CP2a Resultant forces

1 **a** Speed is 20 km/h, so it is not changing.

b The direction is changing all the time so the velocity is changing.

2 **a** Both forces are in the same direction so they are added. Resultant = 15 N, acting backwards (i.e. against the direction of motion).

b 25 N – 15 N = 10 N forwards (or 25 N – 10 N – 5 N = 10 N)

3 **a** resultant = 10 000 N – 10 000 N = 0 N

b resultant = 3000 N – 2500 N = 500 N in the forwards direction

4 **a** balanced

b unbalanced

S1 students' own concept maps

E1 vertical resultant = 900 N – 850 N = 50 N acting downwards

horizontal resultant = 30 N + 100 N – 50 N = 80 N acting forwards

E2 Sketch of diver with downwards arrow and forwards arrow – the forwards arrow should be larger than the downwards one.

Exam-style question

the resultant force is zero (1)

because if there are balanced forces it means that the forces in each direction cancel each other out (or similar wording) (1).

CP2b Newton's First Law

1 **a** her weight, acting downwards

b it will reduce her upwards speed (or change her vertical speed)

2 **a** it will not change, because the forces are balanced/there is no resultant force

b its velocity will increase because the forces are unbalanced and the resultant is acting in the forwards direction

3 **a** The drag force must be 300 N divided by the same size as the force from the sails because it is travelling at a constant speed so the horizontal forces on it must be balanced.

b There is not much friction when something is moving across ice. If the friction on the ice yacht is less than the water resistance on the sailing dingy, then there will be a resultant forwards force on the ice yacht so its velocity will increase.

4 There is a force of gravity on it acting towards the centre of the Earth. This is changing the direction in which the satellite is moving/making it move in a circle, and as its direction is changing its velocity must be changing.

S1 Horizontal: resultant force in the forwards direction, which is why the speed is increasing.

Vertical: no resultant force/resultant = zero, as the motion in the vertical direction is not changing.

E1 Waiting to be fired: weight of human cannonball, upwards force from the platform they are standing on. The resultant force is zero as their motion is not changing.

Being fired: weight acting downwards and upwards force from the platform which is greater than their weight, so there is a resultant force acting upwards. Their velocity increases in an upwards direction.

Flying through the air: weight acting downwards, air resistance acting downwards while they are still moving upwards, then acting upwards once they are moving downwards again. The resultant is always downwards and it causes their upwards speed to get less until they come to a stop at the top of their flight, and then they accelerate downwards again.

Landing in net: weight acting downwards, force from net acting upwards. Resultant is upwards/against the direction of motion and it slows them down until they stop.

A very good answer might also describe the net stretching and the force from the net increasing as it stretches.

E2 A centripetal force is a force on a body that is moving in a circle and acts towards the centre of the circle. This force continuously changes the direction of motion and so continuously changes the velocity of the object.

Examples are tension in strings or wires (such as fairground rides, hammer-throwing, stones on string), friction (road vehicles cornering) and gravity (keeping planets and satellites in orbit).

Exam-style question

the push chair is slowing down so friction is greater (1)

than the force provided by the man (1)

CP2c Mass and weight

1 any of: go to the toilet, cut hair, remove clothing

2 **a** 300 kg – the mass of an object does not change unless the object itself is changed

b weight = 300 kg × 1.4 N/kg = 420 N

3 $g = W / m$ = 685 N / 185 kg = 3.7 N/kg

4 Her mass does not change (and g does not change) so her weight does not change.

5 When she was falling at a constant speed the resultant force was zero. When the air resistance suddenly increases there is a resultant force acting upwards. As her motion is downwards, this reduces her velocity.

S1 Mass is the amount of matter in an object. It is measured in kilograms.

Weight is the force of gravity pulling on an object. It is measured in newtons.

S2 weight = 2 kg × 10 N/kg = 20 N

E1 Mass is the amount of matter in an object, measured in kilograms. Weight is the pull of gravity on an object, measured in newtons. The weight of an object depends on its mass but also on the gravitational field strength. The gravitational field strength on Earth is 10 N/kg.

The mass of an object can only be changed by adding matter to it or taking some away. The weight of an object can be changed by changing its mass, or taking it to a place with a different gravitational field strength, such as a different planet.

E2 mass = weight / gravitational field strength = 280 N / 1.4 N/kg = 200 kg

weight on Earth = mass × g = 200 kg × 10 N/kg = 2000 N

Exam-style question

mass of spanner on the Moon = 0.2 kg (1)

as the mass is the quantity of matter and does not change unless the spanner itself is changed (1).

the weight will be less on the Moon (1)

because the gravitational field strength on the Moon is less (1).

CP2d Newton's Second Law

1 It will start to move, change speed or direction.

2 **a** The car will accelerate faster/at a greater rate than the lorry because it has a smaller mass.

b There would need to be a bigger force on the lorry, to make up for its greater mass.

3 force = 1500 kg × 4 m/s^2 = 6000 N

4 acceleration = 800 N / 1500 kg = 0.53 m/s^2

5 160 N / 2 m/s^2 = 80 kg

S1 The limit on force that the engines can produce is an upper limit on acceleration. The lower limit on mass means that the mass cannot be reduced further, so the acceleration cannot be increased. Both rules set an upper limit on acceleration.

S2 250 kg × 5 m/s^2 = 1250 N

E1 Acceleration depends on resultant force and mass, so you would need to know the mass of each vehicle, the maximum engine force and also the size of the resistive forces (air resistance and friction) to work out the resultant.

E2 Objects with larger masses have larger forces from gravity on them, but the larger mass also needs a larger force to give it a certain acceleration. This is not usually seen on Earth because air resistance affects the rate of fall.

Students studying the Higher Tier could be expected to mention inertial mass in their answer:

The inertial mass is the same value as the mass that is pulled on by gravity. The increased force on an object of larger mass is exactly balanced by the greater force needed to give the same acceleration as experienced by the smaller mass.

Exam-style question

equation (1)

force = mass × acceleration

substitution (1)

3000 N = mass × 2 m/s^2

evaluation (1)

= 1500 N

CP2d Core practical – Investigating acceleration

1 Acceleration is a change in speed over time (1), so find the difference in the two speeds and divide by the time taken to move between the two light gates. (1)

2 Weight is the force of gravity acting on a mass. (1)

3 The most likely suggestion is to prevent the masses or trolley falling on feet (1) by putting a box or other object beneath the masses. (1)

4 Ramp, supports for ramp, trolley, pulley, string, mass hanger, stacking masses, 2 light gates, data logger (1) plus whatever apparatus is involved in the safety suggestion they made in answer to question 3. (1)

5 To measure the time the trolley takes to move between the two light gates (1) as acceleration is calculated from a change in velocity divided by time (or equivalent explanation). (1) Do not accept 'to measure the speed/velocity at the beginning'.

6 The masses on the end of the string are accelerating as well as the trolley and any masses on it. (1) If the masses were just added to the end of the string, the accelerating mass would change each time as well as the force (1) so it would not be a fair test/the effect of the change in force could not be investigated. (1)

7 The acceleration is proportional to the force. (1)

8 a The acceleration gets less as the mass increases. (1) Do not accept 'the acceleration is inversely proportional to the mass' at this point as this cannot be determined for certain from the shape of the graph.

b Plot acceleration against 1/mass (or mass against 1/acceleration), (1) if this is a straight line it will show that the acceleration is inversely proportional to the accelerating mass. (1)

CP2e Newton's Third Law

1 the ground pushing up on the dog

2 a arrows showing weight pushing on ground and ground pushing on person

b arrows showing person pushing on wall and wall pushing on person (or feet pushing sideways on ground and ground pushing sideways on feet)

3 weight downwards and force from the ground upwards

4 a force from the ball on the ground and an equal and opposite force from the ground on the ball

5 The force from the head on the ball causes the ball's velocity to change/ball to bounce off the head. The force of the ball on the head causes the head's velocity to change/pushes the head backwards. The head has a greater mass than the ball (and also the neck muscles provide an opposing force) so the change in motion of the ball is more obvious.

S1 your weight pushing down on the chair and the chair pushing up on you

Balanced forces both act on the same object (the person), whereas action-reaction forces act on different objects.

E1 Various answers are possible.

Action-reaction pairs: pull of one team on the rope, pull of the rope on the team; pull of the Earth's gravity on one team, pull of the team's gravity on the Earth; feet of one team pushing horizontally against the ground, ground pushing horizontally against the feet.

Balanced forces: pull of one team on the rope, pull of the other team on the rope; pull of the Earth's gravity on one team, upwards force from the Earth on the team; feet of one team pushing horizontally against the ground, pull of the rope on the team.

E2 The Earth and the ball attract each other with the same size force but in opposite directions. The pull of the Earth on the ball is a resultant (or the only) force on the ball so it makes the ball accelerate downwards. The pull of the ball on the Earth makes the Earth accelerate upwards. There is the same force on the ball and on the Earth but the Earth's mass is so much greater that the acceleration of the Earth is too small to be noticed.

Exam-style question

force (weight) of apple pulling on spring and force of spring pulling on the apple

OR

weight of apple (force of gravity pulling on the apple) and force of the apple pulling on the Earth (1)

CP2f Momentum H

1 Momentum depends on mass as well as velocity, and motorcycles usually have smaller masses than cars.

2 momentum = 500 kg × 10 m/s
= 5000 kg m/s

3 velocity = momentum / mass
= 1500 kg m/s / 500 kg = 3 m/s

4 force = ($mv - mu$) / t = (1000 kg × 15 m/s – 1000 kg × 0 m/s) / 15 s
= 15 000 / 15 = 1000 N

5 **a** moving penguin: 20 kg × 6 m/s = 120 kg m/s; stationary penguin: zero

b 120 kg m/s

c to the right

d 20 kg × 3 m/s + 20 kg × 3 m/s = 120 kg m/s to the right

e Momentum has been conserved because the momentum after they collide is the same as the momentum before the collision.

S1 momentum of one truck = 5000 kg × 5 m/s = 25 000 kg m/s

momentum of other truck = –25 000 kg m/s (it has the same mass and speed but is travelling in the opposite direction)

total momentum before collision = –25 000 kg m/s + 25 000 kg m/s = 0

After the collision the momentum is zero as the trucks are not moving. Momentum is the same before and after the collision, so momentum has been conserved.

E1 momentum of bullet = 0.001 kg × 300 m/s = 0.3 kg m/s

total mass of bullet and wood = 1.001 kg

Momentum is conserved and the momentum of the block of wood was zero as it was stationary, so the final momentum must be the same as the initial momentum of the bullet.

velocity of bullet + wood = 0.3 kg m/s / 1.001 kg = 0.2997 m/s = 0.3 m/s to 2 s.f.

Exam-style question

equation (1)

momentum = mass × velocity

substitution (1)

= 1800 kg × 35 m/s

evaluation (1)

= 63 000 kg m/s

CP2g Stopping distances

1 in order to leave a safe distance so they do not crash when a hazard appears

2 17 m

3 **a** The car is moving during the driver's reaction time, so the longer the driver takes to respond to a stimulus, the further the car will have moved.

b The faster the car is moving, the further it will go during the driver's reaction time.

4 In a computer test there is just a light/colour change (or a sound); in the simulator there are lots of things to look at/the driver might not be looking in the correct direction when the hazard appears/the driver has to decide if something they can see *is* a hazard.

5 Drinking alcohol increases reaction time, therefore increasing thinking distance. This increases stopping distance, leading to more crashes.

6 The thinking distance is the same but cars have much smaller masses than lorries, so the braking distance (and so the overall stopping distance) will be less.

7 The lower speed limit is for wet weather, when the reduced friction between tyres and the road will make braking distances longer.

S1 A good answer will contain the following points.

Thinking distance is increased by: alcohol; drugs; tiredness; faster speed.

Braking distance is increased by: faster speed; higher mass; worn brakes; worn tyres; lower friction road surface, e.g. mud, gravel, wet, ice.

E1 The paragraph should be coherent and concise, and should contain most of the following points:

- fog does not affect the thinking or braking distances
- fog reduces the distance at which a hazard can be identified
- if the distance at which the hazard is identified is less than the stopping distance, the car will hit the object
- drivers need to reduce their speed in foggy conditions until the stopping distance is less than the maximum distance they can see ahead.

Exam-style question

Description that makes reference to the following points:

- the thinking distance is how far the vehicle travels while the driver is reacting to a hazard (1).
- the faster the vehicle is travelling the greater the distance travelled whilst the driver is thinking (1).
- braking distance is how far the vehicle travels while it is slowing down (1).
- the faster the vehicle is travelling the longer it takes to stop (1)

CP2h Crash hazards

1 **a** The deceleration when it comes to a stop is greater if it was travelling faster to start with, so there is a greater force on the vehicle.

b The lorry has a greater mass than the car, so the force needed to stop it is greater.

2 If a back seat passenger is not wearing a seatbelt they will continue to move forwards until they hit the seats or people in front.

A good answer may include mention of action–reaction pairs – when the flying back seat passenger hits the person in front, there will be equal and opposite forces on both of them, so they will both be injured.

3 On impact, the bubbles squash slowly, reducing the acceleration and so reducing the force on the object being protected.

4 **a** force = (1800 kg × 0 m/s – 1800 kg × 20 m/s) / 0.03 s = –1 200 000 N

b The force is greater because the car has a greater mass and it was moving faster before it crashed, so its starting momentum was greater. It also came to a stop in a shorter time, so the rate of change of momentum was greater.

S1 Any two from: crumple zones, air bags, wearing seat belts, driving more slowly.

Crumple zones increase the time taken for the car to stop; air bags increase the time it takes for a person's head to stop (compared to hitting the dashboard or steering wheel); seat belts ensure the people stop at the same rate as the car (rather than carrying on at their original velocity and then stopping suddenly when in contact with the dashboard/wheel/windscreen). All four methods reduce the deceleration and so reduce the force on the vehicle.

E1 Any suitable set of calculations using the formula relating force to the rate of change of momentum to demonstrate that decreasing the speed or mass of a vehicle, or increasing the time taken to stop (i.e. if the car has a crumple zone), decreases the force.

One possible set of calculations is:

force on a 1000 kg car stopping in 0.05 s from different speeds:

15 m/s: force = (1000 kg × 0 m/s – 1000 kg × 15 m/s) / 0.05 s = –15 000 / 0.05 = –300 000 N

30 m/s: force = (1000 kg × 0 m/s – 1000 kg × 30 m/s) / 0.05 s = –30 000 / 0.05 = –600 000 N

conclusion for speed: When the speed doubles the force doubles (if all other factors stay the same). A good answer may also point out that the force will be proportional to the speed if the mass and time stay the same.

force on two cars of different masses stopping in 0.05 s from 15 m/s:

1000 kg car: as above, force = –300 000 N

2000 kg car: force = (2000 kg × 0 m/s – 2000 kg × 15 m/s) / 0.05 s = –30 000 / 0.05 = –600 000 N

When the mass doubles the force doubles (if all other factors stay the same). A good answer may also point out that the force will be proportional to the mass if the speed and time stay the same.

A crumple zone increases the time for the car to stop:

1000 kg car at 15 m/s stopping in 0.05 s: as above, force = –300 000 N

same car stopping in 0.1 s: force = (1000 kg × 0 m/s – 1000 kg × 15 m/s) / 0.1 s = –15 000 / 0.1 = –150 000 N

The time has doubled and the force has halved. The force is inversely proportional to the time it takes the car to come to a stop.

Exam-style question

Explanation that makes reference to the following points:

- the crumple zone reduces the deceleration when the car hits an obstacle (1)
- and this reduces the force on the car and any passengers strapped into the car (1)
- if the passengers are not strapped in they carry on moving forwards when the car stops (1)
- and the effect of the crumple zones is negligible because the deceleration when the passenger hits the dashboard is so large. (1)