

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.

2 Practice

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.

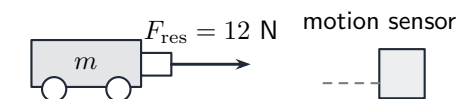
(a) Choose right positive. Find the **resultant force** using $F_{\text{res}} = F_{\text{drive}} - F_f$, then find $a = F_{\text{res}}/m$. [2]



(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]

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]



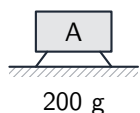
(b) A load is added. The same resultant force now produces an acceleration of 1.5 m s^{-2} . Calculate the mass of the added load. [2]

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]

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

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



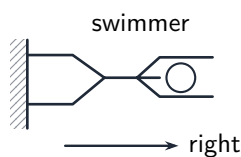
$$F_W = 800 \text{ mN}$$



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

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]

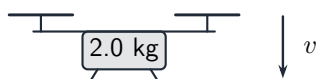


(b) A student says: "These equal and opposite forces cancel, so the swimmer cannot accelerate." Explain the error. [1]

(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]

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]



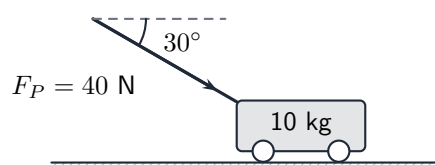
(b) The thrust falls to 15.62 N. Choose a positive direction, write a force equation and calculate the acceleration, including its direction. [2]

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

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]

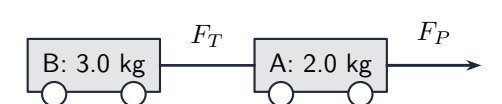
(b) Find the downward component of the push. Write a vertical force equation and calculate the **normal contact force** from the floor. [2]



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

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]

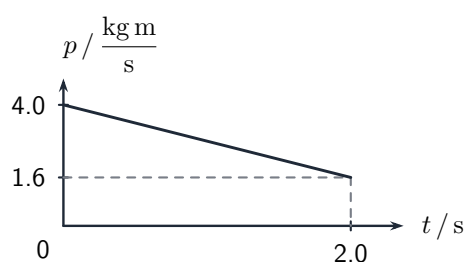


(b) Calculate the motor's pulling force F_P . Show which mass and forces you use. [2]

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

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]

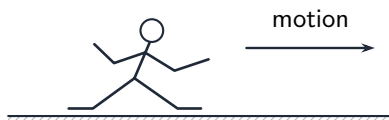


(b) Calculate the initial and final speeds from the graph. Hence calculate the distance travelled in the 2.0 s . [3]

3 Exam-style questions

Work independently. Show your force equations and give directions where needed.

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]

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

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

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

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.



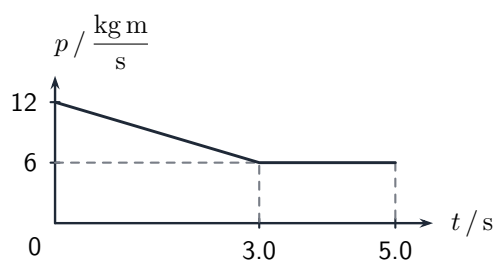
(a) Draw and label the forces on the beam. [2]

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

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

(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]

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.

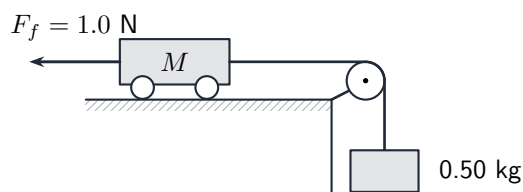


(a) State Newton's second law in terms of momentum. [1]

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

(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]

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]

(b) Calculate the string tension. [2]

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

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