Worksheet - Forces and Newton's laws

Year: Year 12 · 20

Show your working.

Question 1

Question 1 – Mass, weight and force *(Section A · Skills practice)*

Take $g = 9.8$ m/s^2 throughout.

a. Find the weight of a 6.5 kg parcel. [2 marks]
b. A crate has weight 245 N. Find its mass. [2 marks]
c. What force is needed to give a 1 200 kg car an acceleration of 1.5 m/s^2 on a smooth horizontal road? [2 marks]
d. State the units of force and explain the difference between mass and weight. [2 marks]

Question 2

Question 2 – Resultant of two forces *(Section A · Skills practice)*

Find the magnitude and direction of the resultant in each case.

a. A force of 6 N east and a force of 8 N north. [3 marks]
b. Forces of 12 N and 5 N acting at right angles. [2 marks]
c. A force of $(3\mathbf{i} + 4\mathbf{j})$ N and a force of $(-1\mathbf{i} + 2\mathbf{j})$ N. [3 marks]

Question 3

Question 3 – Newton's second law in a line *(Section A · Skills practice)*

A box of mass 8 kg is pulled along a rough horizontal floor by a horizontal force of 50 N. A constant resistance of 18 N opposes the motion. The box starts from rest.

a. Find the acceleration. [3 marks]
b. Find the speed after 5 s. [2 marks]
c. Find the distance travelled in 5 s. [2 marks]
d. The pull is then removed. Find the time for the box to stop. [3 marks]

Question 4

Question 4 – Resolving forces *(Section A · Skills practice)*

Resolve each force into horizontal and vertical components.

a. 20 N at 30° above the horizontal. [2 marks]
b. 15 N at 40° below the horizontal. [2 marks]

c. A 50 N force acts up a slope at 20° to the horizontal. Find the components parallel and perpendicular to the horizontal ground. [2 marks]
d. Find the resultant horizontal force of parts (a) and (b) if they act in the same horizontal direction. [1 mark]

Question 5

Question 5 – Equilibrium *(Section A · Skills practice)*

A particle is in equilibrium under three forces $\mathbf{F}_1 = (5\mathbf{i} + 2\mathbf{j})$ N, $\mathbf{F}_2 = (-3\mathbf{i} + 4\mathbf{j})$ N and $\mathbf{F}_3$.

a. Find $\mathbf{F}_3$. [2 marks]
b. Find the magnitude of $\mathbf{F}_3$ and the angle it makes with the negative x-axis. [3 marks]
c. $\mathbf{F}_3$ is removed. The particle has mass 4 kg. Find its acceleration. [3 marks]

Question 6

Question 6 – A smooth slope *(Section A · Skills practice)*

A box of mass 5 kg slides down a smooth slope inclined at 30° to the horizontal.

a. Draw a force diagram and name the forces. [2 marks]
b. Find the normal reaction. [2 marks]
c. Find the acceleration down the slope. [3 marks]
d. Find the speed after 3 s from rest. [1 mark]

Question 7

Question 7 – Riding the lift *(Section B · Real-life practice)*

A person of mass 60 kg stands on the floor of a lift. Let R be the reaction of the floor on the person. Take $g = 9.8$.

a. Find R when the lift accelerates upwards at 1.2 m/s^2. [3 marks]
b. Find R when the lift accelerates downwards at 0.8 m/s^2. [3 marks]
c. Find R when the lift moves at a constant speed. [2 marks]
d. The scales read the value of R. Explain what you feel in each case. [2 marks]

Question 8

Question 8 – Towing a caravan *(Section B · Real-life practice)*

A car of mass 1 200 kg tows a caravan of mass 800 kg along a straight horizontal road. The driving force is 3 500 N. The resistances are 600 N on the car and 400 N on the caravan. The tow bar is a light rigid connection.

a. Find the acceleration. [3 marks]

b. Find the tension in the tow bar. [3 marks]
c. The car reaches 20 m/s. The driver then stops driving and brakes with a total extra braking force of 2 000 N on the car. Find the new acceleration of the system and the force in the tow bar. [5 marks]

Question 9

Question 9 – Two masses on a pulley *(Section B · Real-life practice)*

Particles of mass 3 kg and 5 kg are attached to the ends of a light inextensible string that passes over a smooth fixed pulley. They are released from rest with the string taut.

a. Write down an equation of motion for each particle. [2 marks]
b. Find the acceleration. [2 marks]
c. Find the tension in the string. [2 marks]
d. Find the speed after 2 s and the distance each particle moves. [3 marks]

Question 10

Question 10 – Pushing a box with friction *(Section B · Real-life practice)*

A box of mass 20 kg rests on rough horizontal ground. The coefficient of friction between the box and the ground is 0.3. Friction is limiting when the box is about to slip: $F = \mu R$.

a. Find the normal reaction and the maximum friction. [3 marks]
b. A horizontal push of 50 N is applied. Does the box move? [2 marks]
c. The push is increased to 80 N. Find the acceleration. [3 marks]
d. Find the time to travel 5 m from rest. [2 marks]

Question 11

Question 11 – Hanging a sign *(Section B · Real-life practice)*

A traffic light of weight 200 N is suspended from two light cables attached to two posts. Each cable makes an angle θ with the horizontal and the system is in equilibrium. The tension in each cable is T.

a. Show that $2T\sin\theta = 200$. [2 marks]
b. Find T when $\theta = 30^\circ$. [1 mark]
c. Find T when $\theta = 20^\circ$ to 1 decimal place. [2 marks]
d. Explain why T can never be less than 100 N, and why it grows as the cables get flatter. [2 marks]

Question 12

Question 12 – A crane lifting a load *(Section B · Real-life practice)*

A crane lifts a load of mass 250 kg using a vertical cable.

a. Find the tension when the load accelerates upwards at 0.4 m/s^2. [2 marks]
b. Find the tension when the load moves up at constant speed. [1 mark]
c. The load is brought to rest from 2 m/s while rising, with constant deceleration over 5 m. Find the deceleration and the tension. [4 marks]
d. The maximum safe tension is 2 600 N. Find the greatest upward acceleration allowed. [2 marks]

Question 13

Question 13 – Two tugs *(Section B · Real-life practice)*

Two tugs pull a ship with ropes at an angle of 60° to each other. Each pulls with a force of 5 kN. The ship has mass 40 tonnes and the water resistance is 6 kN.

a. Find the resultant of the two forces in the direction of motion. [3 marks]
b. Find the net force on the ship. [1 mark]
c. Find the acceleration in m/s^2 (1 tonne = 1 000 kg). [2 marks]
d. The ropes are pulled to 90° apart. Find the new resultant and comment. [3 marks]

Question 14

Question 14 – Braking distance *(Section B · Real-life practice)*

A car of mass 900 kg travelling at 25 m/s brakes to a stop in a distance of 50 m with constant deceleration.

a. Find the deceleration. [2 marks]
b. Find the braking force. [2 marks]
c. Find the time taken to stop. [1 mark]
d. On a wet road the braking force is only 3 600 N. Find the stopping distance from 25 m/s. [3 marks]

Question 15

Question 15 – The train and its trucks *(Section C · Problem solving)*

A locomotive of mass 40 tonnes pulls three identical trucks, each of mass 10 tonnes, along horizontal track. The engine\'s driving force is 60 kN. There is a resistance of 500 N per tonne on every part of the train. The couplings are light and rigid.

Part	Mass (tonnes)	Resistance (N)
Locomotive	40	20 000
Truck 1	10	5 000
Truck 2	10	5 000
Truck 3	10	5 000

a. Find the acceleration of the train. [3 marks]
b. Find the tension in the coupling between the locomotive and truck 1. [3 marks]
c. Find the tension in the coupling between truck 2 and truck 3. [3 marks]
d. Find the thrust in the coupling between the locomotive and truck 1 if the driver brakes the locomotive with a braking force of 20 kN (no driving force). [4 marks]

Question 16

Question 16 – A table and a hanging mass *(Section C · Problem solving)*

Particle A of mass 4 kg lies on a rough horizontal table (coefficient of friction 0.25). It is connected by a light inextensible string over a smooth pulley at the table\'s edge to particle B of mass 6 kg hanging freely 1.2 m above the floor. The system is released from rest.

a. Write the equation of motion for each particle. [3 marks]
b. Find the acceleration and the tension. [4 marks]
c. Find the speed of B when it hits the floor. [2 marks]
d. A continues to slide (the string goes slack). How much further does it travel before stopping? [4 marks]

Question 17

Question 17 – Hanging a load from two ropes *(Section C · Problem solving)*

A load of mass 50 kg is held at rest by two light ropes. Rope 1 makes an angle of 40° with the horizontal and rope 2 makes an angle of 25° with the horizontal, on opposite sides of the load.

a. Write down the two equilibrium equations (horizontal and vertical) in terms of T_1 and T_2. [3 marks]
b. Show that $T_1 = 490$ N. [4 marks]
c. Find T_2. [2 marks]
d. Which rope is more likely to break first and why? [1 mark]

Question 18

Question 18 – A block on a rough slope *(Section C · Problem solving)*

A block of mass 8 kg is on a rough slope at 30° to the horizontal. The coefficient of friction is 0.4.

a. Find the normal reaction and the maximum friction. [3 marks]
b. If the block is released from rest, does it slide? Find its acceleration if it does. [4 marks]
c. A rope parallel to the slope pulls the block up with tension 80 N. Find the acceleration up the slope. [3 marks]
d. Find the smallest tension that will make the block start to move up. [2 marks]

Question 19

Question 19 – Phases of a lift journey *(Section C · Problem solving)*

A lift of mass 800 kg is raised by a vertical cable. Its journey has three phases. A passenger of mass 70 kg is inside.

Phase	Motion	Acceleration
1	speeding up (upwards)	$+1.5$ m/s^2
2	constant speed	0
3	slowing down (upwards)	-1.2 m/s^2

a. Find the tension in the cable in each phase (lift only, passenger included in the 800 kg). [6 marks]
b. Find the reaction on the passenger from the floor in each phase. [4 marks]
c. Which phase is the cable most likely to break? [1 mark]

Question 20

Question 20 – Challenge: forces in vector form *(Section D · Challenge)*

A particle P of mass 2 kg is acted on by three forces $\mathbf{F}_1 = (3k\mathbf{i} + 2\mathbf{j})$ N, $\mathbf{F}_2 = (-4\mathbf{i} + (k+1)\mathbf{j})$ N and $\mathbf{F}_3 = (\mathbf{i} - 4\mathbf{j})$ N, where k is a constant. P is in equilibrium.

a. Find k (the two components must both be consistent). [4 marks]
b. $\mathbf{F}_3$ is removed. Find the acceleration of P in vector form and its magnitude. [4 marks]
c. Find the angle the acceleration makes with the positive x-axis. [2 marks]