Question 1

1. The following is part of a student's report on an experiment to verify the principle of conservation of momentum.

> "I ensured that no net external forces acted on body A or body B. When I released body A it was moving at a constant velocity; body B was at rest. I allowed body A to collide with body B and they moved off together after the collision."

The following data was recorded:

Mass of body A	= 325.1 g
Mass of body B	= 349.8 g
Velocity of body A before the collision	= 0.84 m s^{-1}
Velocity of bodies A and B after the collision	= 0.41 m s^{-1}

Draw a labelled diagram of the apparatus used in the experiment.

State what measurements the student took and how these measurements were used to calculate the velocities. (21)

Using the recorded data, show how the experiment verifies the principle of conservation of momentum. (9)

When carrying out this experiment the student ensures that there is no net external force acting on the bodies.

What are the two forces that the student needs to take account of to ensure this?

Describe how the student reduced the effects of these forces. (10)

Question 2

6. Compare vector and scalar quantities.
Give one example of each. (8)

Describe an experiment to find the resultant of two vectors. (9)

A golfer pulls his trolley and bag along a level path. He applies a force of 277 N at an angle of 24.53° to the horizontal. The weight of the trolley and bag together is 115 N and the force of friction is 252 N.

Calculate the net force acting on the trolley and bag. (9)

What does the net force tell you about the golfer's motion? (3)

Use Newton's second law of motion to derive an equation relating force, mass and acceleration. (9)

A force of 5.3 kN is applied to a golf ball by a club. The mass of the ball is 45 g and the ball and club are in contact for 0.54 ms.

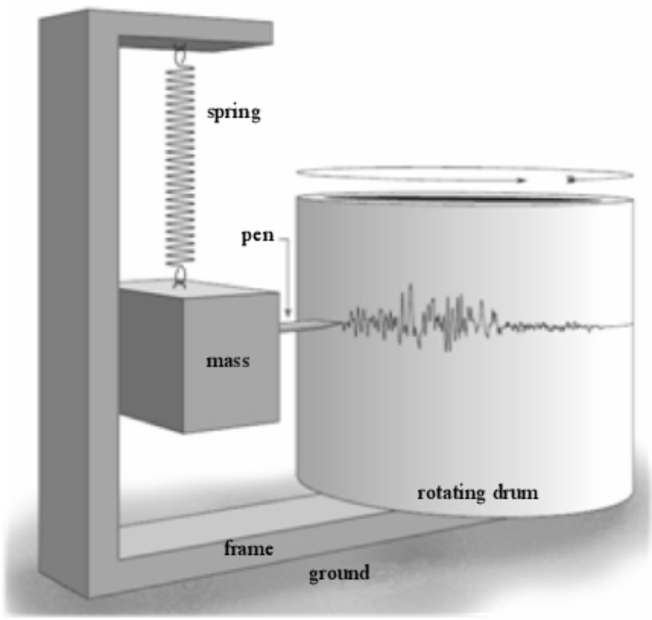
Calculate the speed of the ball as it leaves the club. (9)

The ball leaves the club head at an angle of 15° to the horizontal. Calculate the maximum height reached by the ball. Ignore the effect of air resistance. (9)

(acceleration due to gravity, $g = 9.8\ \mathrm{m\ s^{-2}}$)

Question 3

11. Read the following passage and answer the accompanying questions.



A seismometer consists of a sensor that detects ground motion, attached to a recording system. A seismometer that is sensitive to up-down motions of the ground, as caused by an earthquake, can be understood by visualising a mass hanging on a spring as shown in the diagram. The frame and the drum move up and down as the seismic wave passes by, but the mass remains stationary.

If a recording system is installed, such as a rotating drum attached to the frame and a pen attached to the mass, this relative motion between the suspended mass and the ground can be recorded to produce a seismogram, as shown in the diagram.

Modern seismometers do not use a pen and drum. The relative motion between a magnet that is attached to the mass, and the frame, generates a potential difference that is recorded by a computer.

(Adapted from *www.iris.edu Education and Outreach Series No.7: How does a Seismometer Work?*)

(*a*) Seismic waves can be longitudinal or transverse. What is the main difference between them?

(*b*) An earthquake generates a seismic wave that takes 27 seconds to reach a recording station. If the wave travels at 5 km s^{-1} along the earth's surface, how far is the station from the centre of the earthquake?

(*c*) Draw a diagram to show the forces acting on the suspended mass when the seismometer is at rest.

(*d*) At rest, the tension in the spring is 49 N. What is the value, in kilograms, of the suspended mass?

(*e*) What type of motion does the frame have when it moves relative to the mass?

(*f*) During an earthquake the ground was observed at the recording station to move up and down as the seismic wave generated by the earthquake passed. Give an equation for the acceleration of the ground in terms of the periodic time of the wave motion and the displacement of the ground.

(*g*) If the period of the ground motion was recorded as 17 seconds and its amplitude was recorded as 0.8 cm, calculate the maximum ground acceleration at the recording station.

(*h*) In some modern seismometers a magnet is attached to the mass and a coil of wire is attached to the frame. During an earthquake, there is relative motion between the magnet and the coil. Explain why an emf is generated in the coil.

(acceleration due to gravity, $g = 9.8$ m s^{-2}) (8 × 7)

Question 4

1. A student carried out an experiment to verify the principle of conservation of momentum. The student adjusted the apparatus till a body **A** was moving at a constant velocity u. It was then allowed to collide with a second body **B**, which was initially at rest, and the two bodies moved off together with a common velocity v.

The following data were recorded:

mass of body **A** .... = 230 g
mass of body **B** .... = 160 g
velocity u .... = 0.53 m s^{-1}
velocity v .... = 0.32 m s^{-1}

Draw a labelled diagram of the apparatus used in the experiment.

What adjustments did the student make to the apparatus so that body **A** would move at constant velocity? (15)

How did the student know that body **A** was moving at constant velocity?

Describe how the student measured the velocity v of the bodies after the collision. (15)

Using the recorded data, show how the experiment verifies the principle of conservation of momentum.

How could the accuracy of the experiment be improved? (10)

Question 5

6. (*a*) Define the moment of a force.

A toy, such as that shown, has a heavy hemispherical base and its centre of gravity is located at **C**. When the toy is knocked over, it always returns to the upright position. Explain why this happens. (12)

(*b*) State the conditions necessary for the equilibrium of a body under a set of co-planar forces. (9)

Three children position themselves on a uniform see-saw so that it is horizontal and in equilibrium. The fulcrum of the see-saw is at its centre of gravity. A child of mass 30 kg sits 1.8 m to the left of the fulcrum and another child of mass 40 kg sits 0.8 m to the right of the fulcrum.

Where should the third child of mass 45 kg sit, in order to balance the see-saw? (12)

(*c*) A simple merry-go-round consists of a flat disc that is rotated horizontally. A child of mass 32 kg stands at the edge of the merry-go-round, 2.2 metres from its centre. The force of friction acting on the child is 50 N.

Draw a diagram showing the forces acting on the child as the merry-go-round rotates.

What is the maximum angular velocity of the merry-go-round so that the child will not fall from it, as it rotates? (18)

If there was no force of friction between the child and the merry-go-round, in what direction would the child move as the merry-go-round starts to rotate? (5)

Question 6

6. On 16 August, 1960, Joseph Kittinger established a record for the highest altitude parachute jump. This record remains unbroken.
Kittinger jumped from a height of 31 km. He fell for 13 seconds and then his 1.8-metre canopy parachute opened. This stabilised his fall. Only four minutes and 36 seconds more were needed to bring him down to 5 km, where his 8.5-metre parachute opened, allowing him to fall at constant velocity, until he reached the surface of the earth.

(Adapted from *http://www.centennialofflight.gov*)

Automatic camera recording of Kittinger as he jumped.

(i) Calculate the acceleration due to gravity at a height of 31 km above the surface of the earth. (12)

(ii) What was the downward force exerted on Kittinger and his equipment at 31 km, taking their total mass to be 180 kg? (6)

(iii) Estimate how far he fell during the first 13 seconds.
What assumptions did you take in this calculation? (12)

(iv) What was his average speed during the next 4 minutes and 36 seconds? (9)

(v) Assuming that the atmospheric pressure remains constant, how much was the force on a hemispherical parachute of diameter 8.5 m greater than that on a similar parachute of diameter 1.8 m? (9)

(vi) Calculate the upthrust that acted on Kittinger when he reached constant velocity in the last stage of his descent (assume $g = 9.81$ m s^{-2} during this stage). (8)

(radius of earth $= 6.36 \times 10^6$ m; mass of earth $= 5.97 \times 10^{24}$ kg)

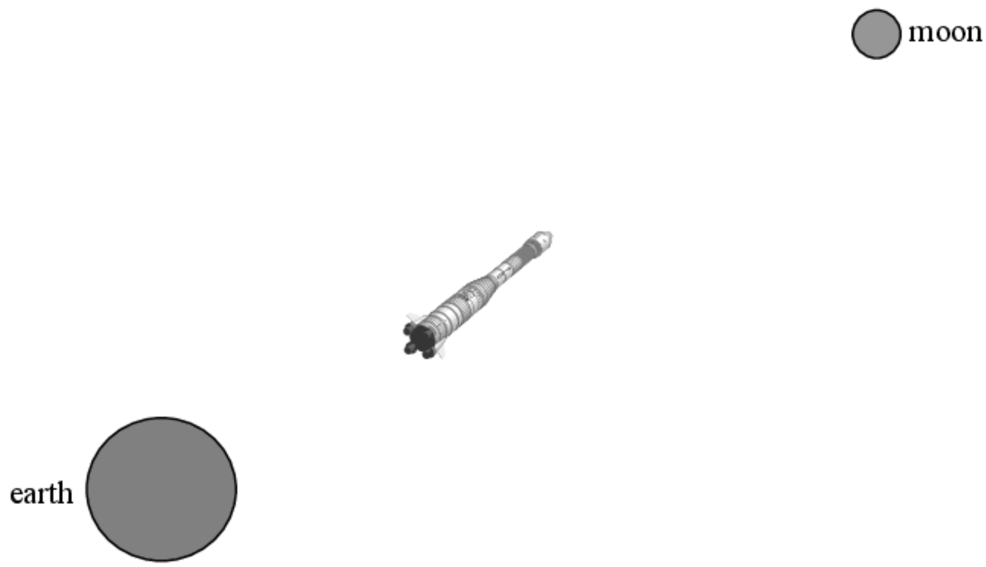
Question 7

(*b*) State the law of conservation of momentum.

Question 8

6. State Newton's law of universal gravitation.

Use this law to calculate the acceleration due to gravity at a height above the surface of the earth, which is twice the radius of the earth. (18)



A spacecraft carrying astronauts is on a straight line flight from the earth to the moon and after a while its engines are turned off.

(i) Explain why the spacecraft continues on its journey to the moon, even though the engines are turned off. (6)

(ii) Describe the variation in the weight of the astronauts as they travel to the moon. (6)

(iii) At what height above the earth's surface will the astronauts experience weightlessness? (12)

(iv) The moon orbits the earth every 27.3 days.
What is its velocity, expressed in metres per second? (9)

(v) Why is there no atmosphere on the moon? (5)

(Radius of the earth = 6.36×10^6 m
Acceleration due to gravity at the earth's surface = 9.81 m s^{-2}
Distance from the centre of the earth to the centre of the moon =3.84×10^8 m
Assume the mass of the earth is 81 times the mass of the moon.)

Question 9

(a) What is friction? (6)

A car of mass 750 kg is travelling east on a level road. Its engine exerts a constant force of 2.0 kN causing the car to accelerate at 1.2 m s^{-2} until it reaches a speed of 25 m s^{-1}.

Calculate (i) the net force, (ii) the force of friction, acting on the car. (12)

If the engine is then turned off, calculate how far the car will travel before coming to rest. (10)

Question 10

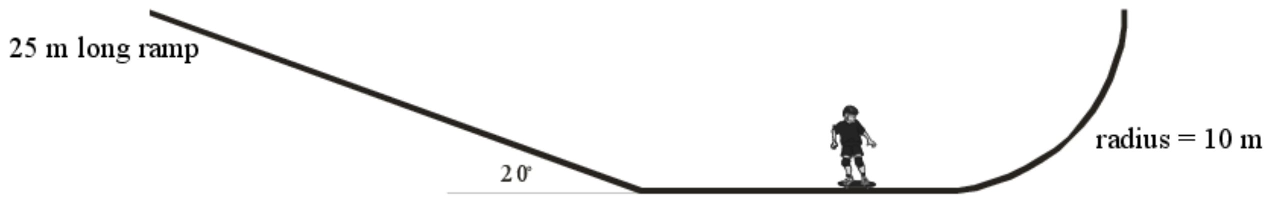
(a) State Newton's third law of motion. (7)

Question 11

6. State Newton's laws of motion. (12)

Show that $F = ma$ is a special case of Newton's second law. (10)

A skateboarder with a total mass of 70 kg starts from rest at the top of a ramp and accelerates down it. The ramp is 25 m long and is at an angle of 20° to the horizontal. The skateboarder has a velocity of 12.2 m s^{-1} at the bottom of the ramp.



Calculate

(i) the average acceleration of the skateboarder on the ramp.
(ii) the component of the skateboarder's weight that is parallel to the ramp.
(iii) the force of friction acting on the skateboarder on the ramp. (18)

The skateboarder then maintains a speed of 10.5 m s^{-1} until he enters a circular ramp of radius 10 m.
What is the initial centripetal force acting on him?
What is the maximum height that the skateboarder can reach? (12)

Sketch a velocity-time graph to illustrate his motion. (4)

(acceleration due to gravity = 9.8 m s^{-2})

Question 12

1. In an experiment to verify the principle of conservation of momentum, a body A was set in motion with a constant velocity. It was then allowed to collide with a second body B, which was initially at rest and the bodies moved off together at constant velocity.
The following data was recorded.

Mass of body A = 520.1 g

Mass of body B = 490.0 g

Distance travelled by A for 0.2 s before the collision = 10.1 cm

Distance travelled by A and B together for 0.2 s after the collision = 5.1 cm

Draw a diagram of the apparatus used in the experiment. (9)

Describe how the time interval of 0.2 s was measured. (6)

Using the data,

- calculate the velocity of the body A (i) before, (ii) after, the collision;
- show how the experiment verifies the principle of conservation of momentum. (18)

How were the effects of friction and gravity minimised in the experiment? (7)