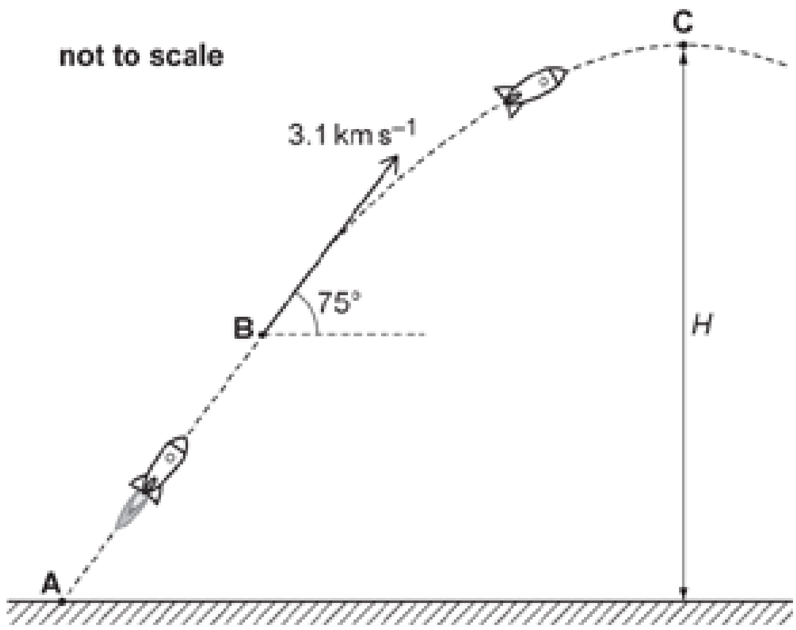
1. A scientist uses a rocket to study the Earth's atmosphere.

The scientist launches the rocket from rest at the point **A** at t = 0 seconds. The force produced by the rocket's engine causes it to accelerate.

At t = 50 seconds, the rocket's engine no longer produce an accelerating force as all of the fuel has been used. The rocket has reached point **B**. Its velocity is now 3.1 km s^{-1} at an angle of 75° to the horizontal.



The rocket engine works by expelling hot gas backwards.

Explain, using Newton's laws of motion, how the engine causes the rocket to accelerate between t = 0 and t = 50 s.

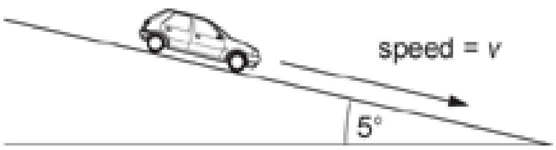
[3]

2(a). A car of weight 9300 N is moving at speed v. The total resistive force, F, acting against the motion of the car is given by the formula

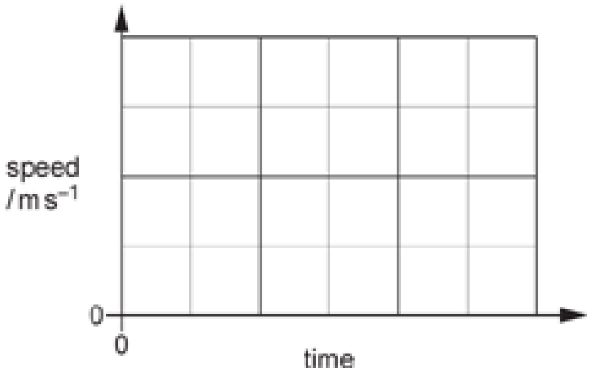
$F = kv^2$

where k is a constant.

The car is allowed to roll from rest down a slope of 5° to the horizontal. The engine of the car is not switched on. The car reaches a maximum speed of 30 m s^{-1}.



i. Sketch a graph on the axes below to show how the speed of the car changes over time. Add a suitable value to the vertical axis.



[2]

ii. Explain why the car reaches a maximum speed.

[2]

iii. Show that the value of *k* in the equation $F = kv^2$ is about 1.

[3]

(b). The car is now moving along a straight, level track. The engine of the car delivers a maximum power of 75 kW.

Calculate the maximum speed of the car.

maximum speed of car = ... m s^{-1} **[3]**

(c). Changes are made to the engine of the car so that it can produce double the original maximum power.

Explain why the maximum speed of the modified car is **not** doubled.

[2]

3(a). State Newton's second law of motion.

[1]

(b). A model of an aircraft is being tested in a wind tunnel. The model is fixed in position by a support, and air is blown horizontally towards it by fans.

In one second, 35 kg of air moving at 50 m s^{-1} hits the model. After flowing around the model, the airflow is diverted downwards at an angle of 30° to the horizontal. The speed of the diverted airflow remains at 50 m s^{-1}.

i. Calculate the horizontal and vertical components of the velocity of the diverted airflow.

horizontal component of velocity = ... m s^{-1}

vertical component of velocity = ... m s^{-1}

[2]

ii. Explain how the airflow around the model produces a force on the model.

[2]

iii. Calculate the **vertical** lift force *F* acting on the model due to the airflow around it.

F = ... N **[3]**

4. An object of mass 1.0kg is moving in a straight line at velocity $10ms^{-1}$.

It collides with an identical object also travelling at 10 ms^{-1} in a straight line. Their initial velocities are perpendicular.

The two objects stick together.

What is the magnitude in ms^{-1} of the new combined velocity?

A 7.1
B 10
C 14
D 20

Your answer ☐ **[1]**

5. A particle **X** collides with a stationary particle **Y**.

No external forces act and the collision is inelastic.

Which quantity is conserved in the collision?

A momentum of **X**
B momentum of **Y**
C momentum of **X** + momentum of **Y**
D kinetic energy of **X** + kinetic energy of **Y**

Your answer ☐ **[1]**

6. According to Newton's third law, forces always occur in pairs.

Which statement is **not** true for a Newton's third law force pair?

A The forces are acting in opposite directions.
B The forces are acting on the same body.
C The forces have the same magnitude.
D The forces are the same type.

Your answer ☐ **[1]**

7(a). In ice hockey, players use a stick to hit an object called a puck, across the surface of the ice.
Assume that the frictional force between the ice and the puck is negligible.
The mass of each puck is 0.16 kg.

State Newton's second law of motion.

---[1]

(b). A player hits a single, stationary, puck. The stick is in contact with the puck for a time of 0.033 s and the puck moves at a velocity of 20 ms^{-1} across the ice.

Calculate:

i. the impulse of the force applied to the puck. Include an appropriate unit.

impulse = ... unit .... **[2]**

ii. the average force *F* that the stick exerts on the puck.

F = ...N **[1]**

(c). A mass *m* is stuck on top of a puck B. Puck B is stationary. The single puck travels across the surface of the ice towards B as shown in the diagram.

The single puck collides **elastically** head-on with B.

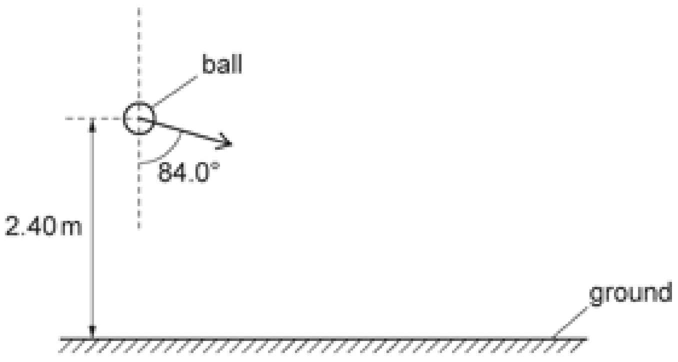
i. Explain what is meant by a perfectly elastic collision.

---[1]

ii. After the collision B travels across the surface of the ice with a velocity of 8.0 m s^{-1}.
The velocity of the single puck after the collision is −12 m s^{-1}.
Determine *m*.

m = ... kg **[3]**

8(a). A student throws a ball of mass 0.210 kg. The hand of the student is a vertical distance of 2.40 m above the ground. The ball leaves the student's hand with a velocity of 22.3 m s^{-1} at an angle of 84.0° to the vertical as shown in the diagram.



(not to scale)

Assume that air resistance is negligible.

Show that the vertical component u_v of the velocity of the ball as it leaves the student's hand is about 2.33 m s^{-1}.

[1]

(b). Show that the vertical component v_v of the velocity of the ball as it hits the ground is about 7.25 m s^{-1}.

[2]

(c). Calculate the kinetic energy E_k of the ball as it hits the ground.

E_k = ...J **[3]**

(d). Explain why the momentum of the ball changes as the ball travels from the hand to the ground.

[2]

9(a).

A sealed container contains *n* moles of an ideal gas. The gas has pressure *p*, absolute temperature *T* and occupies volume *V*.

The mass of one mole of the gas is *M*.

Use an ideal gas equation to show that the density ρ of the gas is given by the expression $\rho = \frac{pM}{RT}$.

[3]

(b). An airship has a cabin suspended underneath a gasbag inflated with helium.

The airship is floating above the ground and is stationary.

The volume of the gasbag is 12 000 m^3.
The temperature of the helium and the surrounding air is 20°C.
Atmospheric pressure is 1.0×10^5 Pa.
The molar mass of air is 0.029 kg mol^{-1}.
The volume of the cabin is negligible compared to the volume of the gasbag.

i. Show that the density of air under the conditions described is about 1.2 kg m^{-3}.

[1]

ii. Calculate the weight of air displaced by the airship.

weight of air .... N **[2]**

iii. Explain why the weight of air displaced by the airship has the same magnitude as the weight of the airship and its contents.

[2]

---

iv. The pressure of the helium in the gasbag is maintained at a value only slightly greater than atmospheric pressure.
Suggest why a larger pressure is not used.

[2]

(c). The airship engine drives a fan which moves 7.8 kg of air per second at a relative speed of 45 m s^{-1}, so the airship starts to move.
All other conditions given in **(b)** remain the same.

Calculate the thrust that the engine produces.

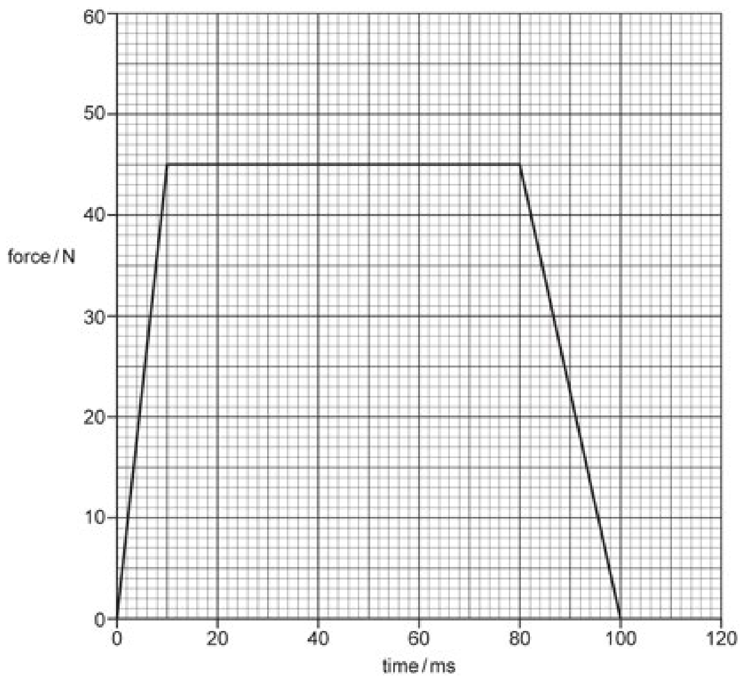
thrust ....N **[2]**

(d). The airship has a higher maximum speed at high altitudes, but also produces less thrust from the engine.

Explain these observations.

[2]

10. A tennis ball is hit with a racket. The graph shows the force the ball exerts on the racket.



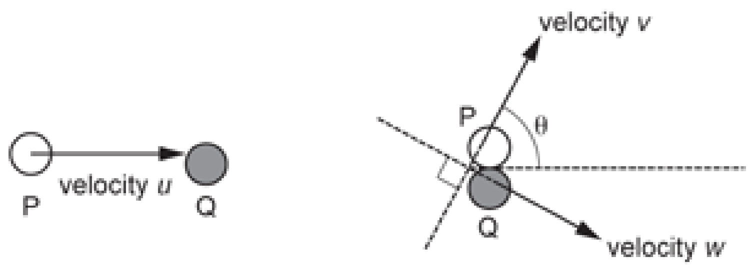
What is the magnitude of the change in momentum of the ball?

A 2.3 kg m s^{-1}
B 3.8 kg m s^{-1}
C 2300 kg m s^{-1}
D 3800 kg m s^{-1}

Your answer [1]

11. A particle P of mass *m* and moving at velocity *u* collides **elastically** with a stationary particle Q also of mass *m*.

After the collision particle P moves with velocity *v* at an acute angle θ to the direction of the original motion.
Particle Q moves in a perpendicular direction to P with velocity *w*.
The velocities *u*, *v* and *w* are constant.



Before collision After collision

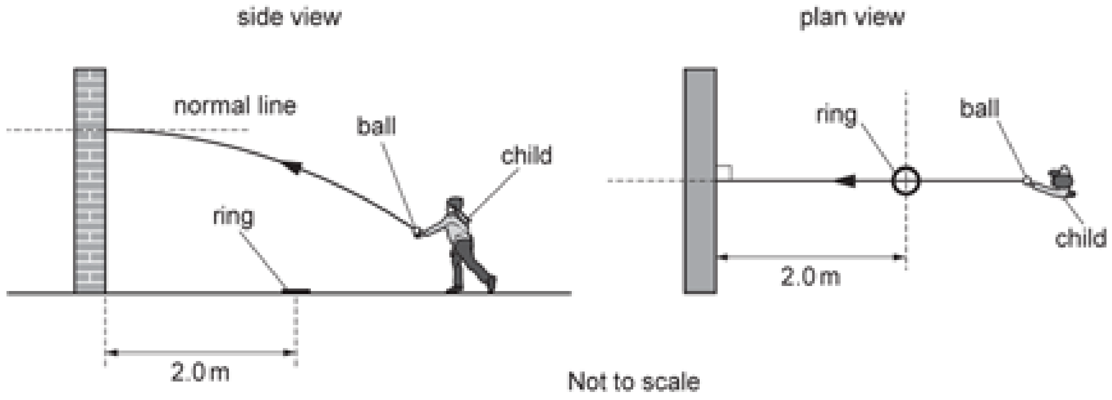
Which of the following equations is/are correct?

1. $u = w \cos \theta + v \cos \theta$
2. $w \cos \theta = v \sin \theta$
3. $u^2 = w^2 + v^2$

A 1 only
B 1 and 2
C 2 and 3
D 1, 2 and 3

Your answer [1]

12. In a game, a child throws a ball at a flat, vertical wall. The ball rebounds from the wall. The child wins the game if the ball lands within a circular ring placed on the ground.



The ring has a radius of 15 cm. The centre of the ring is 2.0 m from the wall. The child throws a ball with a mass of 0.058 kg towards the wall.

The ball is incident normally on the wall with a horizontal velocity of 7.2 m s^{-1}. The ball is in contact with the wall for 52 ms before rebounding normally with a horizontal velocity of 3.6 m s^{-1}.

Calculate the average magnitude of the force that the wall exerts on the ball.

force = ... N **[3]**

13. An object is in equilibrium.

Only two forces, **X** and **Y**, act on the object.

Which of the following statements must be correct?

1 **X** and **Y** are equal and opposite.
2 **X** and **Y** are a Newton's 3rd law force pair.
3 The object is at rest.

A Only 1
B 1 and 2
C 1 and 3
D 1, 2 and 3

Your answer ☐ **[1]**

14(a). A tent is secured by 3 ropes along each of its long sides, as shown in **Fig. 18. 1**.

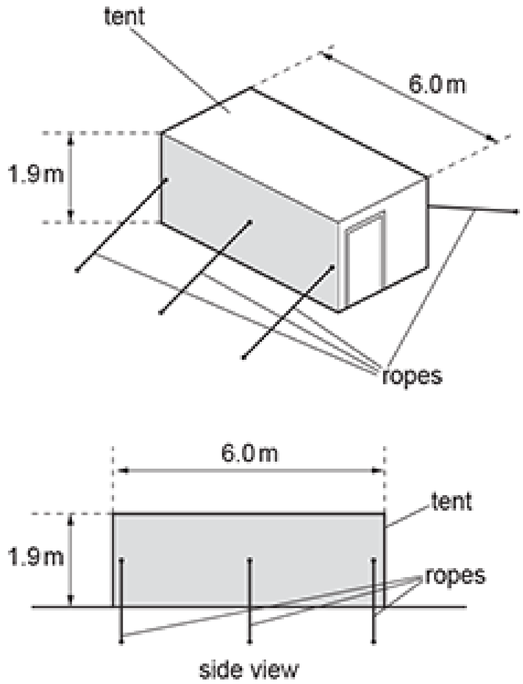


Fig. 18.1

Wind of speed 12 ms^{-1} blows at right angles to the **shaded** side of the tent for 3.0 s. The density of air is 1.2 kg m^{-3}.

i. Show that the mass of air which hits the tent in this time is about 490 kg.

[3]

ii. All of the air incident on the shaded side of the tent is deflected at 90° to the original direction as shown in **Fig. 18. 2**.

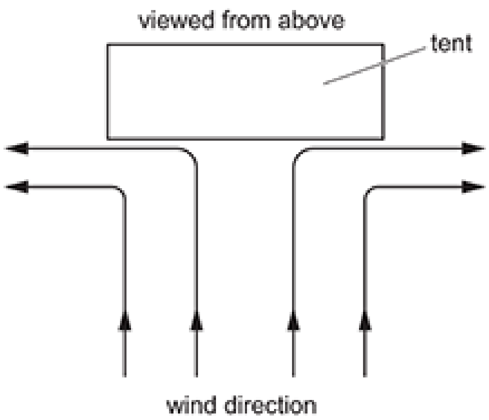


Fig. 18.2

Use the information given in **(a)(i)** to calculate the magnitude of the force *F* exerted by the wind on the shaded side of the tent.

F = ... N **[2]**

(b). *When the wind speed exceeds 20 ms^{-1} the ropes securing the tent break.

Describe, and explain in terms of forces, how the ropes and the shape of the tent could be modified to withstand wind speed exceeding 40 ms^{-1}.

[6]

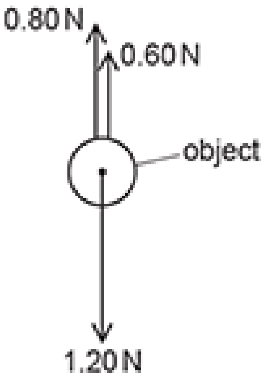
15. A student has plotted a velocity against time graph for a trolley moving down a ramp.

Which of the following pair of quantities can be determined from the gradient of the graph and the area under the graph?

A acceleration, displacement
B acceleration, impulse
C displacement, kinetic energy
D force, work done

Your answer [ ] **[1]**

16. The diagram below shows the directions and magnitudes of the three forces acting on an object at a specific time as it moves through water.



The weight of the object is 1.20 N, the upthrust on the object is 0.80 N and the drag is 0.60 N.

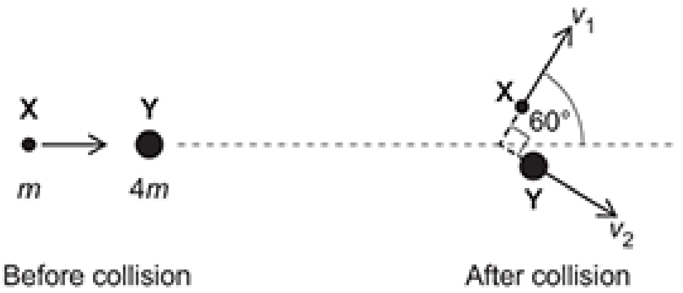
Which statement is correct about this object at this specific time?

A It has reached its terminal velocity.
B It is accelerating.
C It is decelerating.
D It is moving upwards.

Your answer [ ] **[1]**

17. A particle **X** of mass m collides with a stationary particle **Y** of mass $4m$.

Immediately after the collision the particle **X** is moving at velocity v_1 at an angle of 60° to its original direction and the particle **Y** is moving with velocity v_2 at 90° to the velocity of particle **X**.



What is the value of the ratio $\frac{v_1}{v_2}$?

A 2.3
B 3.9
C 4.0
D 6.9

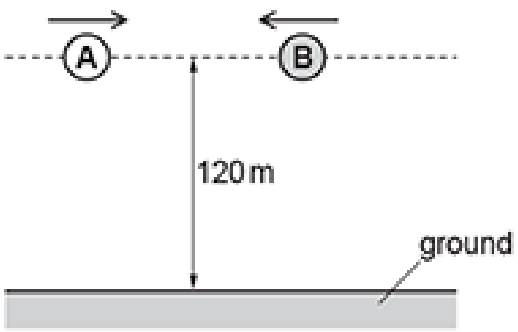
Your answer ☐ **[1]**

18. Which pair of quantities do **not** have the same, or equivalent, units?

A acceleration, gravitational field strength
B angular frequency, angular velocity
C gravitational potential, kinetic energy
D impulse, momentum

Your answer ☐ **[1]**

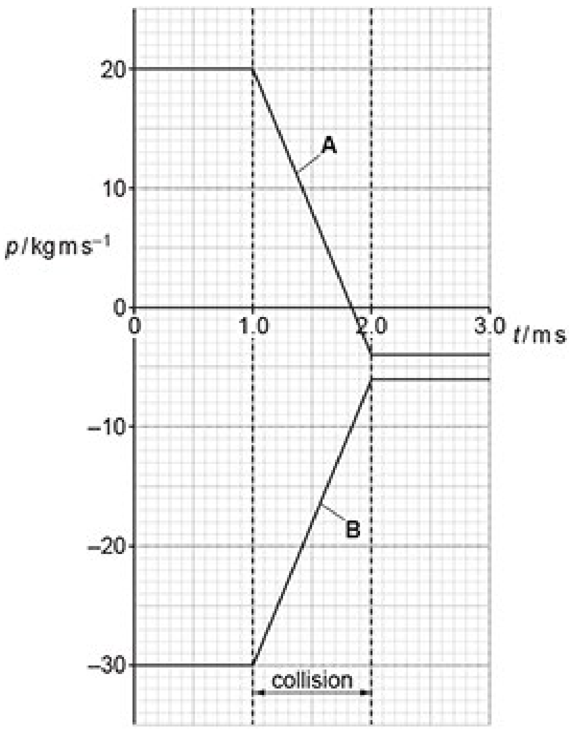
19(a). Two objects **A** and **B** are travelling horizontally and in opposite directions. The objects collide in mid-air at a height of 120 m above the horizontal ground, as shown below.



The mass of **A** is 2.0 kg and the mass of **B** is 3.0 kg.

After the collision the objects are joined together.

The momentum *p* against time *t* graphs for each object before, during and after the collision are shown below.



Explain how the graphs demonstrate Newton's third law during the collision.

[2]

(b). Use the graphs to show that momentum is conserved in the collision.

[2]

(c). Calculate the magnitude of the horizontal velocity *v* of the combined objects immediately after the collision.

v = ... m s^{-1} **[2]**

(d). Air resistance has negligible effect on the motion of the objects.

Calculate the time taken for the combined objects to reach the ground after the collision.

time taken = ... s **[3]**

END OF QUESTION PAPER