Complete VCE Education

VCE Physics Specialists

Complete Bible

High-Yield Motion Questions and Solutions

Written by

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How to use this handbook

This 'Complete Bible' is a compilation of 20 difficult high-yield questions pertaining to motion content covered in in VCE physics. These questions have been designed around the following four subtopics; kinematics, forces and momentum, torque and equilibrium, and energy. These questions are designed to reinforce students' conceptual knowledge and enhance their ability to apply these concepts to difficult and unfamiliar scenarios.

Due to the difficulty of these questions, it is recommended that students have covered the content beforehand and are confident in answering basic types of questions (eg. textbook questions) prior to attempting the questions in this handbook. This handbook is divided into two parts; Part A and Part B. Part A of this handbook contains the questions without solutions, and Part B contains the solutions to the questions in Part A along with additional useful tips and advice. To get the most out of this handbook, it is recommended that students attempt the questions in Part A prior to viewing the solutions in Part B.

We hope that you find this handbook to be an invaluable tool for your VCE physics studies. If you have any queries, please do not hesitate to contact us via our email address: completevceeducation@gmail.com.

About the authors

Asel Kumarasinghe is the head of resources at Complete VCE Education and is currently pursing a Bachelor of Biomedicine degree under the Chancellor's Scholarship. He graduated in 2022, achieving a raw 50 and a Premier's Award in VCE physics, along with a 99.95 ATAR.

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Part A

Questions

Question 1

A tennis ball travelling with a velocity of 10 m s^{-1} S45°E is struck by a bat so that its velocity becomes 5.0 m s^{-1} N20°E. Determine the change in the ball's velocity and provide your answer in compass bearings. (3 marks)

Question 2

A red P-plater is cruising along a backroad at 41.7 m s^{-1} in a 100.0 km h^{-1} zone and passes a highway patrol car. The highway patrol car begins aggressively pursuing the driver 2.50 s later, accelerating uniformly for 7.50 s until they reach a speed of 50.0 m s^{-1}. They then maintain that speed throughout the remainder of the chase.

a) Sketch the velocity-time graph of the P-plater and the highway patrol car for 30 s on the axes below. (2 marks)

b) Determine how long it takes for the highway patrol car to catch up with the P-plater from the time it passes the police car. (3 marks)

c) Determine how far the P-plater travelled before the highway patrol car caught up with it. (2 marks)

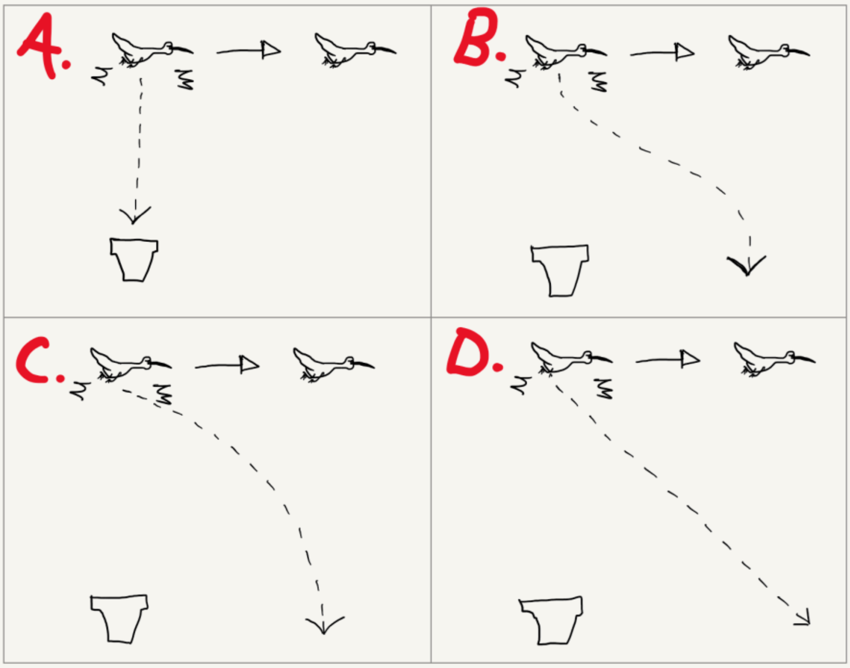
Question 3

A UFO hovering at 75 m above the ground begins to fly straight up at a constant speed of 7.8 m s^{-1}. As soon as the helicopter begins its ascent, a cow drops out and falls to the ground. Assuming that there is no air resistance and this takes place on planet Earth, determine the time it takes for the cow to return to its paddock, on the ground below. (2 marks)

Question 4

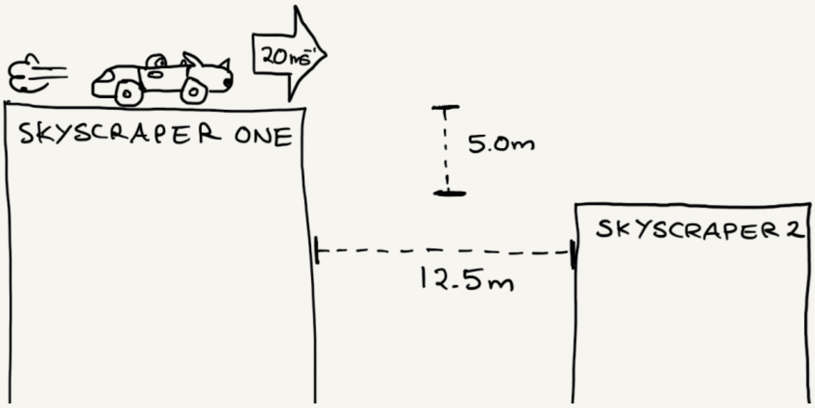
While flying in the same direction, an ibis drops a chicken sandwich it stole from nearby parkgoers as it was simply too heavy to carry. Assume that the effects of air resistance are negligible and that there are no winds.

Select the correct approximate path of travel from the options below: (1 mark)



Question 5

A stuntman is driving a 1002 kg roadster across two skyscrapers as depicted in the diagram below:

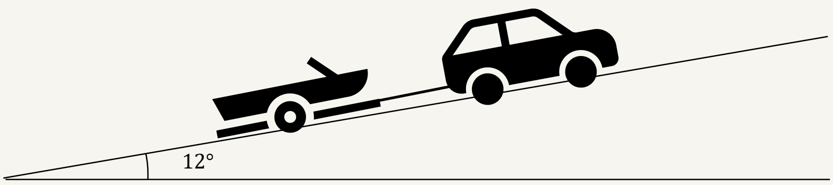


This vehicle is 3.98 m long, with the centre of the rear and front wheels being both 0.50 m from each respective bumper. Count the beginning of descent as the rear tyres leaving the surface of skyscraper one.

Assuming that the effects of air resistance are negligible and the stuntman resides on planet Earth, will the stuntman be able to land with the entire car fully on the second skyscraper (ie. with no part hanging off) at its current departure speed? Explain your answer with calculations. (3 marks)

Question 6

A car is pulling a boat trailer up a ramp with an initial acceleration of 3.0 m s^{-2}. The ramp makes an angle of 12° with the horizontal. A frictional force of 450 N acts on the boat trailer. The total mass of the boat trailer is 1000 kg.



a) Calculate the tension in the metal bar joining the boat trailer and the car. (3 marks)

b) If a frictional force of 500 N acts on the car and the engine provides the power for a driving force of 9000 N on the car, find the mass of the car. (3 marks)

Question 7

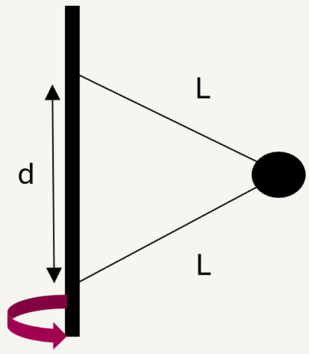
Two crash-test cars of identical mass are travelling at 20.0 m s^{-1} towards a brick wall. Car A is fitted with airbags while car B does not have airbags. Both cars contain a dummy in the driver's seat. Upon impact, the dummy in car A is cushioned by the airbag and comes to rest in 0.250 s. However, the dummy in car B comes to rest in 0.0851 s.

a) By what factor does the average force on the dummy in car B compare to car A? (2 marks)

b) When a car hits the brick wall, it comes to a complete rest. Explain what happens to both the momentum and the kinetic energy of the car once it hits the concrete block. No calculations are required. (2 marks)

Question 8

In the figure below, a 1.50 kg ball is connected to a vertical rotating rod by two massless strings, each of length L=1.55 m. The strings are tied to the rod with separation d=1.55 m and are taut. The tension in the upper string is 40 N.



Calculate the tension in the lower string. (2 marks)

Question 9

A basketball of mass 700 g is dropped from a height of 2.10 m onto concrete. It rebounds and reaches a height of 1.80 m above the ground. Calculate the magnitude of the average force on the basketball if it was in contact with the ground for 0.700 s. (4 marks)

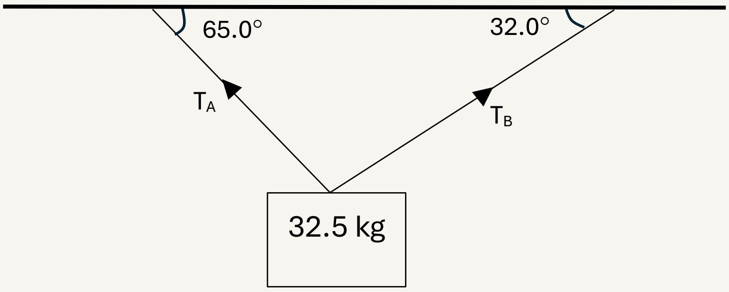
Question 10

A truck travelling at 72 km h^{-1} brakes to a complete stop over a distance of x m under a constant braking force.

Determine the braking distance, in terms of x, required for the same truck to come to a stop when travelling at 36 km h^{-1} and braking with the same constant braking force? (3 marks)

Question 11

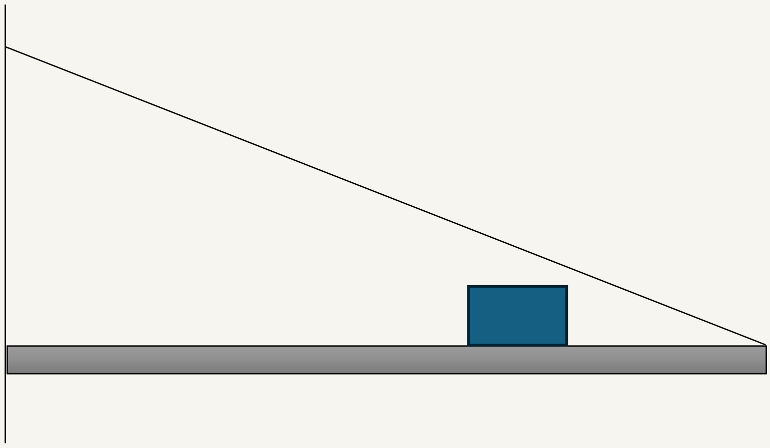
A 32.5 kg sign is suspended in equilibrium by two ropes A and B as shown below.



Determine T_A, the magnitude of the tension in rope A. (3 marks)

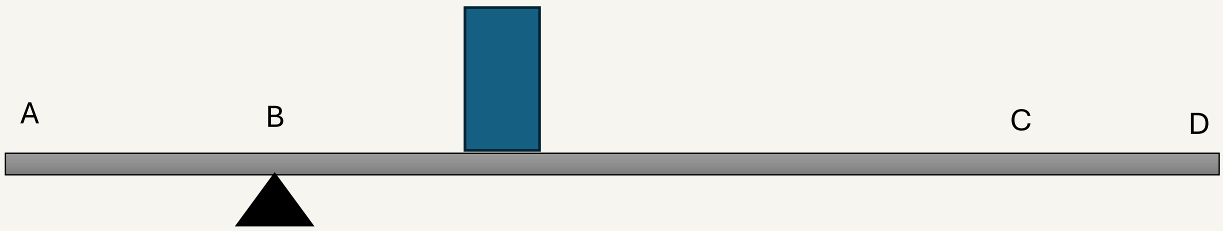
Question 12

A 3.0 m long uniform beam of mass 4.5 kg is suspended to a wall by a massless cable. The cable, which is attached to the end of the beam, makes an angle of 60° with the wall. A box of mass 3.5 kg is placed on the beam, such that the central point of contact between the box and the beam is 1.0 m away from the edge of the beam. Calculate the tension in the cable. (2 marks)



Question 13

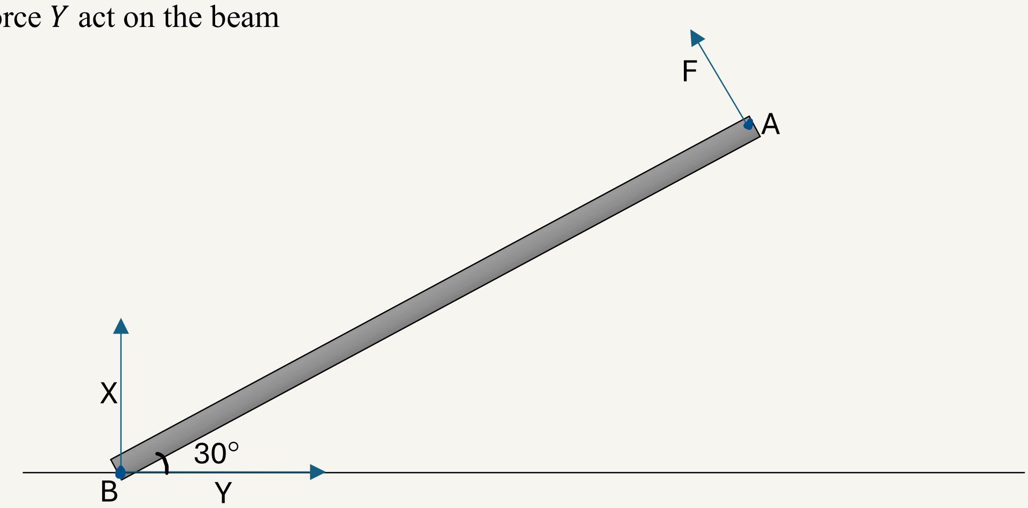
A 70 kg package is placed on a horizontal uniform beam AD, such that the central point of contact between the package and the beam is 3.2 m away from end A. The beam has a mass of 35 kg and is 8.0 m long. The beam is supported by a vertical force F_B at pivot B and F_C at pivot C. Pivot B is a distance of 2.5 m from end A and pivot C is a distance of 1.5 m from end D.



a) Calculate F_C. (2 marks)
b) The package is now moved to a different position on the beam. Determine the minimum horizontal distance from end D that the centre of the package can be placed without tipping the beam. (3 marks)

Question 15

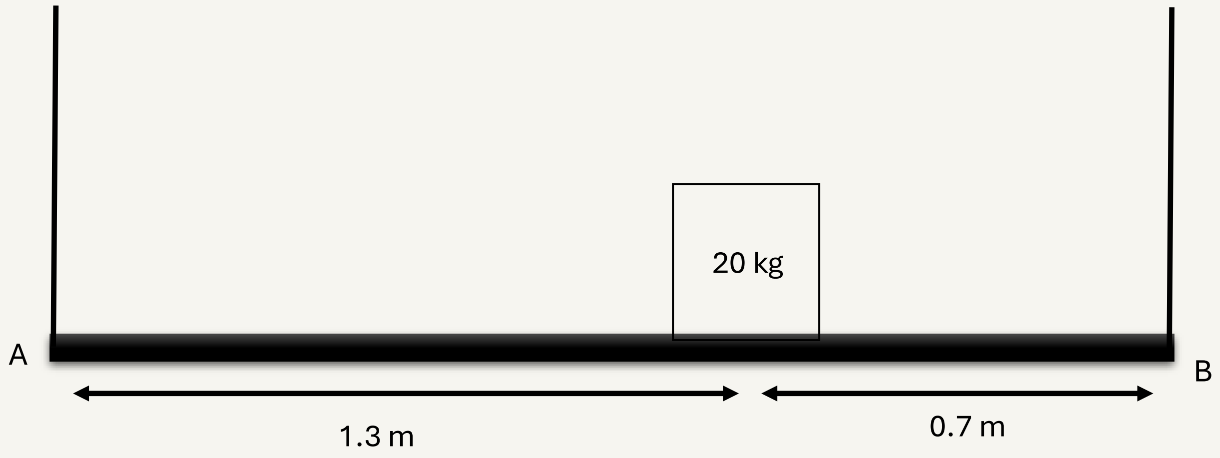
A 12 kg uniform beam AB of length 4.0 m is placed on a flat horizontal surface at an angle of 30° to the horizontal. At point A, a force *F* acts perpendicular to the beam to stabilise the beam. At point B, which is in contact with the ground, a vertical force *X* and a horizontal force *Y* act on the beam



a) Calculate the magnitude of the force *F* acting on the beam. (2 marks)
b) Calculate the magnitude of the force *X* and force *Y* on the beam. (3 marks)

Question 14

Two ropes are used to hold up a 5.0 kg uniform horizontal beam AB as shown, which is 2.0 m in length. A 20 kg mass is placed 1.3 m from the left rope.



Calculate the tension in the left rope. (2 marks)

Question 17

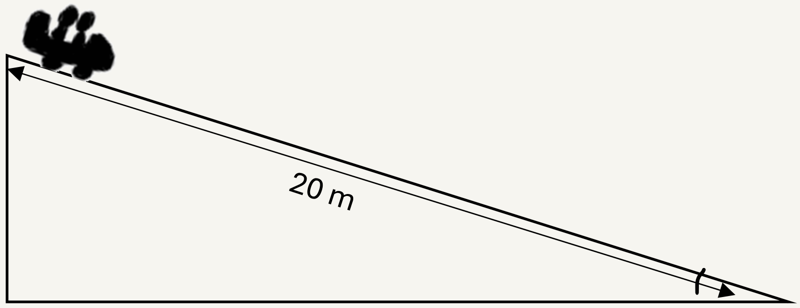
A vertical spring with a spring constant of 55 N m^{-1} is shown below. While unstretched, a mass of 1.2 kg is attached to the end of the spring while at rest and released, causing the spring to oscillate freely.

a) Calculate the extension of the spring from its unstretched length once the mass comes to rest after oscillating. (2 marks)

b) Calculate the maximum speed of the mass during its oscillation. (3 marks)

Question 16

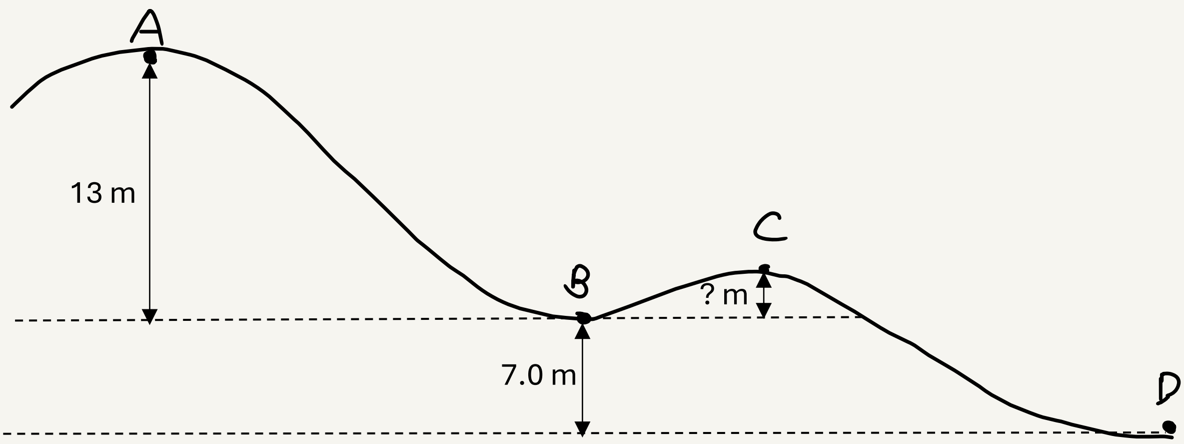
Two riders in a go-kart are launched down a ramp at 0.50 m s^{-1} as shown below. The combined mass of the riders and go-kart is 185 kg. The ramp is 20 m long and is angled at 10 degrees to the horizontal. A constant frictional force of 30 N acts on the riders as they ride down the ramp.



What will be their final speed at the bottom of the ramp? (3 marks)

Question 18

A rollercoaster is shown below. The rollercoaster cart is travelling at a speed of 3.0 m s^{-1} as it passes point A. The combined mass of the rollercoaster cart and its riders is 900 kg. Assume that friction is negligible.

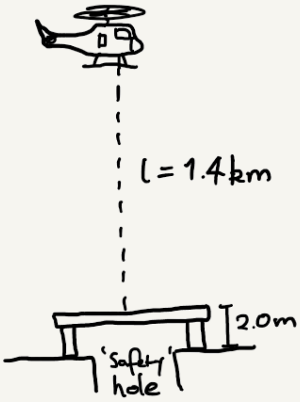


a) Calculate the change in speed of the cart between points B and D (3 marks)

b) The height of point C relative to point B is unknown. However, the speed of the cart was recorded to be 8.5 m s^{-1} at C. Using this information, calculate the height difference between point A and C. (2 marks)

Question 20

Earl has decided to help complete a test run of an exciting new skydiving feature at Tasmania Jones' theme park. Jones has hired you, a VCE Physics student, to complete some last-minute calculations for safety purposes before Earl reaches the ground.
The 'ride' is depicted below in the diagram:

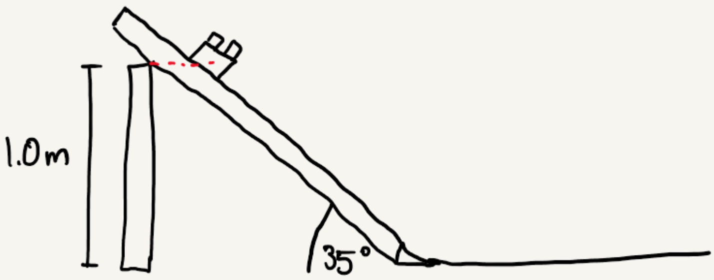


A trampoline is set up below the jump spot with a 'safety hole' of a depth Jones and Co estimated to be 50.0 m. The trampoline has a height of 2.0 m above the ground, while the jump point is 1.4 km above the surface of the trampoline. In addition, the trampoline happens to be an ideal spring, with spring constant of $k = 100\ N\ m^{-1}$, while Earl weighs 81 kg. Assume that Earl does not have any horizontal velocity or experience any air resistance when jumping out, and that the trampoline will not break regardless of how much it stretches. Also assume he lands exactly in the middle of the trampoline.

Explain using calculations whether the current depth of the 'safety hole' is enough to contain the maximum depth the trampoline stretches downward when Earl lands into it. (3 marks)

Question 19

A student is playing with a toy building block, sliding it down a ramp as depicted below.



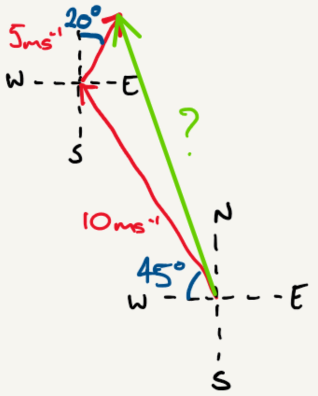
The 90 g block slides down the ramp from rest. In addition, the student has covered the ramp and surface adjacent to the base in the same continuous piece of material, providing a resistive force of 0.20 N throughout the block's travel.
Calculate the displacement of the block from its original position. Give your answer with the angle below the horizontal. (3 marks)

Part B

Solutions

Question 1

A tennis ball travelling with a velocity of 10 m s^{-1} S45°E is struck by a bat so that its velocity becomes 5.0 m s^{-1} N20°E. Determine the change in the ball's velocity and provide your answer in compass bearings. (3 marks)



Note: $\Delta\vec{v} = \vec{v} - \vec{u}$ (use vector subtraction, reverse direction of u).

Since the triangle is not a right-angled triangle, the approach would be to resolve the vectors into perpendicular components (x and y directions) and add these

$v_x = 5.0\sin(20°) = 1.71\text{ m s}^{-1}$ East

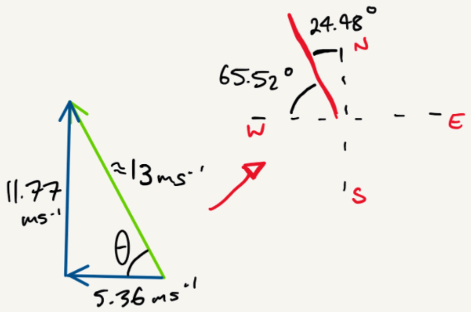
$v_y = 5.0\cos(20°) = 4.70\text{ m s}^{-1}$ North

$(-u)_x = 10\cos(45°) = 7.07\text{ m s}^{-1}$ West

$(-u)_y = 10\sin(45°) = 7.07\text{ m s}^{-1}$ North (1 mark)

Sum of x-components $= 7.07 - 1.71 = 5.36\text{ m s}^{-1}$ West

Sum of y-components $= 7.07 + 4.70 = 11.77\text{ m s}^{-1}$ North



$\Delta v = \sqrt{5.36^2 + 11.77^2} = 13\text{ m s}^{-1}$ (2 s.f.) (1 mark)

<u>Direction:</u>

$$\tan(\theta) = \frac{11.77}{5.36}$$

$\theta = 65.52°$

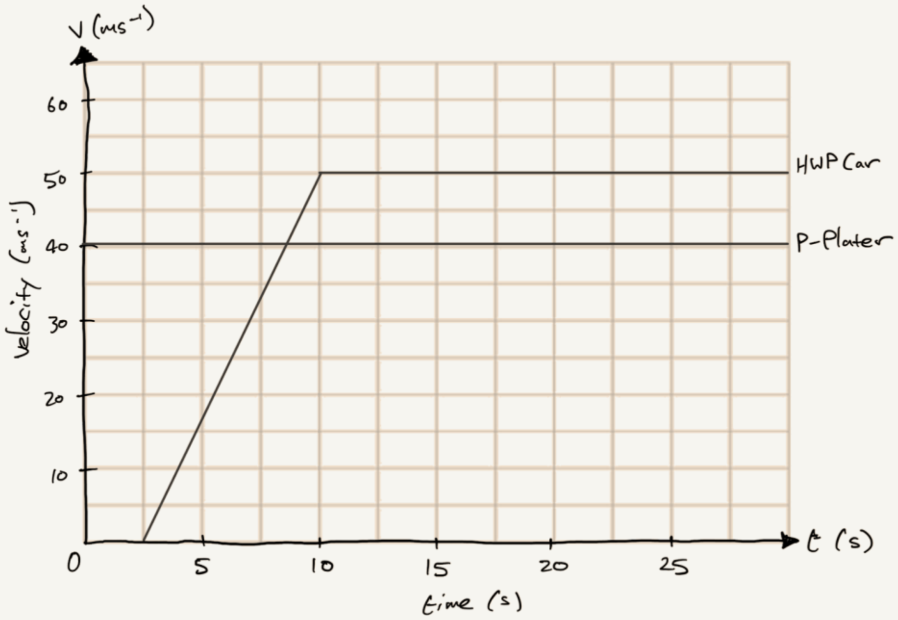
$\therefore$ Direction $= 90 - 65.52 = 24.48 \approx N24°W$ (1 mark)

NOTE: The main potential point to mess up will be the initial recognition of vector subtraction, which can throw off the entire rest of the working-out if not realised. It is important to always remember that vector subtraction involves inverting the direction of the subtracted vector.

Question 2

A red P-plater is cruising along a backroad at 41.7 m s^{-1} in a 100.0 km h^{-1} zone and passes a highway patrol car. The highway patrol car begins aggressively pursuing the driver 2.50 s later, accelerating uniformly for 7.50 s until they reach a speed of 50.0 m s^{-1}. They then maintain that speed throughout the remainder of the chase.

a) Sketch the velocity-time graph of the P-plater and the highway patrol car for 30 s on the axes below. (2 marks)



1 mark – correct scale and labelling
1 mark – correct graphs

b) Determine how long it takes for the highway patrol car to catch up with the P-plater from the time it passes the police car. (3 marks)

Let t be the time the police car catches up with the motorcyclist (after the motorcyclist passes the police car).

$Area_{mc} = Area_{pc}$

$41.7t = \frac{1}{2} \times 7.5 \times 50 + 50(t - 10)$ (1 mark for each correct area expression)

$41.7t = 50t - 312.5$

$t = 37.7$ s (3 s.f.) (1 mark)

c) Determine how far the P-plater travelled before the highway patrol car caught up with it. (2 marks)

$s = 41.7 \times 37.7$ (1 mark)

$s = 1.57 \times 10^3$ m (3 s.f.) (1 mark)

Question 3

A UFO hovering at 75 m above the ground begins to fly straight up at a constant speed of 7.8 m s^{-1}. As soon as the helicopter begins its ascent, a cow drops out and falls to the ground. Assuming that there is no air resistance and this takes place on planet Earth, determine the time it takes for the cow to return to its paddock, on the ground below. (2 marks)

Take upwards as positive

$t = ?, u = 7.8 \text{ m s}^{-1}, a = -9.81 \text{ m s}^{-2}, s = -75$

$s = ut + \frac{1}{2}at^2$

$-75 = 7.8t + \frac{1}{2}(-9.81)t^2$ (1 mark)

$4.905t^2 - 7.8t - 75 = 0$

$t = \frac{7.8 \pm \sqrt{7.8^2 - 4 \times 4.905 \times (-75)}}{2 \times 4.905}$ (include quadratic formula on your cheat sheet)

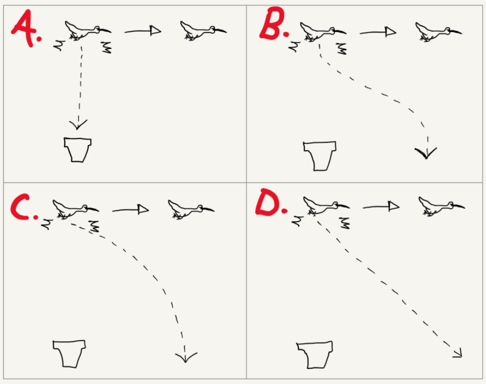
$t = 4.8$ s (since t>0) (2 s.f) (1 mark)

NOTE: The main challenge of this question will be the use of the quadratic formula. Of course experience from math methods or specialist will help here, but ideally every student should have this rearranged version of the SUVAT equation on their cheat sheet. This helps avoid the time taken to rearrange into the quadratic formula and allows yourself to plug values straight in.

Question 4

While flying in one direction, an ibis drops a chicken sandwich it stole from nearby parkgoers as it was simply too heavy to carry. Assume that the effects of air resistance is negligible and that there are no winds.

Select the correct approximate path of travel from the options below: (1 mark)

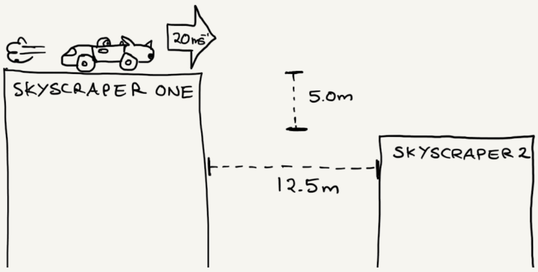


Answer = C

*NOTE: This is a bit of an odd scenario, but the key part to note is that **air resistance was negligible**. This means there is no horizontal forces acting against the sandwich! Since the only external force is gravity, the path of motion will be parabolic as the vertical velocity increases downwards, but horizontal velocity is maintained until impact with the ground.*

Question 5

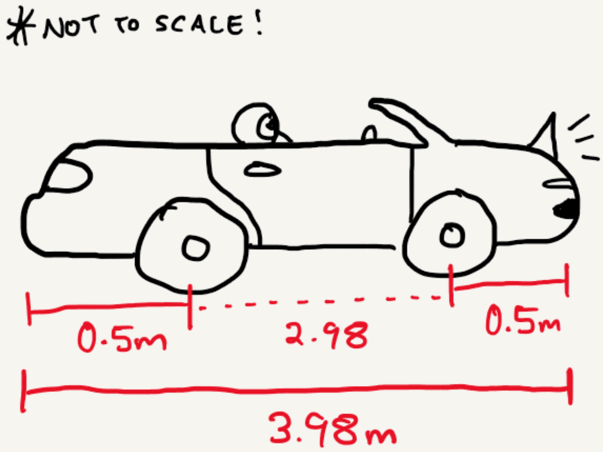
A stuntman is driving a 1002 kg roadster across two skyscrapers as depicted in the diagram below:



This vehicle is 3.98 m long, with the centre of the rear and front wheels being both 0.50 m from each respective bumper. Count the beginning of descent as the rear tyres leaving the surface of skyscraper one.

Assuming that the effects of air resistance are negligible and the stuntman resides on planet Earth, will the stuntman be able to land with the entire car fully on the second skyscraper (ie. with no part hanging off) at its current departure speed? Explain your answer with calculations. (3 marks)

Divide into vertical and horizontal motion:



Time to drop 5.0 m:

Take downwards as positive

$s = 5.0$, $a = 9.81$ m s^{-2} , $u = 0$, $t = ?$

$s = ut + \frac{1}{2}at^2$

$5.0 = \frac{1}{2}(9.81)t^2$

$t = 1.01$ s (1 mark)

Distance travelled horizontally in 1.01 s:

$d = vt = 1.01 \times 20 = 20.2$ m (1 mark)

Since descent begins with rear tyres, 3.48 m of the car is already past the building edge.

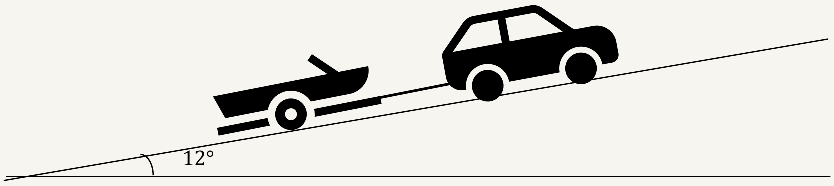
Therefore distance rear bumper travels from edge of skyscraper 1 **= -0.5 + 20.2 = 19.7 m**

As 19.7 > 12.5, the stuntman will successfully make the jump at this speed. (1 mark)

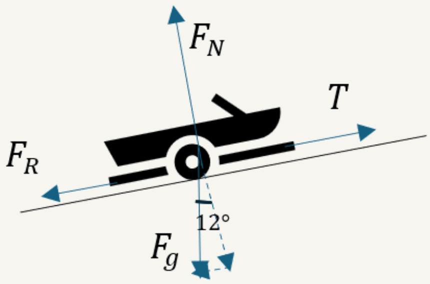
NOTE: This question is rather simple at first glance. However many students will miss the final section of determining whether the entire car will make it on top skyscraper 2 without teetering off the side of the building. In this case it does, but if the drop distance were even less, it is likely that only the front axle would make the jump, causing the car to fall off the second building. The weight is also meaningless in this question and simply a red herring for students who have not seen this type of question yet.

Question 6

A car is pulling a boat trailer up a ramp with an initial acceleration of 3.0 m s^{-2}. The ramp makes an angle of 12° with the horizontal. A frictional force of 450 N acts on the boat trailer. The total mass of the boat trailer is 1000 kg.



a) Calculate the tension in the metal bar joining the boat trailer and the car. (3 marks)



<u>For boat</u>

$F_{net} = ma$ (up the ramp)

$T - mg\sin(12°) - F_R = ma$ (1 mark)

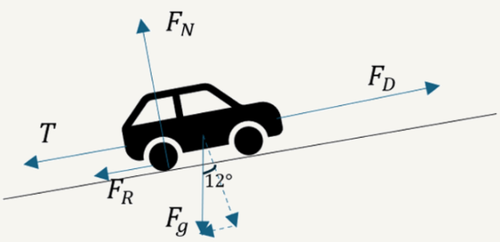
$T - 1000 \times 9.81\sin(12°) - 450 = 1000 \times 3.0$ (1 mark)

$T = 5489.6 \text{ N} \approx 5.5 \times 10^3 \text{ N}$ (2 s.f.) (1 mark)

NOTE: in this question, we must analyse just the boat trailer, not the entire system. If you consider the entire system (boat trailer + car), then there will be two equal and opposite tension forces which will cancel out.

Also, when analysing the boat trailer, the vertical forces (perpendicular to the ramp) do not need to be considered since the normal force and the vertical component of the gravitational force cancel out anyways.

b) If a frictional force of 500 N acts on the car and the engine provides the power for a driving force of 9000 N on the car, find the mass of the car. (3 marks)



<u>For car</u>

$F_{net} = ma$ (up the ramp)

$F_D - mg\sin(12°) - F_R - T = ma$ (1 mark)

$9000 - m \times 9.81\sin(12°) - 500 - 5489.6 = m \times 3.0$ (1 mark)

$9000 - 500 - 5489.6 = \left(3.0 + 9.81\sin(12°)\right)m$

$m = \frac{9000-500-5489.6}{3.0+9.81\sin(12°)}$

$m = 597 \text{ kg} \approx 6.0 \times 10^2 \text{ kg}$ (2 s.f.) (1 mark)

NOTE: the tension force is pulling the car backwards, hence it is negative in the net force equation.

Question 7

Two crash-test cars of identical mass are travelling at 20.0 m s^{-1} towards a brick wall. Car A is fitted with airbags while car B does not have airbags. Both cars contain a dummy in the driver's seat. Upon impact, the dummy in car A is cushioned by the airbag and comes to rest in 0.250 s. However, the dummy in car B comes to rest in 0.0851 s.

a) By what factor does the average force on the dummy in car B compare to car A? (2 marks)

$I = F_{av}\Delta t$, however the impulse (change in momentum) is the same for both cars since they have the same mass and change in velocity.

$F_{av\,(A)}\Delta t_A = F_{av\,(B)}\Delta t_B$ (same impulse)

$\frac{F_{av\,(B)}}{F_{av\,(A)}} = \frac{\Delta t_A}{\Delta t_B}$

$\frac{F_{av\,(B)}}{F_{av\,(A)}} = \frac{0.250}{0.0851}$ (1 mark)

$\frac{F_{av\,(B)}}{F_{av\,(A)}} = 2.94$ times greater (3 s.f.) (1 mark)

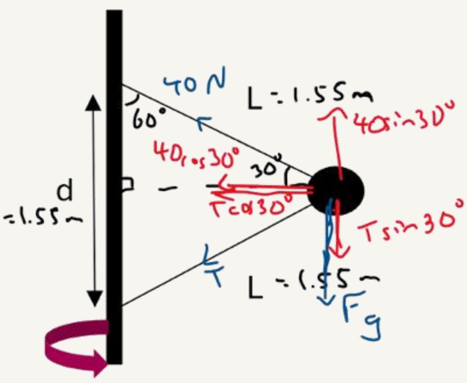
b) When a car hits the brick wall, it comes to a complete rest. Explain what happens to both the momentum and the kinetic energy of the car once it hits the concrete block. No calculations are required. (2 marks)

- The car's momentum has been transferred to the Earth via the brick wall. (1 mark)
- The car's kinetic energy has been transformed to other forms of energy such as heat, sound, and deformation of the car. (1 mark)

Question 8

In the figure below, a 1.50 kg ball is connected to a vertical rotating rod by two massless strings, each of length L=1.55 m. The strings are tied to the rod with separation d=1.55 m and are taut. The tension in the upper string is 40 N.

Calculate the tension in the lower string. (2 marks)



NOTE: the triangle is equilateral.

Note also that the tension in the lower string is different to the tension in the upper string due to the effect of the gravitational force.

$F_{net} = 0$ (vertically)

$40\sin(30°) - T\sin(30°) - 1.50 \times 9.81 = 0$ (1 mark)

$T = 10.57\text{ N} \approx 10.6\text{ N}$ (2 s.f.) (1 mark)

Question 9

A basketball of mass 700 g is dropped from a height of 2.10 m onto concrete. It rebounds and reaches a height of 1.80 m above the ground. Calculate the magnitude of the average force on the basketball if it was in contact with the ground for 0.700 s. (4 marks)

To find the average force, we require the impulse (change in momentum) of the ball. We therefore need to find the velocity of the ball just before and just after the bounce (using constant acceleration formulae).

Take upwards as positive

Velocity prior to bounce:

$v^2 = u^2 + 2as$ (for downwards journey)
$v^2 = 0 + 2 \times (-9.81) \times (-2.10)$
$v = -6.42 \text{ m s}^{-1}$ (down) (1 mark)

Velocity after bounce:

$v^2 = u^2 + 2as$ (for upwards journey)
$0 = u^2 + 2 \times (-9.81) \times 1.80$
$u = 5.94 \text{ m s}^{-1}$ (up) (1 mark)

$I = \Delta p$

$F_{av}\Delta t = m(v - u)$
$F_{av} \times 0.700 = 0.700(5.94 - (-6.42))$ (1 mark)
$F_{av} = 12.4$ N (3 s.f.) (1 mark)

NOTE: You could also have used energy conservation, instead of the constant acceleration formulae, to determine the velocity of the ball just before and just after the bounce. This would involve equating the gravitational potential energy and the kinetic energy ($GPE = KE \rightarrow mgh = \frac{1}{2}mv^2 \rightarrow \therefore v = \sqrt{2gh}$)

Question 10

A truck travelling at 72 km h^{-1} brakes to a complete stop over a distance of x m under a constant braking force.

Determine the braking distance, in terms of x, required for the same truck to come to a stop when travelling at 36 km h^{-1} and braking with the same constant braking force? (3 marks)

Scenario 1:

$s = x, u = \frac{72}{3.6} = 20 \text{ m s}^{-1}, v = 0 \text{ m s}^{-1}, a = ?, t = N/A$

Using the SUVAT equation that relates the three known variables with the one unknown variable:

$v^2 = u^2 + 2as$

$0^2 = 20^2 + 2ax$

$\therefore a = -\frac{200}{x} \text{ m s}^{-2}$ (1 mark)

Scenario 2:

$s = ?, u = \frac{36}{3.6} = 10 \text{ m s}^{-1}, v = 0 \text{ m s}^{-1}, a = -\frac{200}{x}, t = N/A$

Using the SUVAT equation that relates the three known variables with the one unknown variable:

$v^2 = u^2 + 2as$

$0^2 = 10^2 + 2(-\frac{200}{x})s$ (1 mark)

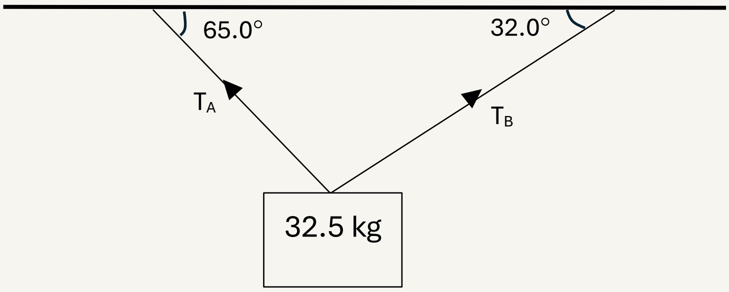
$\therefore s = \frac{x}{4}$ (1 mark)

NOTE: since the braking force is identical, from Newton's 2nd Law, the acceleration in the two scenarios is also identical.

It is recommended that students follow a structured method when doing constant acceleration questions. The first step should involve making a 'SUVAT checklist' and then identifying the suitable formula that relates the known variables with the unknown variable.

Question 11

A 32.5 kg sign is suspended in equilibrium by two ropes A and B as shown below.



Determine T_A, the magnitude of the tension in rope A. (3 marks)

NOTE: cannot use vector triangle as there are two unknowns.

$F_{net} = 0$, so equate vector components in x and y directions.

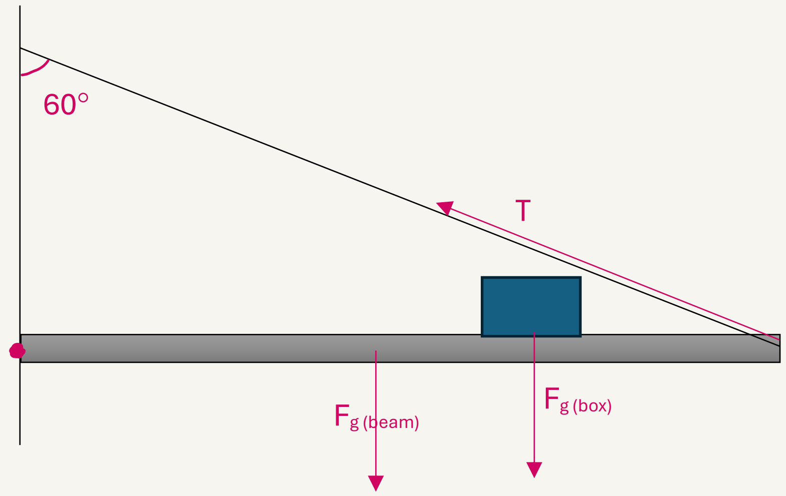
Horizontally: $T_{A\,(x)} = T_{B\,(x)}$
$T_A \cos(65.0°) = T_B \cos(32.0°)$
$T_B = 0.498T_A$ (1 mark)

Vertically: $T_{A\,(y)} + T_{B\,(y)} = F_g$

$T_A \sin(65.0°) + T_B \sin(32.0°) = 32.5 \times 9.81$ (1 mark)
$T_A \sin(65.0°) + (0.498T_A) \sin(32.0°) = 32.5 \times 9.81$
$1.170T_A = 318.825$
$T_A = 272$ N (3 s.f) (1 mark)

Question 12

A 3.0 m long uniform beam of mass 4.5 kg is suspended to a wall by a massless cable. The cable, which is attached to the end of the beam, makes an angle of 60° with the wall. A box of mass 3.5 kg is placed on the beam, such that the central point of contact between the box and the beam is 1.0 m away from the edge of the beam. Calculate the tension in the cable. (2 marks)



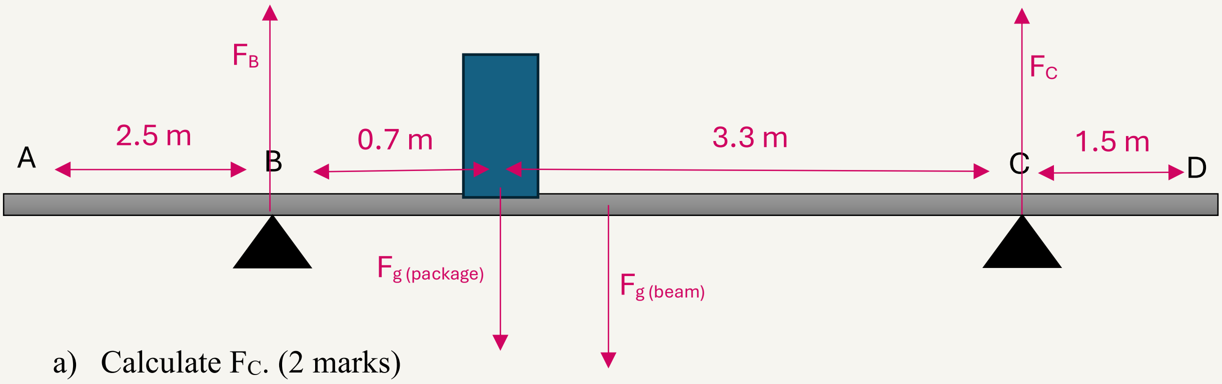
Let clockwise be positive.

$\tau_{net} = 0$
$4.5 \times 9.81 \times 1.5 + 3.5 \times 9.81 \times 2.0 - T sin(30°) \times 3 = 0$ (1 mark)
$T = 90$ N (2 s.f.) (1 mark)

NOTE: when calculating torque we consider all the forces acting <u>*on*</u> *the beam. Although* $F_{g(box)}$ *is acting on the box, the box will also be exerting a force on the beam (ie. the reaction force to the normal force on the box), which will be of equal magnitude to the gravitational force on the box.*

Question 13

A 70 kg package is placed on a horizontal uniform beam AD, such that the central point of contact between the package and the beam is 3.2 m away from end A. The beam has a mass of 35 kg and is 8.0 m long. The beam is supported by a vertical force F_B at pivot B and F_C at pivot C. Pivot B is a distance of 2.5 m from end A and pivot C is a distance of 1.5 m from end D.



a) Calculate F_C. (2 marks)

NOTE: take torque around point B (because F_B is unknown and does not contribute to the torque around B). Let clockwise be positive.

$\tau_B = 0$
$70 \times 9.81 \times 0.7 + 35 \times 9.81 \times 1.5 - F_c \times 4.0 = 0$ (1 mark)
$F_c = 2.5 \times 10^2$ N upwards (2 s.f.) (1 mark)

b) The package is now moved to a different position on the beam. Determine the minimum horizontal distance from end D that the centre of the package can be placed without tipping the beam. (3 marks)

Let distance from end D = x m

Beam starts to tip when $F_B = 0$ N. (1 mark) Take torque around point C. Let clockwise be positive.

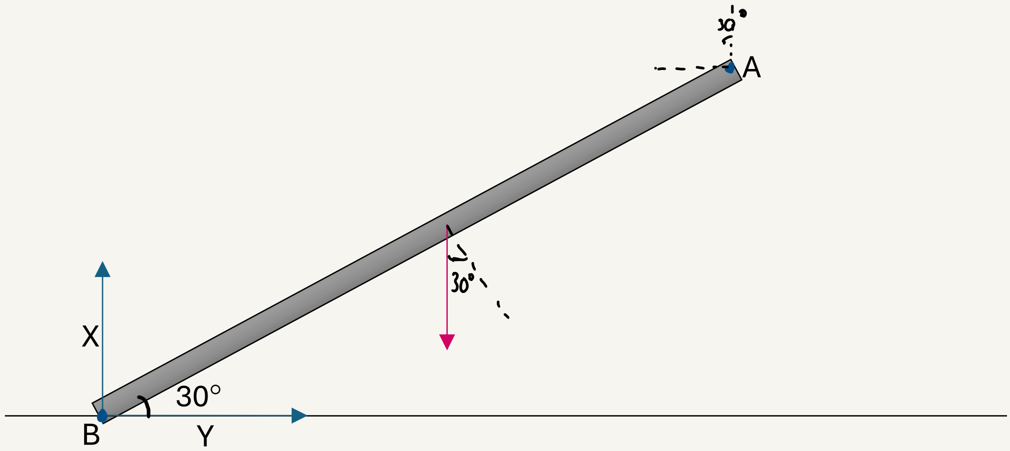
$\tau_C = 0$

$70 \times 9.81 \times (1.5 - x) - 35 \times 9.81 \times 2.5 - 0 = 0$ (1 mark)

$1.5 - x = 1.25$
$x = 0.25$ m from end A (2 s.f.) (1 mark)

Question 15

A 12 kg uniform beam AB of length 4.0 m is placed on a flat horizontal surface at an angle of 30° to the horizontal. At point A, a force F acts perpendicular to the beam to stabilise the beam. At point B, which is in contact with the ground, a vertical force X and a horizontal force Y act on the beam.



c) Calculate the magnitude of the force F acting on the beam. (2 marks)

Take torque around point B. Let clockwise be positive (remember to take into account the gravitational force acting on the beam)

$\tau_B = 0$
$12 \times 9.81\cos(30°) \times 2.0 - F \times 4.0 = 0$ (1 mark)
$F = 51$ N (2 s.f) (1 mark)

a) Calculate the magnitude of the force X and force Y on the beam. (3 marks)

NOTE: Cannot use torque (ie. rotational equilibrium) here, since X and Y are acting at the pivot point and do not contribute to the torque. Instead, we use the net force (ie. translational equilibrium).

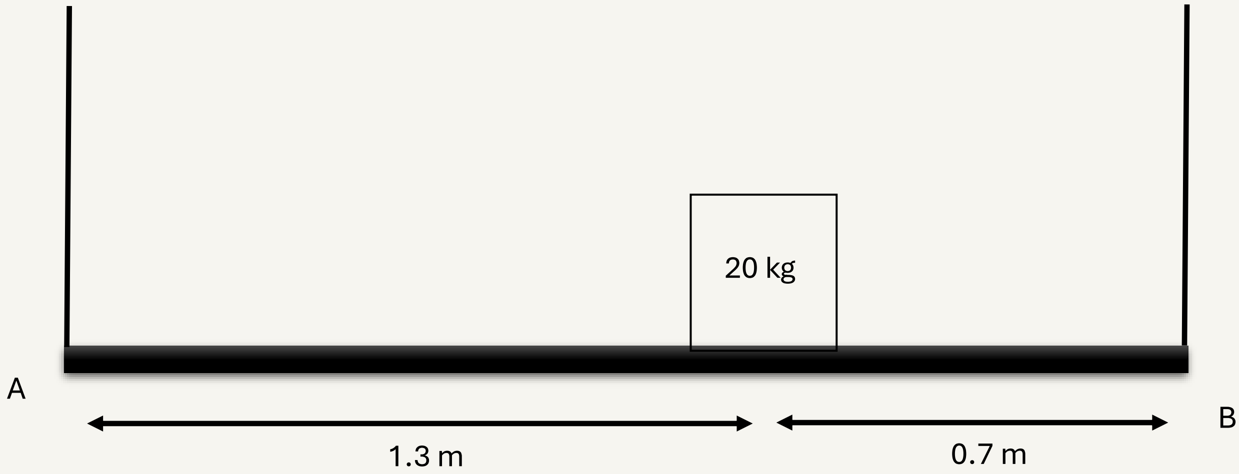
$F_{net} = 0$ (vertically, let upwards be positive)
$F cos(30°) + X - F_g = 0$
$50.97\cos(30°) + X - 12 \times 9.81 = 0$ (1 mark)
$X = 74$ N (2 s.f) (1 mark)

$F_{net} = 0$ (horizontally, let right be positive)

$Y - F sin(30°) = 0$
$Y - 50.97\sin(30°) = 0$
$Y = 25$ N (2 s.f) (1 mark)

Question 14

Two ropes are used to hold up a 5.0 kg uniform horizontal beam AB as shown, which is 2.0 m in length. A 20 kg mass is placed 1.3 m from the left rope.



Calculate the tension in the left rope. (2 marks)

Since the tension in the right rope is unknown, we need to take the torque around point B. Let clockwise be positive.

$\tau_B = 0$
$T_A - 20 \times 9.81 \times 1.3 - 5.0 \times 9.81 \times 1.0 = 0$ (1 mark)
$T_A = 3.0 \times 10^2$ N (2 s.f.) (1 mark)

NOTE: whenever dealing with a torque question with two unknown forces, take the torque at the point of one of the unknown forces. This is because, when calculating the torque around a pivot point, any unknown forces acting at that point will not contribute to the torque and so are not included in the calculation.

Question 17

A vertical spring with a spring constant of 55 N m^{-1} is shown below. While unstretched, a mass of 1.2 kg is attached to the end of the spring while at rest and released, causing the spring to oscillate freely.

a) Calculate the extension of the spring from its unstretched length once the mass comes to rest after oscillating. (2 marks)

$F_{net} = 0$
$F_g = F_s$
$mg = k\Delta x$
$1.2 \times 9.81 = 55\Delta x$ (1 mark)
$\Delta x = 0.21$ m (2 s.f.) (1 mark)

a) Calculate the maximum speed of the mass during its oscillation. (3 marks)

NOTE: max speed occurs when net force first becomes zero. This is because prior to reaching the max speed, the net force is downwards (accelerating downwards), so speed increases, but after the max speed, the net force is upwards (slowing down), so speed decreases.

$F_{net} = 0$
$\Delta x = 0.21$ m (from part a) (1 mark)

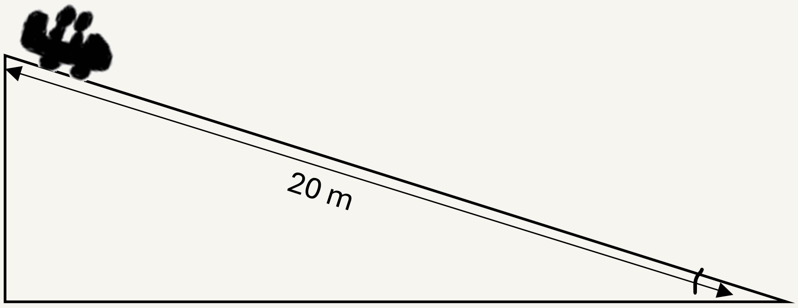
NOTE: gravitational potential energy transformed into kinetic energy + spring potential energy (conservation of energy).

$\Delta E_g = \Delta E_s + \Delta E_k$

$mg\Delta x = \frac{1}{2}k(\Delta x)^2 + \frac{1}{2}mv^2$
$1.2 \times 9.81 \times 0.21 = \frac{1}{2} \times 55 \times 0.21^2 + \frac{1}{2} \times 1.2 \times v^2$ (1 mark)
$v = 1.4$ m s^{-1} (2 s.f) (1 mark)

Question 16

Two riders in a go-kart are launched down a ramp at 0.50 m s^{-1} as shown below. The combined mass of the riders and go-kart is 185 kg. The ramp is 20 m long and is angled at 10 degrees to the horizontal. A constant frictional force of 30 N acts on the riders as they ride down the ramp.



What will be their final speed at the bottom of the ramp? (3 marks)

Height of ramp = $20 \sin 10° = 3.5$ m (2 s.f)

Change in GPE = $mgh = 185 \times 9.81 \times 3.5 = 6.4 \times 10^3$ J (1 mark)

Work done to go-kart = $Fd = 30 \times 20 = 6.0 \times 10^2$ J

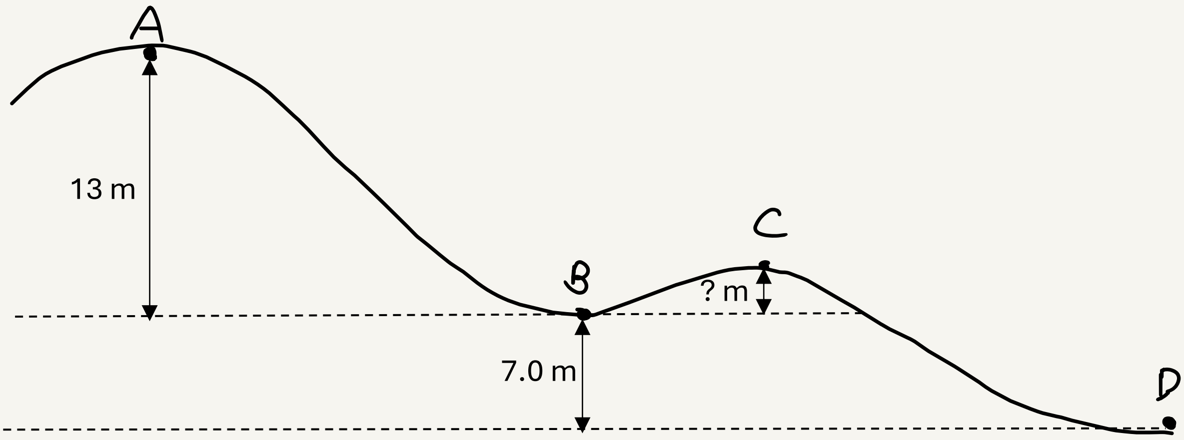
Kinetic Energy at bottom of ramp = $6.4 \times 10^3 - 6.0 \times 10^2 = 5.8 \times 10^3$ J (1 mark)

Speed at bottom = $\sqrt{\frac{2 \times 5.8 \times 10^3}{185}} = 7.9$ m s^{-1} (1 mark)

NOTE: The two 'catches' to avoid in this question are recognising that it is an energy question, and knowing when to use W = Fd. It's important to remember that energy is ***not a vector*** *and is thus not required to have a direction – think of it more like a currency that keeps getting exchanged between different types. Some students may also be tempted to use SUVAT, which while technically possible, is ill advised due to it requiring significantly more steps.*

Question 18

A rollercoaster is shown below. The rollercoaster cart is travelling at a speed of 3.0 m s^{-1} as it passes point A. The combined mass of the rollercoaster cart and its riders is 900 kg. Assume that friction is negligible.



a) Calculate the change in speed of the cart between points B and D (3 marks)

Kinetic energy at A = $\frac{1}{2}mv^2 = \frac{1}{2} \times 900 \times 3.0^2 = 4.1 \times 10^3$ J

Kinetic energy at B = $4.1 \times 10^3 + 900 \times 13 \times 9.81 = 1.2 \times 10^5$ J

Speed at B = $\sqrt{\frac{2\times1.2\times10^5}{900}} = 16.25$ m s^{-1} (1 mark)

Kinetic energy at D = $4.1 \times 10^3 + 900 \times 20 \times 9.81 = 1.8 \times 10^5$ J

Speed at D = $\sqrt{\frac{2\times1.8\times10^5}{900}} = 20.03$ m s^{-1} (1 mark)

Thus, change in speed = final – initial = $20.03 - 16.25 = 3.8$ m s^{-1} (2 s.f) (1 mark)

NOTE: This question is fairly straightforward. However, the traps come into attempting to shortcut the above solution. Like the previous spring question, we cannot simply find the change in energy and solve for 'v', since that quantity is squared in the KE formula. As such, we need to take the 'long way' of solving for each speed and subtracting final from initial.

b) The height of point C relative to point B is unknown. However, the speed of the cart was recorded to be 8.5 m s^{-1} at C. Using this information, calculate the height difference between point A and C. (2 marks)

Kinetic energy at A = $\frac{1}{2}mv^2 = \frac{1}{2} \times 900 \times 3.0^2 = 4.1 \times 10^3$ J

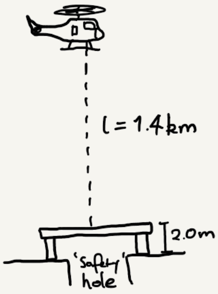
Kinetic energy at C = $\frac{1}{2}mv^2 = \frac{1}{2} \times 900 \times 8.5^2 = 32512.5$ J (1 mark)

$4.1 \times 10^3 + 900 \times 9.81 \times \Delta h = 32512.5$
$\Delta h = 3.2$ m (1 mark)

NOTE: This question involves combining the GPE and KE formulas together into one expression to solve for one variable – in this instance, 'h'. We need to realise that as the cart travels down, GPE is transformed into KE, reflected by the plus sign in the equation created.

Question 20

Earl has decided to help complete a test run of an exciting new skydiving feature at Tasmania Jones' theme park. Jones has hired you, a VCE Physics student, to complete some last-minute calculations for safety purposes before Earl reaches the ground.
The 'ride' is depicted below in the diagram:



A trampoline is set up below the jump spot with a 'safety hole' of a depth Jones and Co estimated to be 50.0 m. The trampoline has a height of 2.0 m above the ground, while the jump point is 1.4 km above the surface of the trampoline. In addition, the trampoline happens to be an ideal spring, with spring constant of k = 100 N m^{-1}, while Earl weighs 81 kg.

Assume that Earl does not have any horizontal velocity or experience any air resistance when jumping out, and that the trampoline will not break regardless of how much it stretches. Also assume he lands exactly in the middle of the trampoline.

Explain using calculations whether the current depth of the 'safety hole' is enough to contain the maximum depth the trampoline stretches downward when Earl lands into it. (3 marks)

$mg(l + x) = \frac{1}{2}kx^2$

$81 \times 9.81 \times (1400 + x) = \frac{1}{2} \times 100 \times x^2$

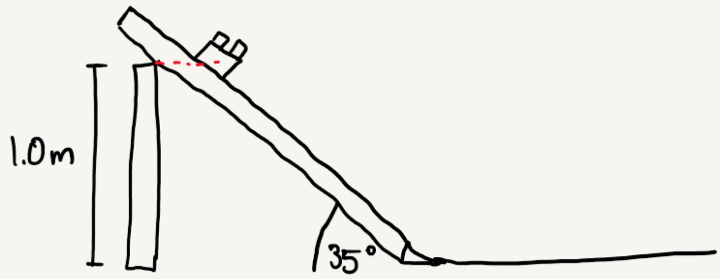
$50x^2 - 795x - 1112454 = 0$ (1 mark)

$\frac{795+\sqrt{(-795)^2-4\times50\times(-1112454)}}{2\times50} = 157.3 \approx 1.6 \times 10^2$ m (2 s.f) (1 mark)

Unfortunately for Earl, since $1.6 \times 10^2 \gg 50.0$, there is in fact not enough space for the trampoline to fully stretch in the 'safety hole'. (1 mark)

NOTE: Not only is this question difficult with the absolute glut of information necessary to know, but the significance of realising that Earl will still be converting GPE to EPE as the trampoline stretches downward. As such, while most students will be able to easily reach the correct conclusion using a crude EPE = GPE equation, those who do that way will not be able to earn the first two working-out marks.
This question also requires the use of the quadratic formula, further reinforcing the message to remember it, or at least have it ready on your note sheet.

Question 19
A student is playing with a toy building block, sliding it down a ramp as depicted below.



The 90 g block slides down the ramp from rest. In addition, the student has covered the ramp and surface adjacent to the base in the same continuous piece of material, providing a resistive force of 0.20 N throughout the block's travel. Assume the block slides smoothly throughout its travel.
Calculate the displacement of the block from its original position. Give your answer with the angle below the horizontal. (3 marks)

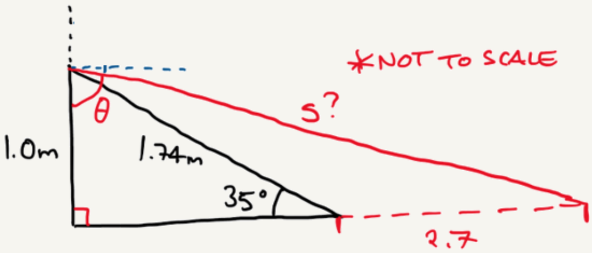
GPE lost $= 0.090 \times 9.81 \times 1.0 = 0.88$ J
$Fd = E_{GP}$
$0.20d = 0.88$
Distance travelled $= d = 4.4$ m (1 mark)

Length of ramp $= \frac{1.0}{\sin(35°)} = 1.7$ m
Stopping distance from ramp $= 4.4 - 1.7 = 2.7$ m (1 mark)

Horizontal displacement $= 2.7 + \frac{1.0}{\tan(35°)} = 4.1$ m

$\theta = tan^{-1}\left(\frac{1.0}{4.1}\right) = 14°$
$s = \sqrt{1.0^2 + 4.1^2} = 4.2$ m

Thus, displacement $= 4.2$ m, $14°$ below the horizontal. (1 mark)



NOTE: This again takes the concept of energy not requiring a direction and now applies it to actual changes in movement. Since the ramp and surface are covered in the same material, the same force will be experienced by the block throughout, making the work equation work for the entire distance of travel. The last potentially tricky bit is simply calculating the displacement vector, which simply relies on trigonometry for the most part.