IB · DP · Physics

3 hours · 15 questions

Structured Questions

2.2 Forces

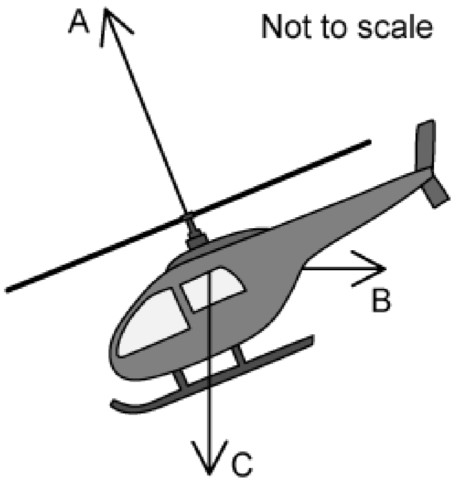
2.2.1 Free-Body Diagrams / 2.2.2 Newton's First Law / 2.2.3 Newton's Second Law / 2.2.4 Newton's Third Law / 2.2.5 Applying Newton's Laws of Motion / 2.2.6 Friction

Easy (5 questions)	/45
Medium (5 questions)	/52
Hard (5 questions)	/57
Total Marks	**/154**

Scan here to return to the course
or visit savemyexams.com

Easy Questions

1 (a) The helicopter below is moving horizontally through still air. The lift force from the helicopter's blades is labelled **A**.



Identify the two forces **B** and **C** that also act on the helicopter.

....

....

(2 marks)

(b) The force **B** has a value of 25 kN and acts horizontally and at right angles to the weight **C**.

Calculate the horizontal component of force **A** needed to keep the helicopter moving at a constant velocity.

....

(1 mark)

(c) The helicopter encounters a problem and accelerates vertically downwards towards the ground. It has a mass of 50 000 kg. Air resistance is negligible.

Calculate the weight of the helicopter.

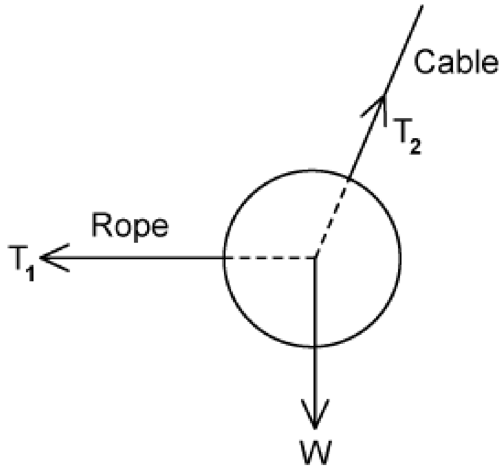
....

(2 marks)

(d) State the name of the law of motion that relates to the equation $F = ma$.

(1 mark)

2 (a) The diagram below shows a ball suspended from a cable. The ball is pulled into the position shown by a rope that is kept horizontal.



In this position, the ball is in equilibrium.

State the force and component that balance:

(i) The force of the rope on the ball

[1]

(ii) The weight of the ball

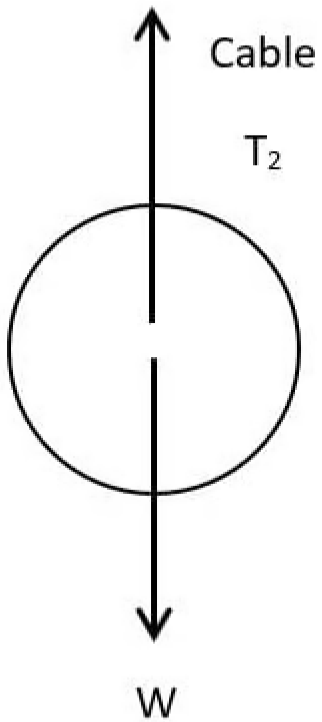
[1]

....

....

(2 marks)

(b) The ball is then detached from the rope, so it is hanging only by the cable. The mass of the ball is 350 kg.



Calculate the new tension in the cable.

....

....

(2 marks)

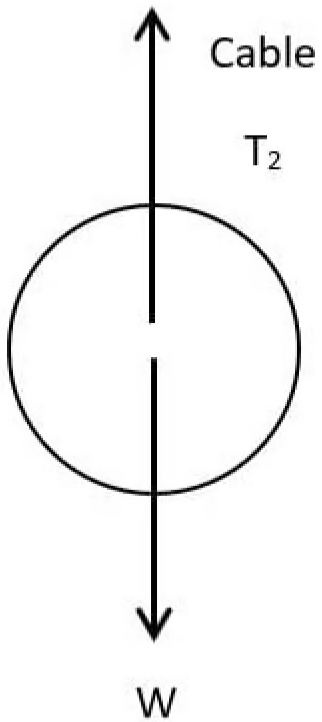
(c) The ball is stationary when hanging from the string.

Define translational equilibrium.

....

(1 mark)

(d) The ball remains hanging and does not fall to the ground.



State, in relation to this situation:

(i) Newton's first law: [1]

(ii) Newton's second law: [1]

(iii) The relationship between tension and weight: [1]

(iv) The behaviour of the ball if the weight was bigger: [2]

....

....

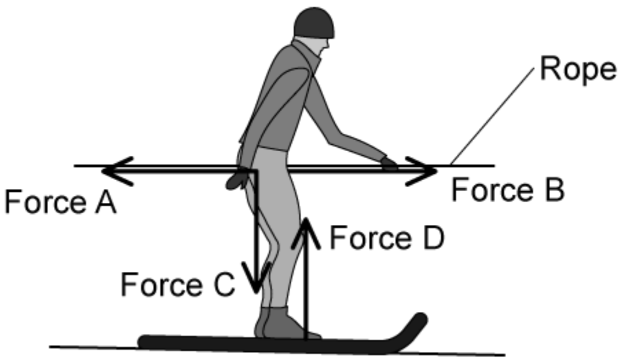
....

....

....

(5 marks)

3 (a) The diagram below shows a skier being towed at a constant speed whilst sinking into the snow.



State the name of each of the forces A - D acting on the skier.

....

....

....

....

(4 marks)

(b) Place a tick (✓) next to the correct statements in the table below:

Force D > Force C	
Force C > Force D	
Force B > Force A	
Force A = Force B	

....

....

(2 marks)

(c) The skier is pulled off the snow onto an area of grass and becomes stuck.

State the type of friction present between the bottom of the skis and the grass when she is stationary.

....

(1 mark)

(d) The mass of the skier is 52 kg and the coefficient of friction between the skis and the grass is 0.12.

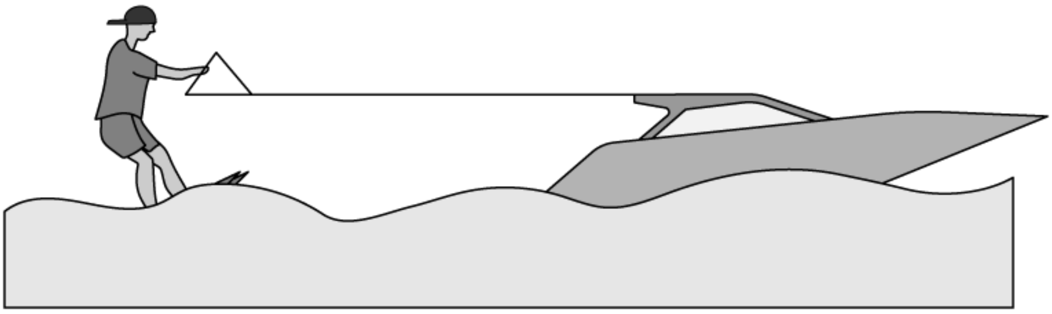
Calculate the minimum force needed from the rope to get the skier just on the point of moving again.

....

....

(2 marks)

4 (a) A remote-controlled boat has a mass of 6 kg and is accelerating with a resultant force of 1.95 N.



Draw a free body diagram showing and labelling the forces acting on the boat.

....

....

....

....

....

(5 marks)

(b) Calculate the acceleration on the boat.

....

....

....

(3 marks)

(c) The boat's velocity changes so that it is travelling at constant speed.

Place a tick (✓) next to the statement or statements that are correct about the motion of the boat.

The sum of the tension, friction and air resistance is larger than the forward force	
The sum of the tension, friction and air resistance is equal to the forward force	
The upthrust is larger than the weight of the boat	
The upthrust is equal to the weight of the boat	

....

....

(2 marks)

(d) After 1.8 s the motor is switched off and the boat decelerates uniformly until it stops. The deceleration of the boat is 0.80 m s^{-2}.

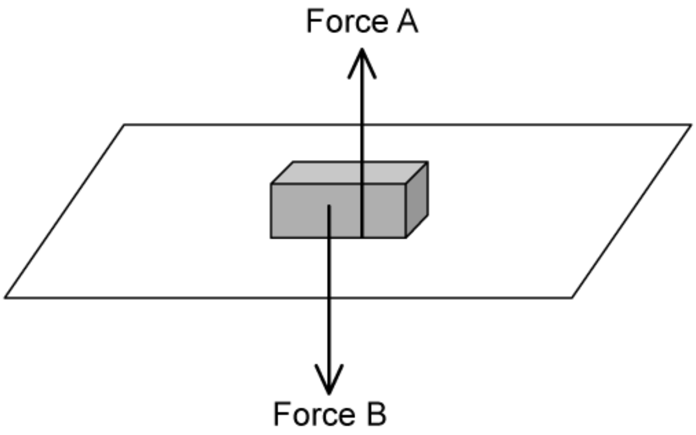
The resistive forces, air resistance, tension and friction are the only forces acting on the boat once the motor is switched off. Calculate the magnitude of these forces.

....

....

(2 marks)

5 (a) A wooden block is resting on a table as shown.



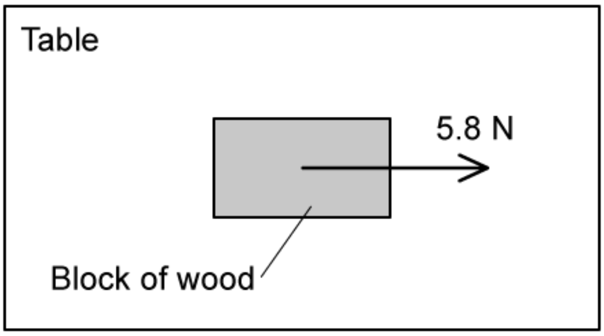
Name the forces **A** and **B** acting on the block.

....

....

(2 marks)

(b) A force of 5.8 N is applied to the block to move it along the table at a constant speed.



Identify the type of friction now present between the block and the table.

....

(1 mark)

(c) State the magnitude of the frictional force on the block.

....

(1 mark)

(d) The block has a mass of 1.5 kg.

Calculate the magnitude of the dynamic coefficient of friction between the block and the table.

....

....

....

....

(4 marks)

Medium Questions

1 Curling is a game played on a horizontal surface of ice. A player pushes a large smooth stone across the ice for several seconds and then releases it.

A 23.1 N force and 3.53 N force act on a stone of mass 19 kg at the same time.

Calculate the magnitude of the maximum and minimum acceleration that can be experienced by the stone.

....

....

(2 marks)

2 (a) Ric is standing in an elevator and has a mass of 68 kg. The elevator is moving upwards at a speed of 2.5 m s^{-1} and comes to rest 3.0 s later.

Calculate the reaction force on Ric from the elevator floor during the time it takes the elevator to come to rest.

(4 marks)

(b) Ric realises that he forgot his lab coat on the floor below. He again travels in the elevator which goes downwards at the same speed, coming to rest in the same time.

Calculate the reaction force on Ric from the elevator floor during the time it takes to come to rest at the floor below.

(3 marks)

(c) Hence, deduce which deceleration period of the elevator would make Ric feel:

(i) Lighter
(ii) Heavier

(2 marks)

(d) In a serious stroke of bad luck, the elevator cable snaps and it falls freely. Ric experiences a sense of weightlessness.

Explain, using appropriate laws of motion, why Ric feels a sense of weightlessness in this situation.

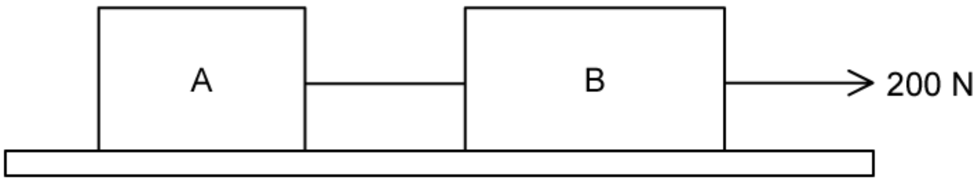
....

....

....

(3 marks)

3 (a) Two blocks A and B are joined by a string and rest on a frictionless horizontal table. A force of 200N is applied horizontally on block B.



Draw free–body diagrams for both boxes.

....

....

....

(3 marks)

(b) Block A has a mass of 3.0 kg and block B has a mass of 7.0 kg.

Calculate the acceleration of each block and the tension in the string.

....

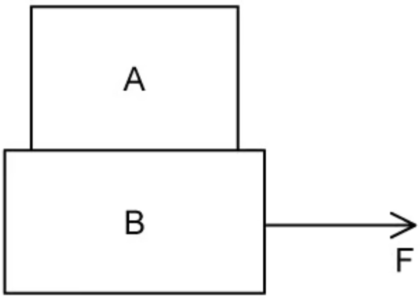
....

....

....

(4 marks)

(c) Block A is now placed on top of block B. The coefficient of static friction between the two blocks is 0.31. The bottom block is pulled with a horizontal force *F*.



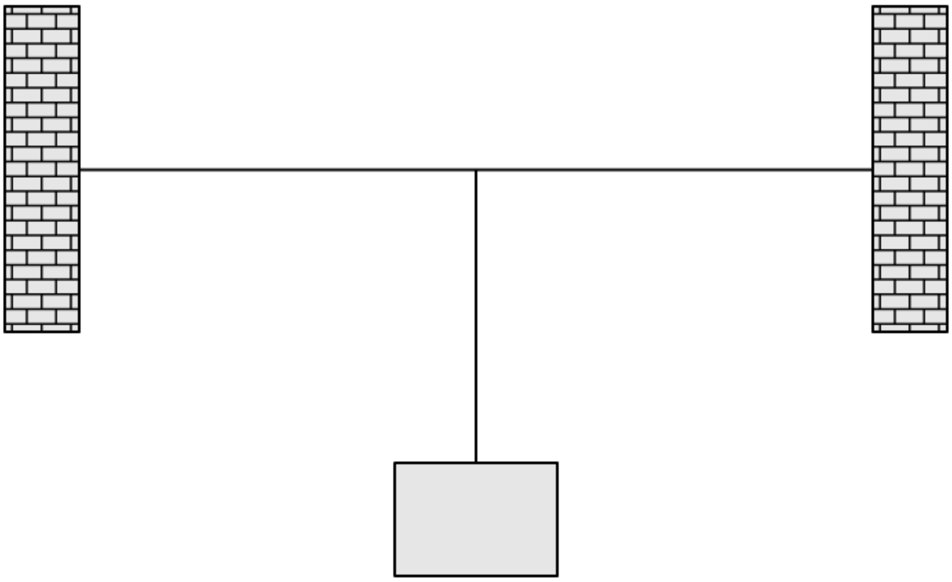
Draw free–body diagrams for both boxes.

(3 marks)

(d) Calculate the magnitude of the maximum force *F* that will result in both blocks moving together without slipping.

(4 marks)

4 (a) A mass is hung from two horizontal strings.



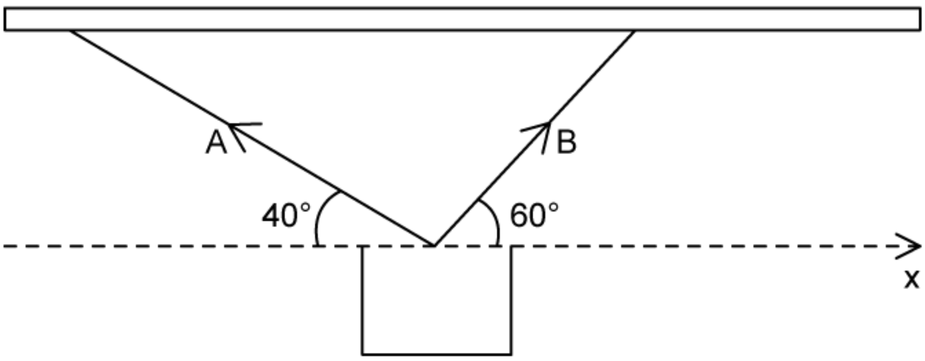
Outline why the mass will not remain in equilibrium when attached to the strings in this way.

....

....

(2 marks)

(b) A flower pot of mass 15 kg hangs from two strings attached to the ceiling with tensions A and B, where it remains in equilibrium.



Derive two equations for A in terms of B. Give any values to an appropriate number of significant figures.

(4 marks)

(c) Hence, calculate tensions A and B.

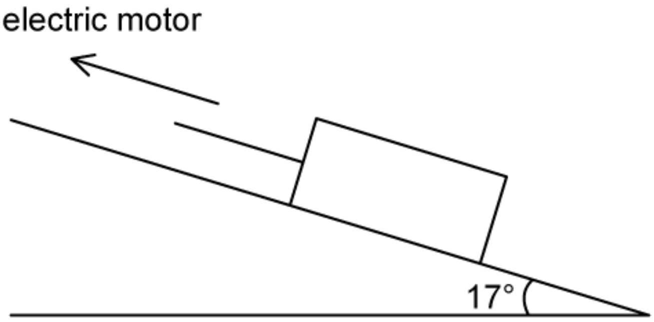
(4 marks)

(d) A gardening enthusiast wants to hang a flower pot from two strings on the ceiling of their balcony. They have two pieces of string, but they are unfortunately quite old and frayed.

Suggest and explain how they can attach the strings to the flower pot in order for them to stay intact.

(2 marks)

5 (a) A stone block is pulled at constant speed up an incline by a cable attached to an electric motor.



The incline makes an angle of 17° with the horizontal. The mass of the block is 180 kg and the tension *T* in the cable of 0.9 kN.

On the diagram draw and label arrows that represent the forces acting on the block.

....

....

(2 marks)

(b) State the type of friction in this system and calculate the frictional force.

....

....

....

....

(4 marks)

(c) Hence, calculate the appropriate coefficient of friction.

....

....

....

(3 marks)

(d) The cable connecting the block to the electric motor abruptly breaks.

Calculate the acceleration of the block.

....

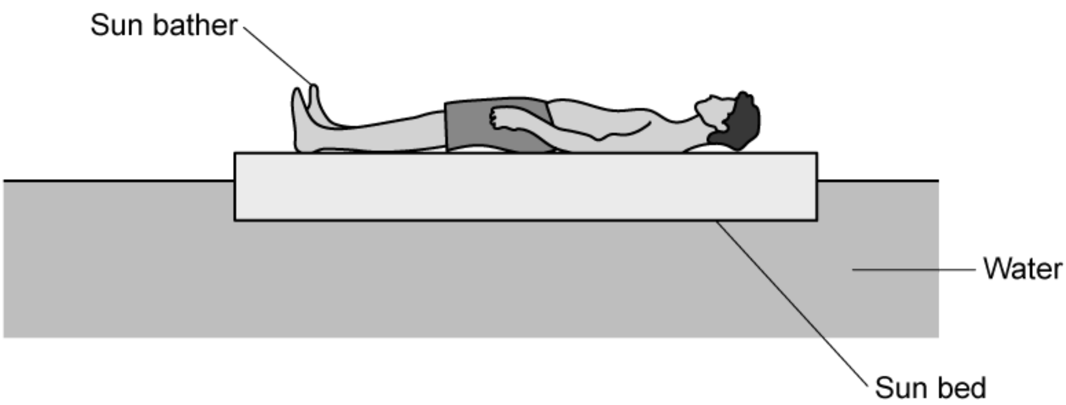
....

....

(3 marks)

Hard Questions

1 (a) A sun bather is supported in water by a floating sun bed.



Draw and label vectors representing the forces acting on the sun bed.

....

....

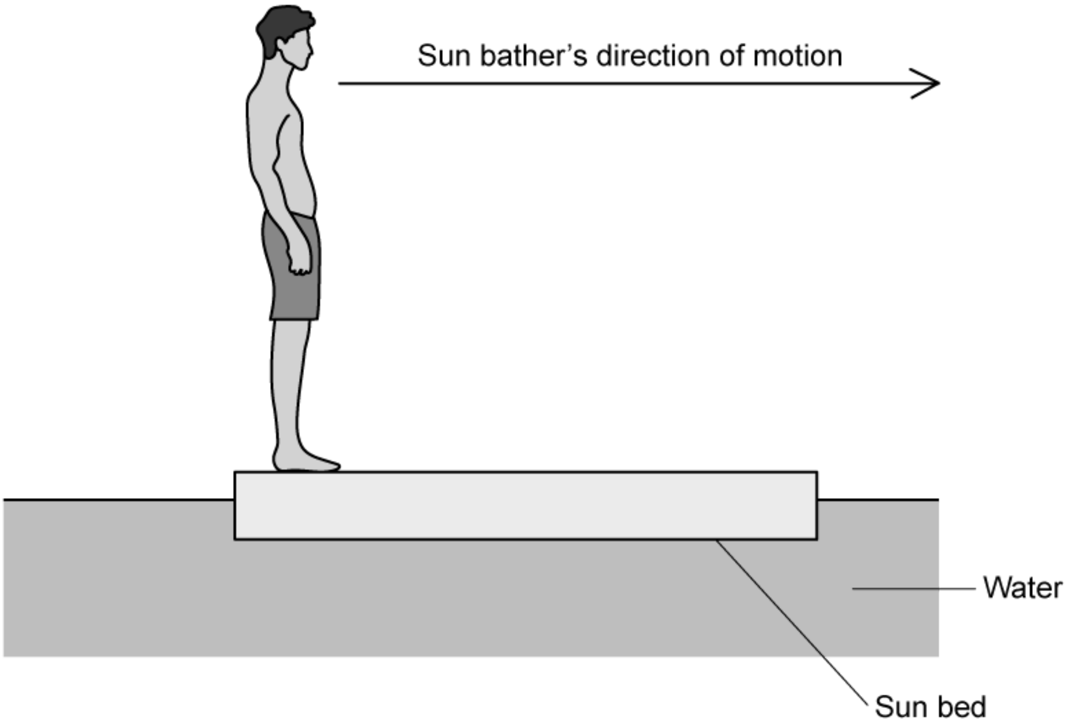
....

....

(4 marks)

(b) The sunbather has incredible core strength and balance.

They stand upright at one end of the sun bed and begin to walk forwards at a constant velocity to the right.



(i) Describe the magnitudes and directions of the forces acting between the sunbather and the sun bed

[4]

(ii) Hence, explain the consequent motion of the sun bed.

[2]

(6 marks)

(c) The sun bed and sunbather may be treated as a single, isolated system.

(i) Explain how the sun bed and sunbather may be considered as a 'single' system

[1]

(ii) Explain how the single system may be considered as 'isolated'.

[1]

....

....

(2 marks)

(d) Treating the sun bed and sunbather as a single, isolated system enables quantitative predictions about its centre of mass.

(i) State and explain the change in position of the isolated system's centre of mass as the sun bather walks along it

[2]

(ii) Describe how the motion of the sun bed would change if it had a much larger mass.

[1]

....

....

....

(3 marks)

2 (a) Describe the microscopic origin of static friction between two objects.

....

....

(2 marks)

(b) Compare and contrast the static force of friction and the dynamic force of friction.

....

....

....

(3 marks)

(c) A block of mass 2.5 kg is at rest on a rough inclined plane. The block just begins to slip down the plane when the angle of inclination is 35°.

Calculate the coefficient of static friction between the block and the inclined plane.

You may use the following result:

$$\tan\theta = \frac{\sin\theta}{\cos\theta}$$

....

....

....

(3 marks)

(d) The angle of inclination is increased to 40°.

Calculate the force that must be applied to the block to move it up the plane with an acceleration of 1.5 m s^{-2}.

Use the following data:

- μ_d = 0.30

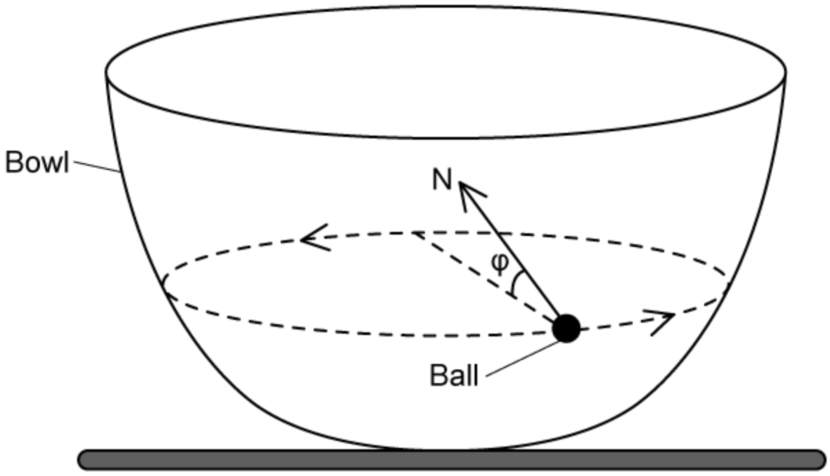
....

....

....

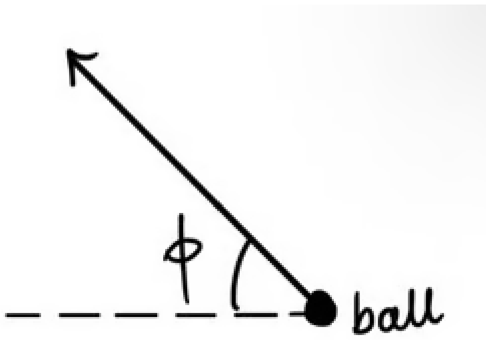
(3 marks)

3 (a) A ball travels in a circular path on the inside surface of a bowl.



The normal reaction force *N* makes an angle *φ* to the plane of the ball's path. Ignore the effects of friction.

On the free-body diagram below, construct an arrow to represent the weight of the ball.



....

....

....

(3 marks)

(b) Determine an equation for the resultant force acting on the ball in terms of its mass *m* and the angle to its plane of orbit *φ*.

You may use the result:

$$\tan\phi = \frac{\sin\phi}{\cos\phi}$$

(2 marks)

(c) The radius of the ball's orbit decreases.

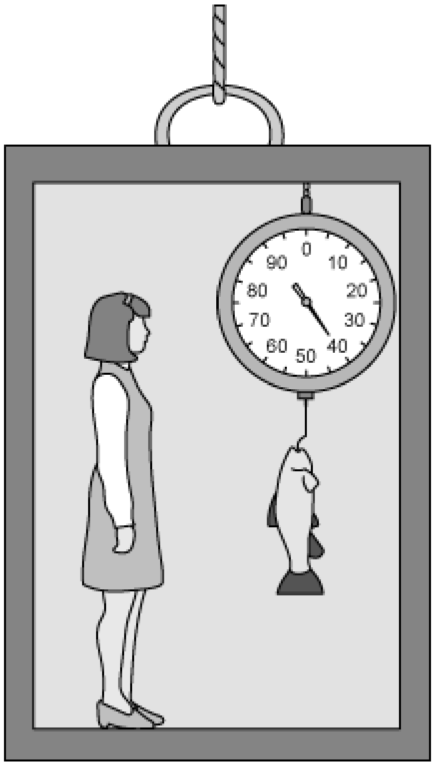
Explain how the effects of friction are related to the decreasing orbital radius.

(3 marks)

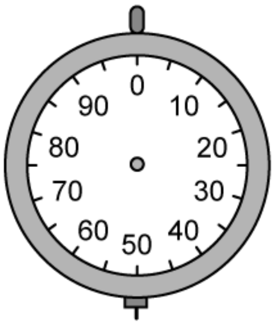
(d) Outline if the ball could travel along a horizontal circular path with an orbital radius equal to the maximum radius of the bowl. Ignore the effects of friction in your answer.

(3 marks)

4 (a) A woman stands in an elevator and measures the weight of a fish attached to a spring scale. The scale reads 40 N when the elevator is stationary.



Sketch the reading on the spring scale as the lift gently accelerates upward.



....

....

(2 marks)

(b) As the elevator continues moving upwards, it gently decelerates to a standstill.

Draw and label a free-body force diagram for the fish as the elevator gently decelerates.

....

....

(2 marks)

(c) The rope that attaches the spring scale to the ceiling of the elevator suddenly snaps. The spring scale and the fish are momentarily in free-fall – but the observer manages to take a reading from the scale it falls.

State and explain the reading on the spring scale as it falls.

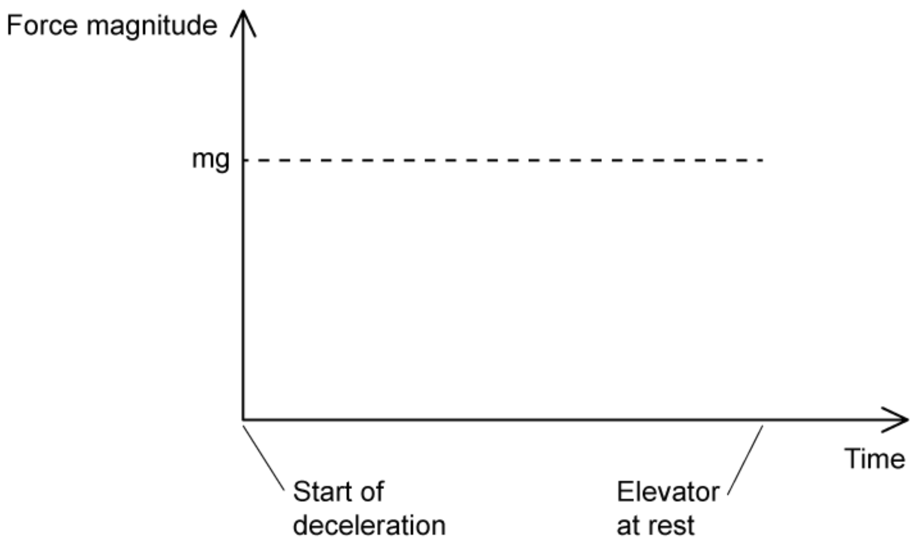
....

....

(2 marks)

(d) Sketch the variation of the contact force on the observer's feet as the elevator decelerates to rest on the axes provided.

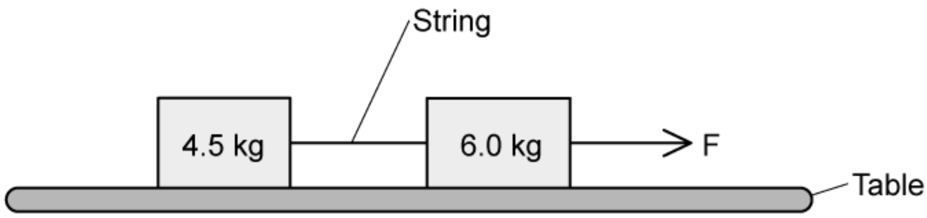
The magnitude of the observers weight, *mg*, is included as a dashed line, for reference.



....

(3 marks)

5 (a) Two blocks of mass 4.5 kg and 6.0 kg are joined by a string and rest on a smooth horizontal table. A force *F* of 100 N is applied to one of the blocks.



Calculate

(i) The acceleration of the blocks

[1]

(ii) The tension in the string.

[1]

....

....

(2 marks)

(b) The 4.5 kg block is now placed on top of the 6.0 kg block. The coeffecient of static friction between them is 0.40.

Calculate the maximum horizontal force *F* that can be applied to the bottom block that would result in both blocks moving together without slipping.

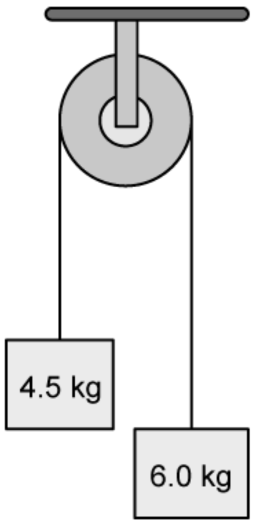
....

....

....

(3 marks)

(c) The two blocks are now attached by a light inextensible string that passes over a smooth pulley. They are held stationary and suddenly released.



Determine the acceleration of each block and the tension in the string.

(4 marks)

(d) The string attaching the blocks over the pulley in part (c) suddenly snaps.

Describe and explain the subsequent motion of the block of mass 4.5 kg. (Assume it was moving upward at the instant the string snapped).

(2 marks)