Past-paper walk-through

Momentum and Newton's laws of motion ▪ 3.1

eXercise

Questions in this set

- 9702/11 N25 Q11 ▪ 1 mark
- 9702/11 N25 Q12 ▪ 1 mark
- 9702/12 N25 Q8 ▪ 1 mark
- 9702/14 N25 Q8 ▪ 1 mark
- 9702/11 J25 Q10 ▪ 1 mark
- 9702/11 J25 Q11 ▪ 1 mark
- 9702/12 J25 Q9 ▪ 1 mark
- 9702/12 J25 Q11 ▪ 1 mark
- 9702/13 J25 Q9 ▪ 1 mark
- 9702/24 J25 Q2 ▪ 10 marks

Questions in this set

- 9702/12 M25 Q8 ▪ 1 mark

Reading the mark scheme

- **B1** a mark that stands on its own – the point is either made or not.
- **M1** a *method* mark: the right approach, even if the number is wrong.
- **A1** an *answer* mark, and it usually needs its M mark first.
- **C1** a working mark on the way to the answer.
- // separates answers the examiner accepts equally.
- **ecf** = error carried forward: a later part is marked on your own earlier answer.
- **owtte** = "or words to that effect" – the wording need not match.

Question 11

9702/11 N25 ▪ Q11 ▪ 1 mark

The graph shows how the momentum of a motorcycle changes with time.

What is the resultant force on the motorcycle? **[1]**

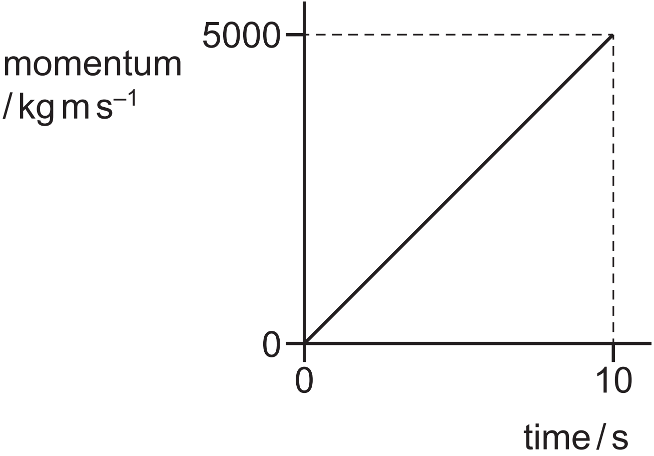
A 500 N

B 5000 N

C 25 000 N

D 50 000 N

Question 11



Solution 11

- **A** 500 N ✓
- **B** 5000 N
- **C** $25\ 000$ N
- **D** $50\ 000$ N

Why

- The resultant force is the gradient of a momentum–time graph.
- The momentum rises by 5000 kg m s^{-1} in 10 s.
- $F = 5000/10 = 500$ N.

Question 12

9702/11 N25 ▪ Q12 ▪ 1 mark

A rocket has a weight of W and an initial acceleration of a as the rocket leaves the ground vertically. The acceleration of free fall is g.
Which expression gives the initial upward force exerted on the rocket due to the engine? **[1]**

A $\frac{Wa}{g} + W$

B $\frac{Wa}{g}$

C $\frac{Wa}{g} - W$

D $Wa + W$

Solution 12

A $\frac{Wa}{g} + W$ ✓

B $\frac{Wa}{g}$

C $\frac{Wa}{g} - W$

D $Wa + W$

Why

- The rocket's mass is $m = W/g$.
- Newton's second law upwards: $F - W = ma = (W/g)a$.
- So $F = Wa/g + W$; C forgets that the engine must also hold up the weight.

Question 8

9702/12 N25 ▪ Q8 ▪ 1 mark

Which statement describes the weight of an object? **[1]**

A It is equal to the mass of the object multiplied by its acceleration.

B It is equal to the resultant force when the object falls at terminal (constant) velocity.

C It is the force acting on the object due to a gravitational field.

D It is the property of the object that resists change in motion.

Solution 8

A It is equal to the mass of the object multiplied by its acceleration.

B It is equal to the resultant force when the object falls at terminal (constant) velocity.

C It is the force acting on the object due to a gravitational field. ✓

D It is the property of the object that resists change in motion.

Why

- Weight is the force a gravitational field exerts on a mass, $W = mg$.
- A is $F = ma$ for any resultant force, not weight in particular.
- At terminal velocity the resultant is zero, so B fails, and D describes inertia – that is mass.

Question 8

9702/14 N25 ▪ Q8 ▪ 1 mark

The acceleration of free fall on the Earth is different to the acceleration of free fall on the Moon.

How do the mass and weight of an object on the Earth compare to its mass and weight on the Moon? **[1]**

A different mass, different weight

B different mass, same weight

C same mass, different weight

D same mass, same weight

Question 8

	mass	weight
A	different	different
B	different	same
C	same	different
D	same	same

Solution 8

A different mass, different weight

B different mass, same weight

C same mass, different weight ✓

D same mass, same weight

Why

- Mass is the quantity of matter in the object and does not depend on where it is.
- Weight is mg, and g on the Moon is about one sixth of its value on Earth.
- So the mass is the same and the weight is different.

Question 10

9702/11 J25 ▪ Q10 ▪ 1 mark

A firework travels vertically upwards in air. Gases are pushed vertically downwards from the firework.

Several forces that act on the firework and gases are shown.

Which forces are a Newton's third law pair? **[1]**

A air resistance and force on gases

B air resistance and thrust

C force on gases and thrust

D thrust and weight

Solution 10

- **A** air resistance and force on gases
- **B** air resistance and thrust
- **C** force on gases and thrust ✓
- **D** thrust and weight

Why

- A third-law pair acts on two *different* bodies, is the same type of force, and is equal and opposite.
- The firework pushes the gases down; the gases push the firework up – that push is the thrust.
- Weight and air resistance both act on the same body, so they can never be a third-law pair.

Question 11

9702/11 J25 ▪ Q11 ▪ 1 mark

Two blocks K and L slide towards each other along a horizontal frictionless surface.
The diagram shows the momentum of the two blocks just before they collide.
During the collision, the blocks are in contact with each other for a time of 0.084 s.
After the collision, the blocks separate and block L moves back along its original path with a momentum of $0.12\ \text{kg m s}^{-1}$.
What is the magnitude of the average force exerted on block L by block K during the collision? **[1]**

A 3.1 N

B 4.0 N

C 6.9 N

Question 11

D 7.1 N

Solution 11

- **A** 3.1 N
- **B** 4.0 N
- **C** 6.9 N ✓
- **D** 7.1 N

Why

- Take K's direction as positive, so L carries -0.46 kg m s^{-1} before the collision.
- L rebounds along its original path, so afterwards its momentum is $+0.12$ kg m s^{-1}.
- $F = \Delta p/\Delta t = (0.12 - (-0.46))/0.084 = 6.9$ N.

Question 9

9702/12 J25 ▪ Q9 ▪ 1 mark

A rocket engine ejects 90 kg of exhaust gas per second at a velocity of 190 m s^{-1} relative to the rocket.

What is the force acting on the rocket due to the ejected gas? **[1]**

A 2.1 kN

B 17 kN

C 18 kN

D 162 kN

Solution 9

- **A** 2.1 kN
- **B** 17 kN ✓
- **C** 18 kN
- **D** 162 kN

Why

- Force is the rate of change of momentum, so $F = (\Delta m/\Delta t)v$.
- $F = 90 \times 190 = 17100$ N, which is 17 kN.
- No extra factor is needed – the mass ejected per second is given directly.

Question 11

9702/12 J25 ▪ Q11 ▪ 1 mark

A cyclist is riding at a constant speed on a level road.

According to Newton's third law of motion, what is equal and opposite to the backward push of the back wheel on the road? **[1]**

A the force exerted by the cyclist on the pedals

B the forward push of the road on the back wheel

C the tension in the cycle chain

D the total air resistance and friction force

Solution 11

A the force exerted by the cyclist on the pedals

B the forward push of the road on the back wheel ✓

C the tension in the cycle chain

D the total air resistance and friction force

Why

- A third-law pair swaps the two bodies and reverses the direction.
- The wheel pushes backwards on the road, so the road pushes forwards on the wheel.
- D balances the driving force on the *same* body, which makes it a first-law balance, not a third-law pair.

Question 9

9702/13 J25 ▪ Q9 ▪ 1 mark

9 Which statement **defines** force?

A When a force acts on a body that is free to move, the force is the product of the mass of the body and its acceleration.

B When a force acts on a body that is free to move, the force is the rate of change of momentum of the body.

C When a force acts on a body that is free to move, the force is the work done by the force divided by the distance moved by the body.

D When a force acts on a lever and causes a moment, the force is the moment divided by the perpendicular distance of the force from the pivot.

Solution 9

Answer: **B**

Why

- Newton's second law defines force as the rate of change of momentum.
- A is only the special case $F = ma$, which holds when the mass is constant.
- C defines work per unit distance, and D a moment divided by a distance.

Question 2

9702/24 J25 ▪ Q2 ▪ 10 marks

An object of constant mass moves in a straight line. The variation with time *t* of the momentum *p* of the object is shown in Fig. 2.1.

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

(b) Calculate the change in momentum of the object from time $t = 0$ to $t = 12$ s. **[1]**

(c) Calculate the magnitude of the resultant force acting on the object. **[2]**

(d) Describe the variation of the speed of the object from time $t = 0$ to $t = 8.0$ s. **[1]**

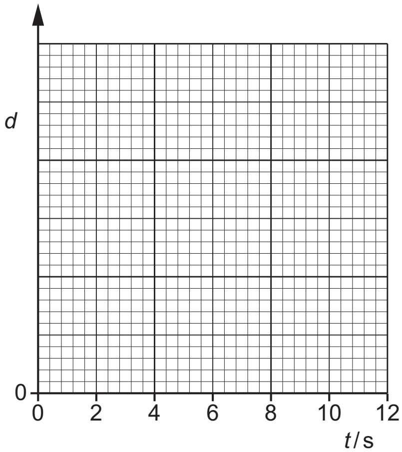
(e) By reference to Fig. 2.1, explain why the resultant force acting on the object during the first 8.0 s of its motion cannot be due to air resistance. **[2]**

(f) At time $t = 0$ the displacement *d* of the object is zero.

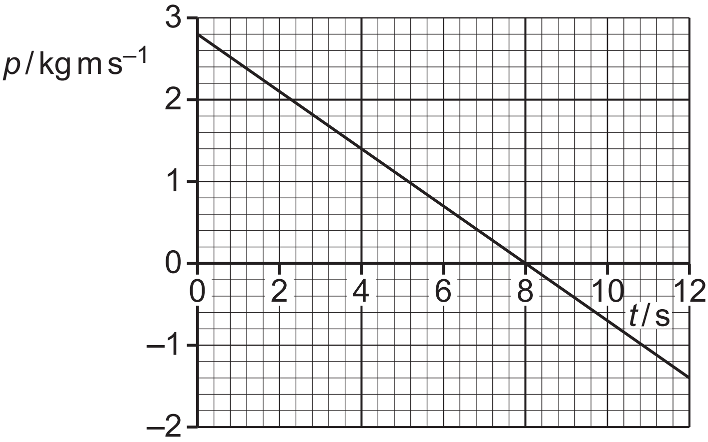
On Fig. 2.2, sketch the variation of *d* with time *t* from $t = 0$ to $t = 12$ s.

Numerical values of *d* are not required. **[3]**

Question 2



Question 2



Solution 2

(a)

Mark scheme

- product of mass and velocity

Solution 2

(b)

Worked steps

Change means final minus initial, and the sign carries the meaning.

- $\Delta p = (-1.4) - (+2.8)$
- $\Delta p = -4.2$ kg m s^{-1} — the minus sign says the momentum reversed direction.

Mark scheme

- change in momentum $= (-1.4) - (+2.8)$
- $= (-)4.2$ kg m s^{-1}

Solution 2

(c) Worked steps

Force is the rate of change of momentum, which on this graph is its **gradient**.

- $F = \dfrac{\Delta p}{\Delta t} = \dfrac{4.2}{12}$
- $F = 0.35$ N

Solution 2

The graph is a straight line, so this force is constant — which is the fact part (e) turns on.

Mark scheme

- $F = \Delta p/(\Delta)t$ **or** $F =$ gradient
- $= 4.2/12$
- $= 0.35$ N

Solution 2

(d)

Mark scheme

- constant / uniform (rate of) decrease (of speed to zero).

Solution 2

(e)

Mark scheme

- The (resultant) force is constant / does not decrease
- air resistance would vary / decrease / not constant
- the force is not zero when speed / velocity is zero / at 8 s

Any two of the above 3 marking points (1 mark each, max 2)

Solution 2

(f) Worked steps

Displacement is built from the velocity, and velocity has the same sign as momentum.

- From $t = 0$ to 8.0 s: momentum is positive but falling, so the object moves forwards ever more slowly. Draw a line from the origin rising with a **decreasing** positive gradient.
- At $t = 8.0$ s the momentum is zero, so the object is momentarily at rest: the curve is at its **maximum**, with zero gradient.
- After 8.0 s the momentum is negative and growing, so it moves backwards ever faster. Draw a falling line whose gradient gets steeper.
- At $t = 12$ s the object has not returned to the start, so leave d **positive**: the area under the negative part of the momentum graph is smaller than the positive part.

Solution 2

Mark scheme

- line from origin with decreasing positive gradient
- gradient changes from positive to negative at 8.0 s
- after $t = 8.0$ s the line has a negative gradient of increasing magnitude and a positive value of d at $t = 12$ s

Question 8

9702/12 M25 ▪ Q8 ▪ 1 mark

8 An astronaut of mass m in a spacecraft experiences a gravitational force $F = mg$ when stationary on the launchpad.

What is the gravitational force on the astronaut when the spacecraft is launched vertically upwards with an acceleration of $0.2g$?

A $1.2mg$ **B** mg **C** $0.8mg$ **D** 0

Solution 8

Answer: **B**

Why

- The gravitational force on the astronaut is their weight, mg, fixed by the field alone.
- Launching changes the *contact* force from the seat, not the Earth's pull.
- They feel heavier, but that sensation is the seat pushing harder, not gravity increasing.