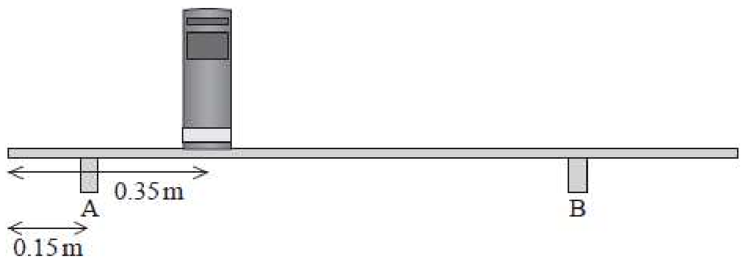
Forces and Moments - Questions by Topic

Q1.

Two brackets, A and B, support a shelf of length 1.2 m. Bracket A is positioned 0.15 m from the left-hand end of the shelf. A book is placed 0.35 m from the left-hand end of the shelf as shown.



(a) The normal contact forces of each bracket on the shelf are equal.

Determine the distance of bracket B from the left-hand end of the shelf.

weight of book = 8.5 N
weight of shelf = 14 N

(5)

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Distance = ...

(b) Bracket B is moved closer to the left-hand end of the shelf.

Explain the effect on the magnitude of the normal contact force of bracket B on the shelf.

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(Total for question = 7 marks)

Q2.

All quantities may be expressed in terms of SI base units.

Which of the following are the base units for the moment of a force?

(1)

☐ **A** kg m s^{-2}

☐ **B** kg m^2 s^{-2}

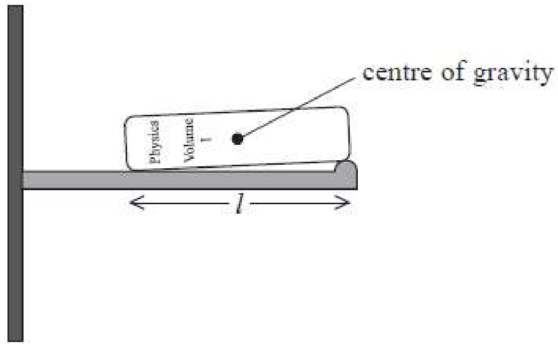
☐ **C** kg m s^{-1}

☐ **D** kg m^2 s^{-3}

(Total for question = 1 mark)

Q3.

A book of length *l* and weight *W* is positioned on a shelf as shown.



(a) State what is meant by centre of gravity.

(1)

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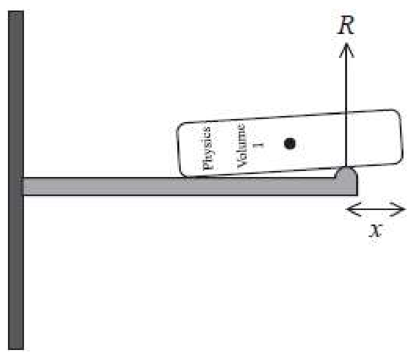
(b) There are contact forces at the two positions where the book touches the shelf.

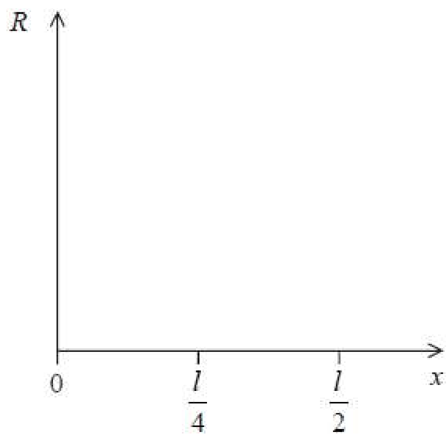
The book is moved a distance *x* to the right as shown.



The magnitude of the contact force *R* varies with *x*.

Sketch on the axes below the variation of *R* with *x* between 0 and $\frac{l}{2}$. You should mark the maximum value of *R* onto the axes.

(3)



(c) Explain why the book will not remain on the shelf if $x > \frac{l}{2}$

(2)

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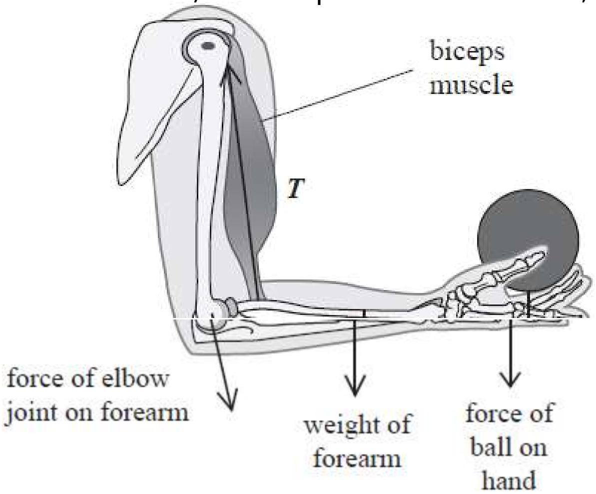
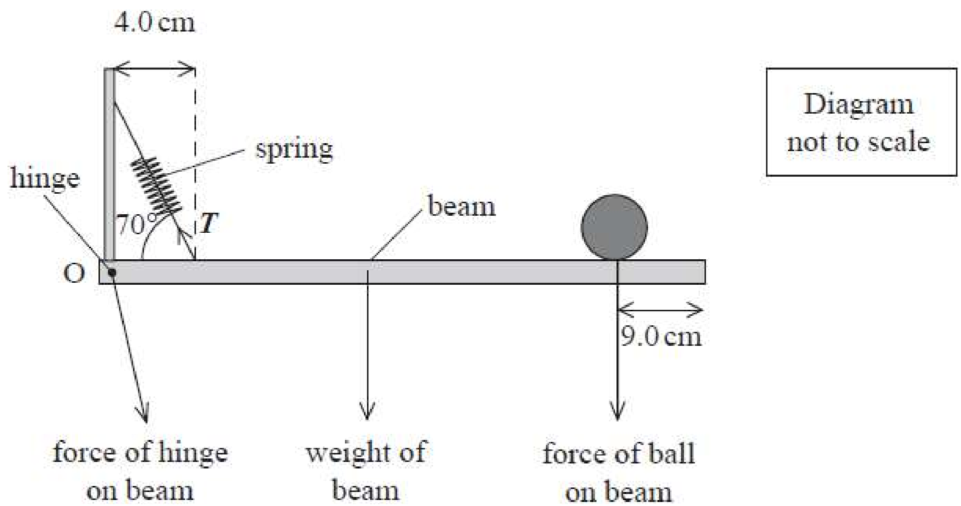
(Total for question = 6 marks)

Q4.

Muscles move body parts by contracting and relaxing. For the forearm to hold a ball in the position shown, the biceps muscle contracts, creating a tension *T* in the muscle as shown.



A student modelled the forces on the forearm using a uniform beam and spring arrangement as shown below. The length and weight of the beam were the same as the length and weight of the forearm.



(a) It can be assumed that the biceps muscle acts as a spring at an angle of 70° to the

beam, 4.0 cm from the pivot O.

Determine the magnitude of *T*. You will need to estimate the total length of the forearm and hand.

force of ball on beam = 4.5 N
weight of beam = 15 N

(5)

Estimate of total length of forearm and hand = ...

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T = ...

(b) Explain a limitation of using a beam to model the forearm.

(2)

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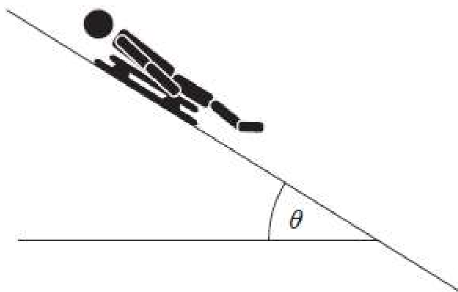
(Total for question = 7 marks)

Q5.

The luge is an event at the Winter Olympics. An athlete lies on a small sledge and races down an icy track, feet first.

Source: www.wtop.com

(a) An athlete accelerates down a straight section of the track as shown. The track is at an angle θ to the horizontal.



Draw a free-body force diagram for the sledge and athlete.
You should consider the relative sizes of the forces when drawing your diagram.

(4)

(b) The mass of the athlete is one of the factors that affects her time to complete the race.

(i) Explain why the mass of the athlete has little effect on the initial acceleration.

(3)

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(ii) Explain, in terms of forces, why the athlete reaches a maximum velocity.

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(iii) It is stated that the maximum speed is greater for athletes of greater mass.

Suggest why this is only correct up to a certain mass.

(2)

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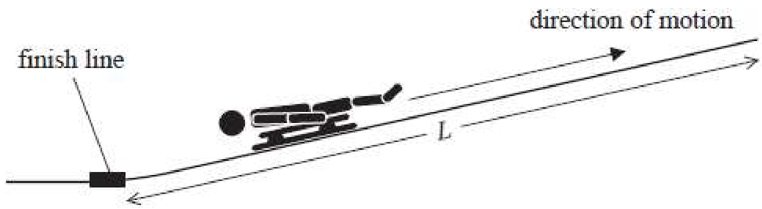
(c) After the finish line there is a straight, uphill section of track for the sledge to decelerate in. The maximum permitted gradient of this section is 20 %.



(i) Show that a track with a gradient of 20% is at an angle to the horizontal of about 11°.

(1)

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(ii) An athlete reaches the finish line at a velocity of 33 m s^{-1}. She then applies a minimum braking force of 240 N as she moves along the uphill section of track to help her come to a stop.

Calculate the minimum uphill length of track *L* that should be available for braking. You should ignore all frictional forces other than those applied by the athlete.

mass of sledge and athlete = 95 kg

(5)

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L = ...

(Total for question = 18 marks)

Q6.

Which of the following statements describes the gravitational field strength acting on a body at a point?

☐ **A** gravitational force per unit length

☐ **B** gravitational force per unit mass

☐ **C** gravitational potential energy per unit length

☐ **D** gravitational potential energy per unit mass

(Total for question = 1 mark)

Q7.

A ball of mass *m* is projected vertically upwards. An air resistance *F* acts on the ball at all times.

Which of the following equations would apply to the ball as it is travelling upwards?

☐ **A** $mg - F = 0$

☐ **B** $mg + F = 0$

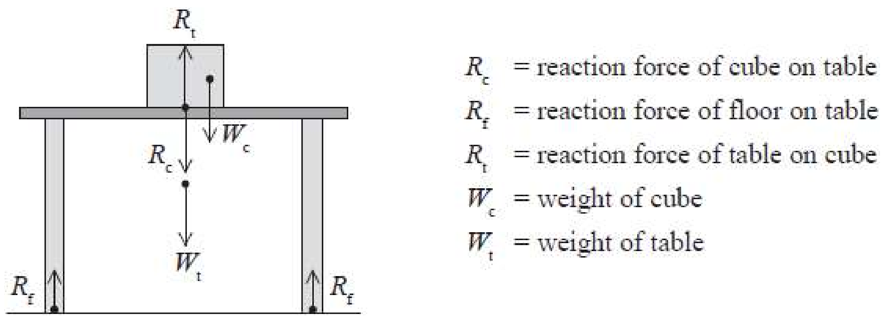
☐ **C** $mg - F = ma$

☐ **D** $mg + F = ma$

(Total for question = 1 mark)

Q8.

A uniform solid cube is placed on a table. The diagram shows the forces acting on the table and on the cube.



The table has four legs.

Which of the following statements is correct according to Newton's third law?

(1)

☐ **A** $4R_f = R_c + R_t$

☐ **B** $4R_f = R_c + W_t$

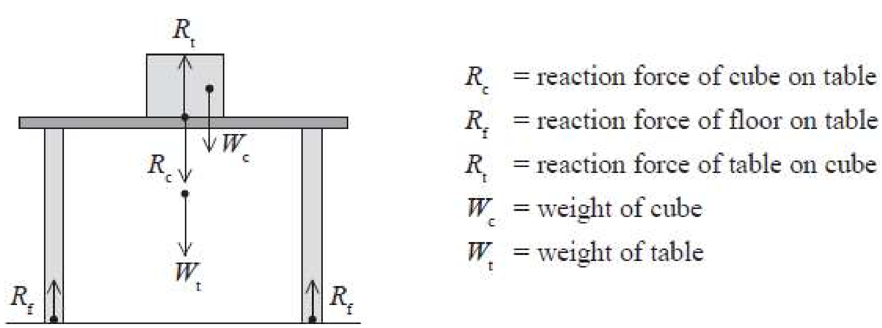
☐ **C** $R_c = R_t$

☐ **D** $R_t = W_c$

(Total for question = 1 mark)

Q9.

A uniform solid cube is placed on a table. The diagram shows the forces acting on the table and on the cube.



The dot at the start of every arrowed line indicates the point at which the force can be considered to act.

Which of the following forces has been drawn in the wrong position?

(1)

☐ **A** R_c

☐ **B** R_t

☐ **C** W_c

☐ **D** W_t

(Total for question = 1 mark)

Q10.

When water vapour in the atmosphere cools it condenses, forming tiny drops of water. These drops increase in size by colliding with each other and fall back to the ground as rain.

(a) As a raindrop falls through the air it eventually reaches its terminal velocity. The upthrust on the raindrop can be considered to be negligible.

(i) Explain what is meant by the terminal velocity of the raindrop. Your answer should include a free-body force diagram for the raindrop when terminal velocity has been reached.

(4)

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(ii) The air resistance F acting on a raindrop travelling at a velocity v, can be determined using the expression

$$F = 0.45\rho A v^2$$

where A is the cross-sectional area of the raindrop and ρ is the density of the air.

Calculate the terminal velocity of a spherical raindrop of radius 2.0×10^{-3} m.

density of air = 1.2 kg m^{-3}
density of rainwater = 1.0×10^3 kg m^{-3}

(4)

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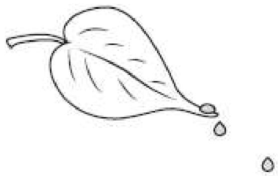
Terminal velocity = ...

(b) Some plants have adapted to high rainfall by having a specialised shape and waxy leaves. This allows rain to slide down a leaf and off the end as a series of drops.

(i) A drop of water slides off a leaf as shown.

Add to the diagram to show the position of the drop at regular intervals of time.
The first two positions have been drawn for you.

(2)



(ii) Water falls from a leaf at a steady rate of five drops per second.

As each drop reaches the ground, there are four drops above it in the air.

Calculate the height of the leaf from the ground. It can be assumed that the drop at the highest position has just left the leaf.

(3)

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Height of leaf = ...

(Total for question = 13 marks)