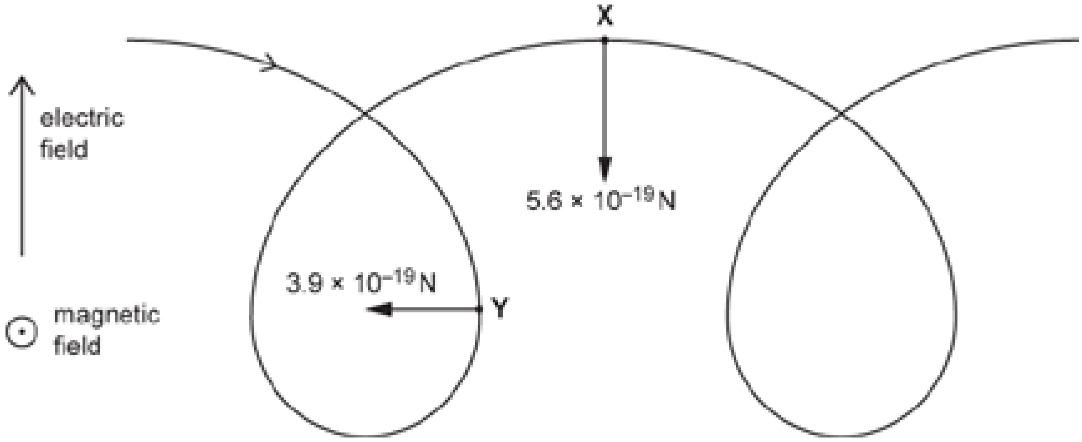
1(a). The figure below shows the path of a proton moving in a region occupied by both an electric field and a magnetic field.

The direction of the electric field lines is perpendicular to the direction of the magnetic field lines.



The uniform electric field is directed upwards, with electric field strength E = 0.90 N C^{-1}.

The uniform magnetic field is directed out of the plane of the paper, with magnetic flux density B = 5.0 × 10^{-5} T.

At point **X** the proton is moving horizontally to the right. The magnitude of the **magnetic** force at **X** is 5.6 × 10^{-19} N.

At point **Y** the proton is moving vertically downwards. The magnitude of the **magnetic** force at **Y** is 3.9 × 10^{-19} N.

The **electric** forces acting on the proton at **X** and **Y** are **not** shown in the figure.

Show that the magnitude of the constant **electric** force acting on the proton is about 10^{-19} N.

[1]

(b).

i. Suggest why the **magnetic** force acting on the proton has a different magnitude at **X** than at **Y**.

____

____

[1]

ii. At **X**, the motion of the proton is instantaneously equivalent to motion in a circle at a constant speed.

Calculate the radius of this circular motion.

radius = ... m **[4]**

iii. **1** Calculate the magnitude of the resultant force on the proton at **Y**.

resultant force = ... N **[2]**

2 Explain why the motion of the proton at **Y** is **not** instantaneously equivalent to motion in a circle at a constant speed.

[2]

2(a). A satellite of mass *m* is in a circular orbit around a planet of mass *M*. The radius of the orbit from the centre of the planet is *r*.

The gravitational potential V_g at a point a distance *r* from the centre of the planet is given by the equation

$$V_g = -\frac{GM}{r}.$$

i. By considering the cause of the centripetal force on the satellite, show that the kinetic energy of the satellite is equal to half the magnitude of its gravitational potential energy.

[2]

ii. A tiny satellite of mass 1.0 kg is to be launched from rest from the surface of the Earth into a low Earth orbit. The gravitational potential at any point in this orbit is −56 MJ k^{-1}.

The value of the gravitational potential at the Earth's surface is −63 MJ kg^{-1}.

Show that the satellite must gain more than 30 MJ of **total** energy to achieve and remain in orbit.

[2]

(b). Large satellites are often launched by rockets from sites near the equator. The rotation of the Earth increases the initial kinetic energy of the rocket and satellite.

A new strategy is to launch using a smaller rocket from a high flying aircraft.

Using the information in part (ii) of the previous question and the data below, evaluate the advantages and limitations of this strategy. Use calculations to support your evaluation

Rotational speed at the equator	460 m s^{-1}

Typical aircraft operating altitude	10,000 m
Aircraft cruise velocity (relative to the ground)	230 m s^{-1}

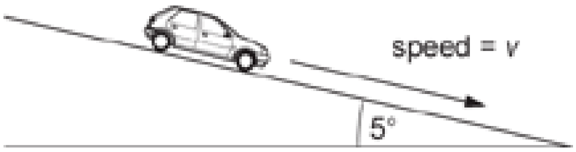
[6]

3(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

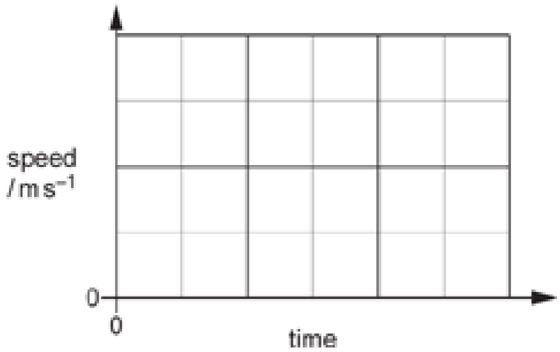
$F = kv^2$

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]

4. 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]

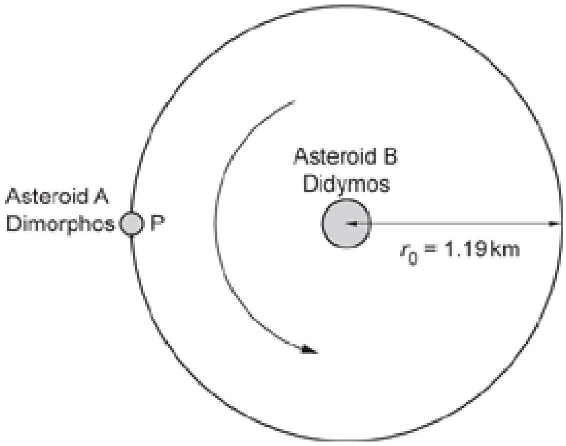
ii. Explain how the airflow around the model produces a force on the model.

[2]

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

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

5. In space, Asteroid A, called Dimorphos travels at constant speed in a circle around a larger Asteroid B, called Didymos. The diagram shows Asteroid A at position P.



The distance r_0 between Asteroid A and Asteroid B is 1.19 km.
The time T_0 for Asteroid A to travel once around Asteroid B is 4.29×10^4 s (11 hours 55 minutes).

Explain **one** similarity and **one** difference between the velocity of Asteroid A at P and its velocity six hours later.

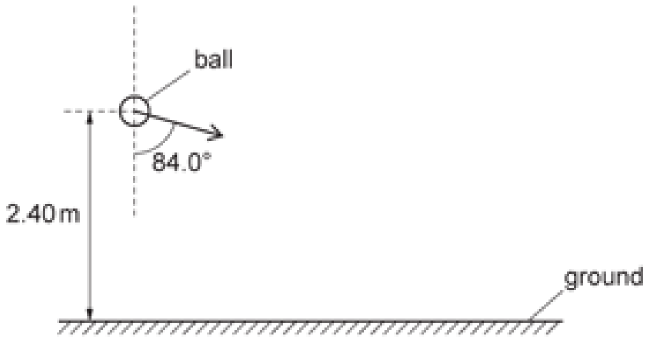
similarity ____________________

____

difference ____________________

____________________ **[2]**

6(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]

7. The figure below shows a stationary glider of mass *m* on an air track.

The glider has identical springs with force constant *k* attached to each end which are secured to fixed posts.

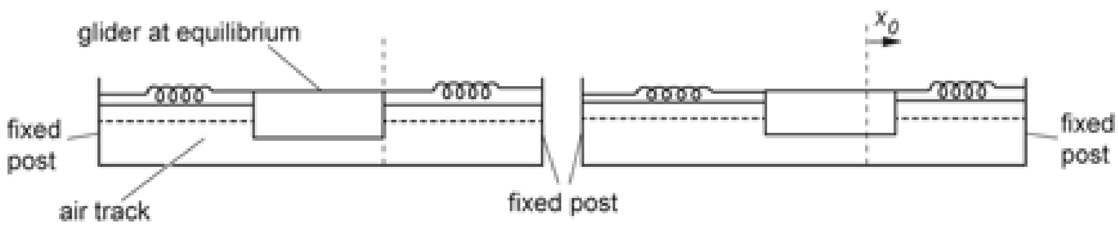
The air track blower is turned on and the glider is displaced a small distance x_0 , as seen in the figure. It is then released.

The glider moves horizontally in simple harmonic motion.

The springs remain in tension throughout the motion.

The time taken for 20 complete oscillations is measured, and the period *T* calculated.

Fig. 21.1 Fig. 21.2



The relationship between the period *T*, the mass of the glider *m* and the force constant *k* is described by the equation $T^2 = \frac{2\pi^2 m}{k}$.

i. Show that the equation above is homogeneous by reducing the equation to SI base units.

[2]

ii. Explain why the magnitude of the resultant force *F* on the glider is given by *F* = 2*kx* where *x* is the displacement at any time.

[2]

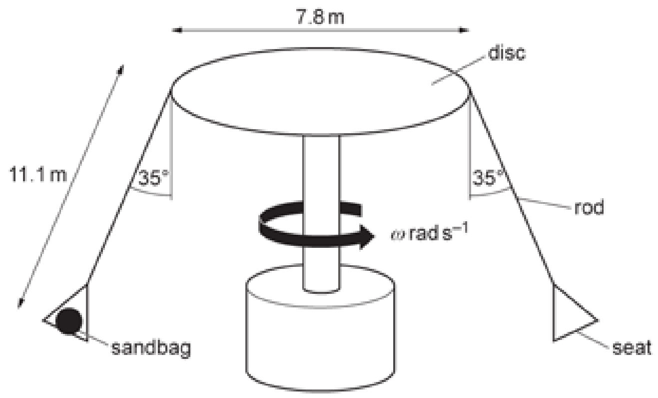
iii. State and explain the effect, if any, of increasing the initial displacement on the period of the subsequent motion.

[2]

8(a). The diagram below shows a fairground ride. Each rider is secured in a seat suspended by a rod.

The distance from the top of the rod to the base of the seat is 11.1 m.

The rod is attached to the edge of a disc of diameter 7.8 m.



(not to scale)

To test the equipment a sandbag is attached to the seat and the ride is started.

The combined mass of the seat and the sandbag is 12 kg.

The rod makes an angle of 35° with the vertical.

i. Draw an arrow labelled T on the diagram to represent the tension in the rod.

[1]

ii. Show that the radius of the circular path followed by the sandbag is about 10 m.

[2]

iii. Calculate the tension *T* in the rod.

T = ...N **[3]**

iv. Show that the angular velocity of the ride is about 0.8 radians per second.

[2]

(b). When the seat is at its highest point the sandbag is 17 m above the ground. The sandbag is released from the seat to model an object being dropped by a rider.

i. Calculate *t*, the time taken for the sandbag to reach the ground.

t = ... s **[2]**

ii. Using your answer to **(a)(iv)**, determine the horizontal displacement *s* travelled by the sandbag before hitting the ground.

s = ...m **[3]**

iii. Determine, with reasons, the effect on the horizontal displacement travelled if the object released from the ride was a shoe from a rider.

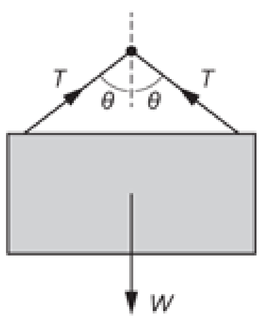
[3]

9. Which row contains **only** scalar quantities?

A Absolute temperature, displacement, moment
B Acceleration, force, momentum
C Gravitational potential, kinetic energy, mass
D Kinetic energy, mass, momentum

Your answer [1]

10. A cable is used to hang a picture from a nail. The diagram shows all the forces acting on the picture. *T* is the tension in the cable and *W* is the weight of the picture.

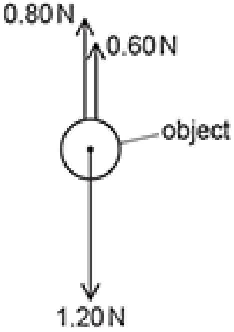


Which is the correct expression for *W*?

A $W = T\cos\theta$
B $W = 2T\cos\theta$
C $W = T\sin\theta$
D $W = 2T\sin\theta$

Your answer [1]

11. 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.



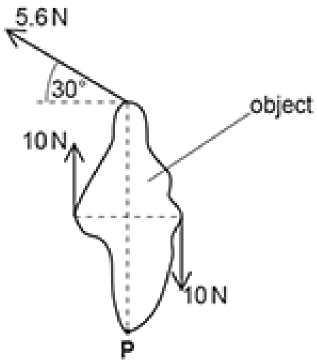
The weight of the object is 1.20 N, the upthrust on the object is 0.80 N and the drag is 0.60 N.

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.

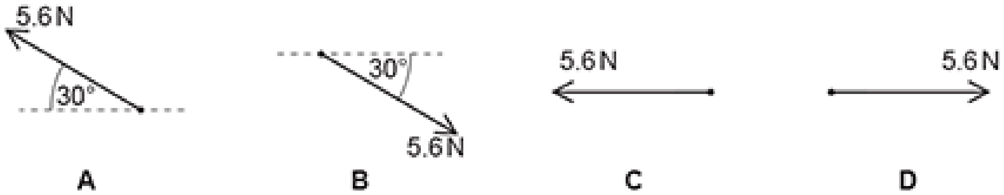
Your answer ☐ **[1]**

12. The object below is in equilibrium.



A force, not shown on the diagram, also acts on the object at point **P**.

Which of the following shows the correct direction and magnitude of the force acting at point **P**?



Your answer ☐ **[1]**

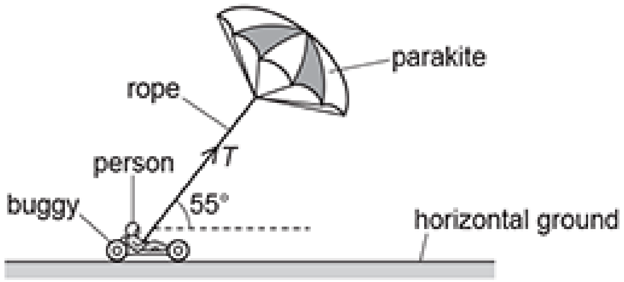
13. A student has constructed the table below of possible scalar and vector quantities.

	Scalar	Vector
A	acceleration	momentum
B	displacement	amplitude
C	frequency	wavelength
D	mass	centripetal force

Which row is correct?

Your answer ☐ **[1]**

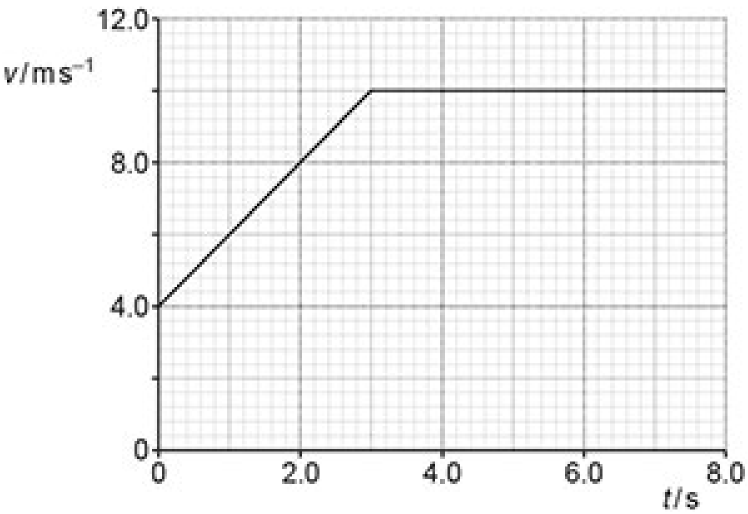
14. A person in a buggy is attached to a large parakite by a rope, as shown below.



Strong wind acting on the parakite moves the buggy along horizontal ground.

The rope makes an angle of 55° to the horizontal. The total mass of the buggy and person is 150 kg.

The velocity *v* against time *t* graph for the buggy is shown below.



At *t* = 1.0 s the buggy is accelerating.

i. Use the graph to show that the acceleration of the person at *t* = 1.0 s is 2.0 m s^{-2}.

[1]

ii. At t = 1.0 s the tension T in the rope is 680 N and the total **horizontal** resistance acting on the buggy and person is R.

Calculate R by resolving the tension in the rope horizontally.

R = ... N **[3]**

15(a).

A ball of mass 0.16 kg is dropped from rest from a height of 2.5 m above the ground.

Assume air resistance is negligible.

Calculate

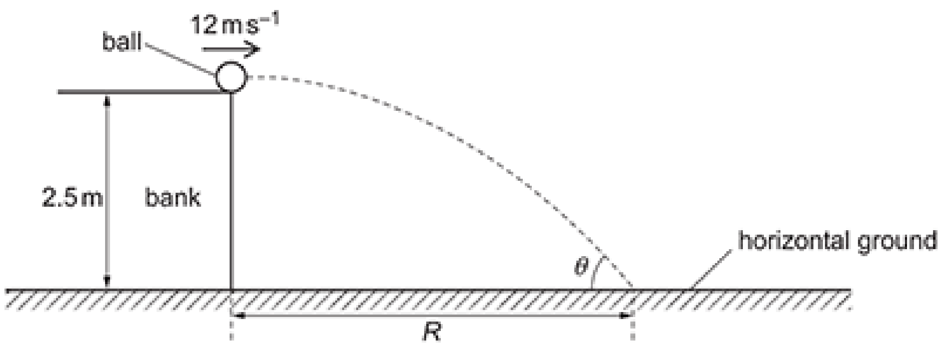
i. the change in gravitational energy E_p

E_p = ... J **[1]**

ii. the velocity v of the ball as it reaches the ground.

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

(b). The ball from **(a)** is now fired horizontally with a speed of 12 ms^{-1} from a bank.
The height of the bank is 2.5 m.
The time for the ball to travel from the edge of the bank to the horizontal ground is 0.71 s.
The path of the ball is shown in the diagram.
The ball hits the horizontal ground a distance R from the bottom of the bank.
Assume air resistance is negligible.



Calculate

i. *R*

R = ... m **[1]**

ii. the kinetic energy E_k of the ball as it reaches the ground

E_k = ... J **[2]**

iii. the angle θ between the ground and the direction of the ball as it reaches the ground.

θ = ... ° **[1]**

END OF QUESTION PAPER