m s^{-1} to 2.0 m s^{-1} in 2.0 s . The pad supplies the only horizontal force.

(c) The speed decreases uniformly. Use $s = \frac{u+v}{2}t$ to calculate the distance travelled during braking. [2]

Exercise 2.8 (c)

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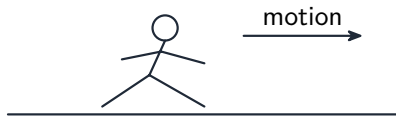
(c) The speed decreases uniformly. Use $s = \frac{u+v}{2}t$ to calculate the distance travelled during braking. [2]

(c) For constant acceleration, distance is average velocity multiplied by time.

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

Exercise 3.1 (a)

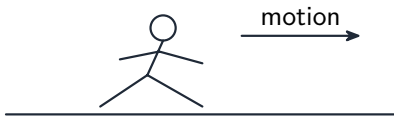
3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



(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.

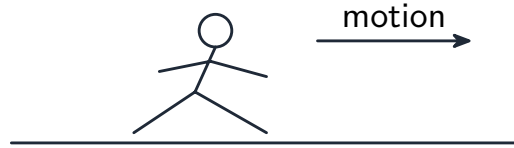
$$a = \frac{v - u}{\Delta t} = \frac{(8.0 - 4.0) \text{ m s}^{-1}}{2.0 \text{ s}} = 2.0 \text{ m s}^{-2}$$

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

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

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]

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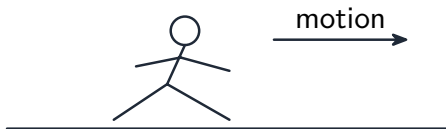
(b) State the size and direction of the force she exerts on the ground horizontally. Name the law used. [2]

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

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Exercise 3.1 (c)

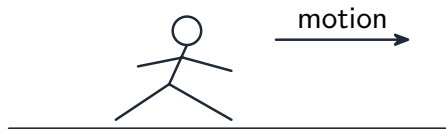
3.1 A 60 kg runner moves along a level track. Her speed increases uniformly from 4.0 m s^{-1} to 8.0 m s^{-1} in 2.0 s. The average air resistance is 30 N.



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

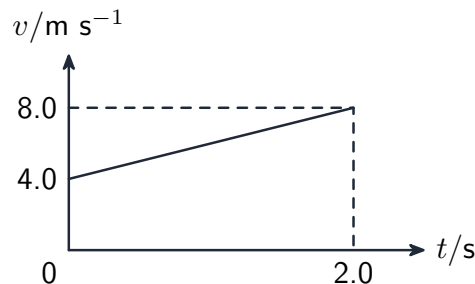
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(c) Sketch her velocity-time graph for these 2.0 s. Label both axes and the start and end values. [2]

(c) Straight line with correct non-zero start; labelled axes and endpoint.



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.

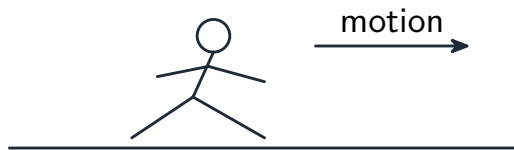


(d) Calculate the distance she travels during these 2.0 s.

[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)

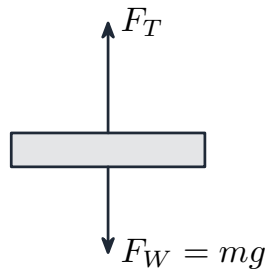
3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



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

[2]

(a) Upward tension and downward weight.



Exercise 3.2 (b)

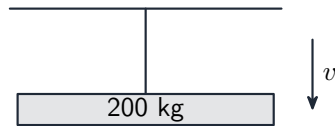
3.2 A crane lowers a 200 kg beam on a vertical cable. The beam moves downwards at 1.2 m s^{-1} and slows uniformly to rest in 3.0 s. Ignore air resistance.



(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.

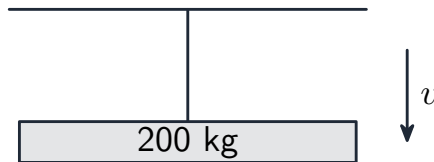


(c) State the force of the beam on the cable, including direction.

[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.



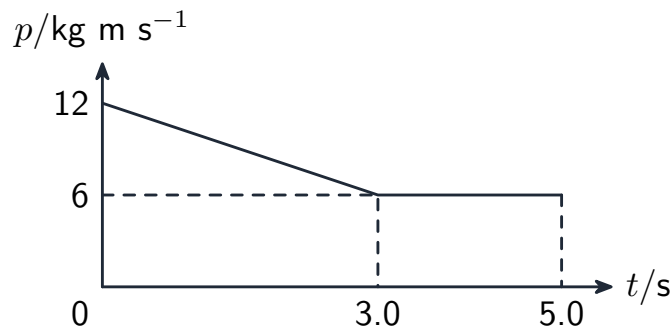
(d) The cable can sustain a maximum tension of 3000 N. Calculate the greatest mass it can raise with an upward acceleration of 0.40 m s^{-2} . [2]

(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.

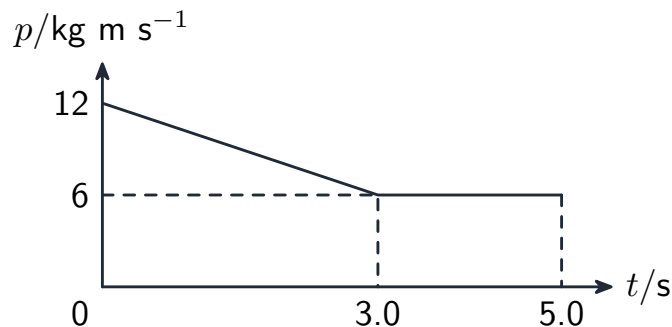


(a) State Newton's second law in terms of momentum.

[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.

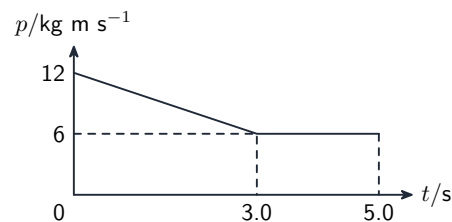


(a) State Newton's second law in terms of momentum. [1]

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

Exercise 3.3 (b)

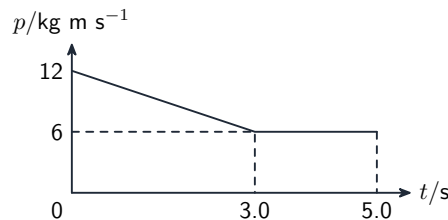
3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.



(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. , .

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

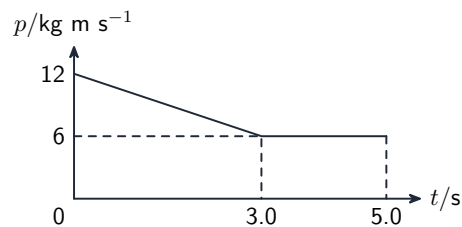
The resultant is 2.0 N leftwards.

$$F_{\text{drive}} - F_f = F_{\text{res}} \quad \Rightarrow \quad F_{\text{drive}} = F_f + F_{\text{res}}$$

$$F_{\text{drive}} = F_f + F_{\text{res}} = 3.0 \text{ N} + (-2.0 \text{ N}) = 1.0 \text{ N}$$

Exercise 3.3 (c)

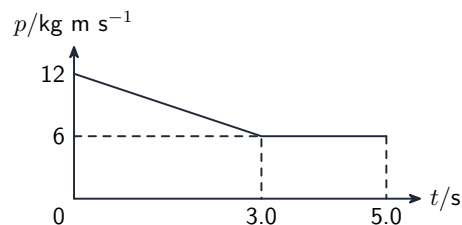
3.3 A small powered vehicle moves right. Its momentum changes as shown. Resistance is constant at 3.0 N leftwards. The motor's driving force F_{drive} acts right.



(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]

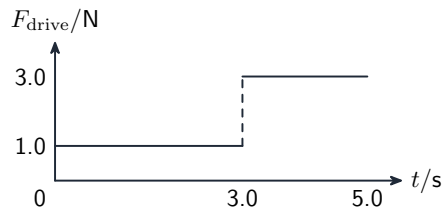
Exercise 3.3 (c)

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.



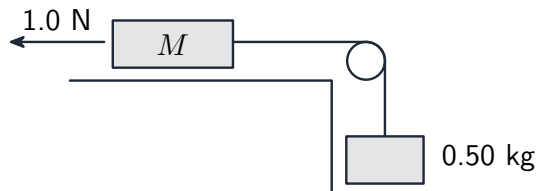
(c) Sketch F_{drive} against time from 0 to 5.0 s. Label the force values and the time at which F_{drive} changes. [3]

(c) The constant-momentum stage requires zero resultant, hence $F_{\text{drive}} = 3.0$ N.
 ,
 . One mark for each level and one for labelled axes and the transition time.



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} .

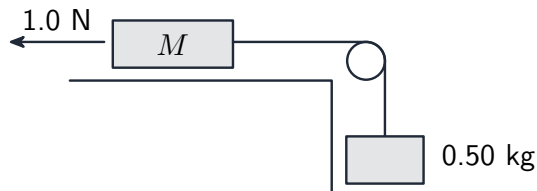


(a) Draw a labelled force diagram for each body.

[2]

Exercise 3.4 (a)

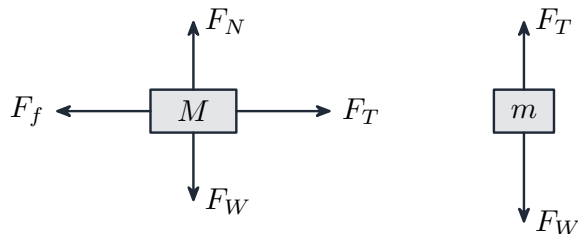
3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



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

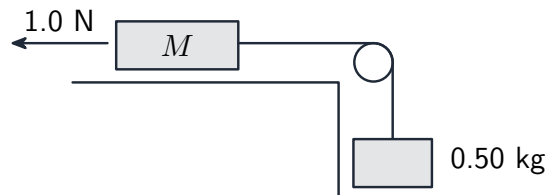
[2]

(a) One mark for each complete diagram.



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} .

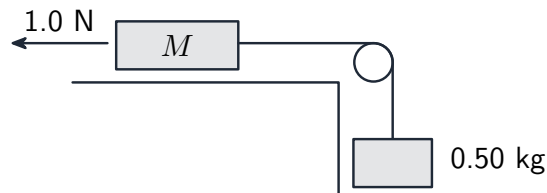


(b) Calculate the string tension.

[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.

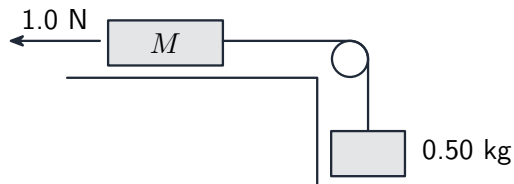
, °

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

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

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} .

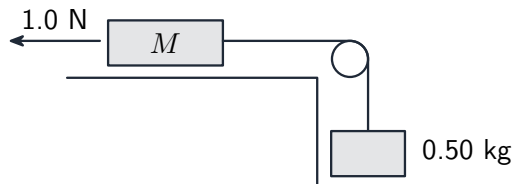


(c) Use the motion of the cart to determine M .

[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]

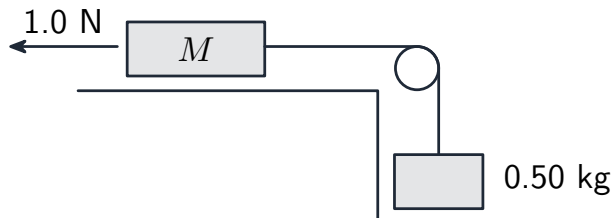
(c) For the cart, tension minus resistance is the resultant. ,
 °

$$F_T - F_f = Ma \quad \Rightarrow \quad M = \frac{F_T - F_f}{a}$$

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

Exercise 3.4 (d)

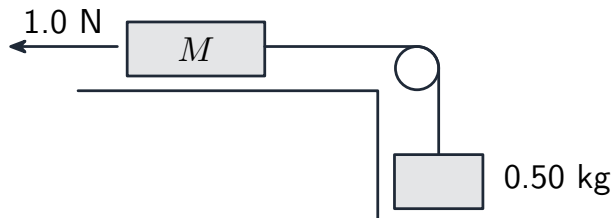
3.4 A cart of unknown mass M is connected to a 0.50 kg hanging mass by a light, taut, inextensible string over a smooth pulley. The cart moves right against 1.0 N resistance. The measured acceleration is 1.50 m s^{-2} .



(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. ; ,

o

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.