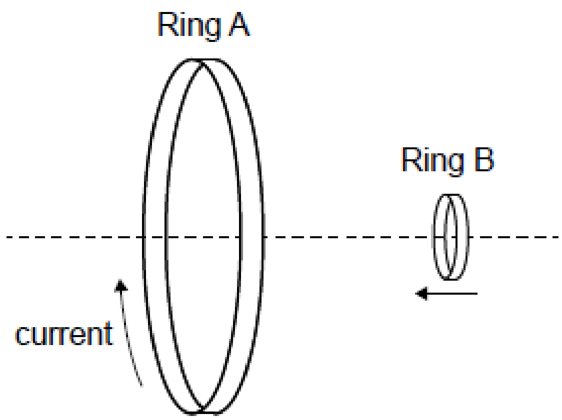
IBY1 A.3 Paper 2 [239 marks]

1. SPM.2.HL.TZ0.5

Two conducting rings, A and B, have their centres on the same line. The planes of A and B are parallel. There is a constant clockwise current in A. Ring A is stationary and ring B moves towards ring A at a constant speed.



(a) Outline why the magnetic flux in ring B increases.

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(b) State the direction of the induced current in ring B.

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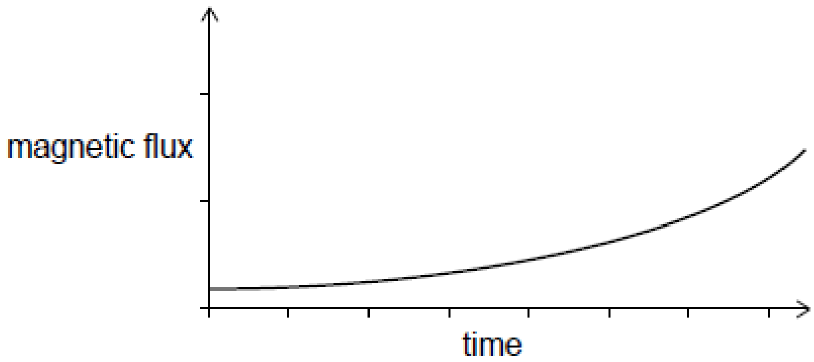
(c) The graph shows how the magnetic flux in ring B varies with time.



Discuss the variation with time of the induced current in ring B.

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(d) Outline why work must be done on ring B as it moves towards ring A at a constant speed.

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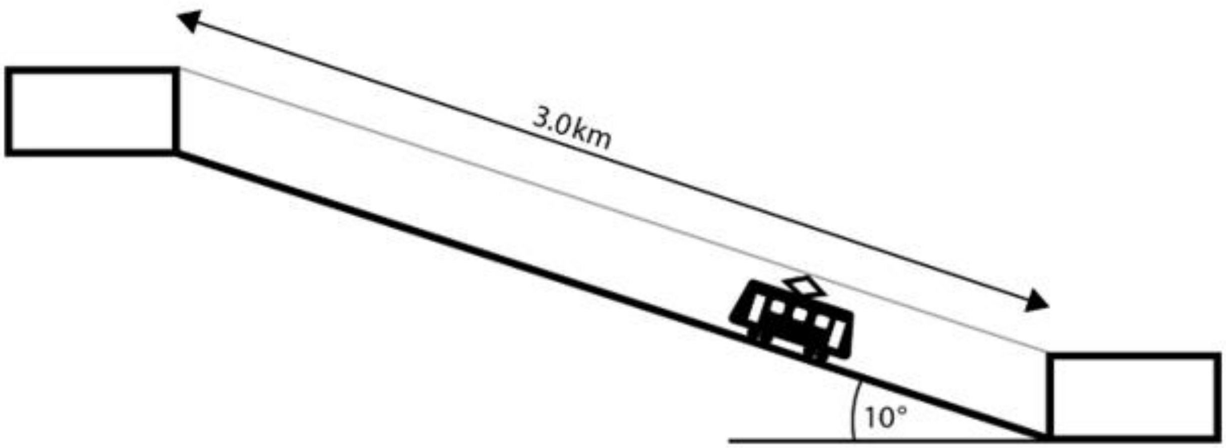
2. EXE.2.SL.TZ0.2

An Alpine village uses an electric tram system to transport visitors from a lower station up to an upper station at the village. The length of the tramline is 3.0 km and the gradient of the tramline is a constant 10°.



The tram has a weight of 5.0×10^4 N and can carry a maximum of 75 passengers of average weight 710 N.

The energy is supplied to each tram through a single overhead cable with a resistance per unit length of $0.024\ \Omega\ km^{-1}$. The tram rails are used for the return path of the current. The return path and the connections from the cable to the electric motor in the tram have negligible resistance.

The power supply maintains a constant emf of 500 V between the rails and the cable at the upper station.

Assume that the current through the motor is constant at 600 A and that the motor efficiency is always 0.90 for the entire range of voltages available to the tram.

(a) A tram is just leaving the lower railway station.

Determine, as the train leaves the lower station,

[[N/A]]

(a.i) the pd across the motor of the tram,

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√ $3.0\ \cancel{km} \cdot 0.024\ \Omega\ \cancel{km^{-1}} = 0.072\ \Omega$ of Total Resistance

~~$0.072\ \Omega \cdot 600\ A = 43.2\ \Omega A = 43.2\ V$~~

~~$pd = 43.2\ V$~~

pd = high voltage − low voltage // voltage difference.

$pd = 500\ V - (0.072\ \Omega \cdot 600\ A)$

$pd = 500\ V - 43.2\ V \cong 457\ V$

(a.ii) the mechanical power output of the motor.

$V = \frac{W}{Q}$ $\frac{J}{C}$

$Q = It$

$V = \frac{W}{It}$ $\frac{J}{As}$

$W = \frac{1}{2}mv^2$

$V = \frac{\frac{1}{2}mv^2}{It}$ $\frac{kg\,m^2 s^{-2}}{As}$

Voltage expressed in SI units is $kg\,m^2 s^{-3} A^{-1}$

$P = \frac{W}{t}$ $\frac{kg\,m^2 s^{-2}}{s} = \frac{kg(ms^{-1})^2}{s}$

[2]

$P = IV$

$P_{In} = (600\,A)(457\,V) = 274.2\,kW$

$P_{out} = 274.2\,kW \cdot 0.90 = 246.78\,kW \approx 247\,kW$

$P_{In} = 600\,\cancel{A} \cdot 457\,kg\,m^2 s^{-3} \cancel{A^{-1}} = 274.2\,kg\,m^2 s^{-3}$

. Where x is a possible value from the original formula.

$\frac{kg(ms^{-1})^2}{s}$

$\approx \frac{x(mv^2)}{t}$

Therefore, P = pd. C

(b) Discuss the variation in the power output of the motor with distance from the lower station.

[2]

Power output of the motor increases with distance from the lower station, as the gravitational potential energy increases in the tram.

(c) The total friction in the system acting on the tram is equivalent to an opposing force of 750 N.

For one particular journey, the tram is full of passengers.

Estimate the maximum speed v of the tram as it leaves the lower station.

[4]

$Q = mc\Delta T$

$\cancel{kg}\, J\, \cancel{kg^{-1}}\, \cancel{K^{-1}}\, \cancel{K}$

$= J$

$W = \frac{1}{2}mv^2 \therefore kg \cdot (ms^{-1})^2 = kgm^2s^{-2}$

P is measured in Watts. Therefore:

$P = Fv,\ v = \frac{P}{F}$

$v = \frac{247\ kW}{18679.2\ N}$

$\frac{kgm^{\cancel{2}}s^{-\cancel{3}2}}{\cancel{kgms^{-1}}} = ms^{-2}$

$v = \frac{247{,}000\ kgm^{\cancel{2}}s^{-2}}{18679.2\ \cancel{kgms^{-1}}} \approx 13.2\ ms^{-1}$

$\Sigma W = (5.0 \cdot 10^4 N + 75(76 N)) = 1.0325 \cdot 10^5 N$

$\Sigma F = 780 + (1.0325 \cdot 10^5)\sin(10)\ N$

$\Sigma F = 18679.2\ N$

(d) The tram travels at *v* throughout the journey. Two trams are available so that one is returning to the lower station on another line while the other is travelling to the village. The journeys take the same time.

It takes 1.5 minutes to unload and 1.5 minutes to load each tram. Ignore the time taken to accelerate the tram at the beginning and end of the journey.

Estimate the maximum number of passengers that can be carried up to the village in one hour.

[4]

$t = \frac{3000\,m}{13.2\,ms^{-1}} = 226.873\,s + 3(60)\,s = 406.873\,s$ per trip

$\frac{3600\,s}{406.873\,s} = 8.84798$ trips

8 trips can be made.

$8\ \cancel{\text{trips}} \cdot 75\ \text{passengers}/\cancel{\text{trip}} = 600$ passengers

Therefore, a maximum of 600 passengers can be carried up to the village in one hour.

(e) There are eight wheels on each tram with a brake system for each wheel. A pair of brake pads clamp firmly onto an annulus made of steel.

The train comes to rest from speed *v*. Ignore the energy transferred to the brake pads and the change in the gravitational potential energy of the tram during the braking.

Calculate the temperature change in each steel annulus as the tram comes to rest.

Data for this question

The inner radius of the annulus is 0.40 m and the outer radius is 0.50 m.

The thickness of the annulus is 25 mm.

The density of the steel is 7860 kg m^{-3}

The specific heat capacity of the steel is 420 J kg^{-1} K^{-1}

So close but I forgot PI in the GDC Arghh!!..!!

[4]

$A_a = \pi(0.50\,m)^2 - \pi(0.40\,m)^2 = 0.009\pi\ m^2$

$V_a = 0.009\pi\ m^2 \cdot 25\cdot10^{-3}\ m = 2.25\cdot10^{-3}\ m^3$ $7.07\cdot10^{-3}\ m^3$

$7860\ kg\,m^{-3} = \frac{m\ kg}{2.25\cdot10^{-3}\ m^3}$ 7.07

55.5702

$m = 7860\ kg\,\cancel{m^{-3}}(2.25\cdot10^{-3}\ \cancel{m^3}) = 17.685\ kg$ 7.07

By Law of Conservation of Energy, $\frac{1}{2}m_w v^2 = m_a c \Delta T$

$J = kg\,m^2 s^{-2}$

$\frac{\frac{1}{2}(5\cdot10^4)(13.2)^2\ \cancel{kg\,m^2 s^{-2}}}{17.685\ \cancel{kg}\cdot 420(\cancel{kg\,m^2 s^{-2}})K^{-1}\cancel{kg^{-1}}} = \Delta T$, $\Delta T \approx 559\ K$

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55.5702

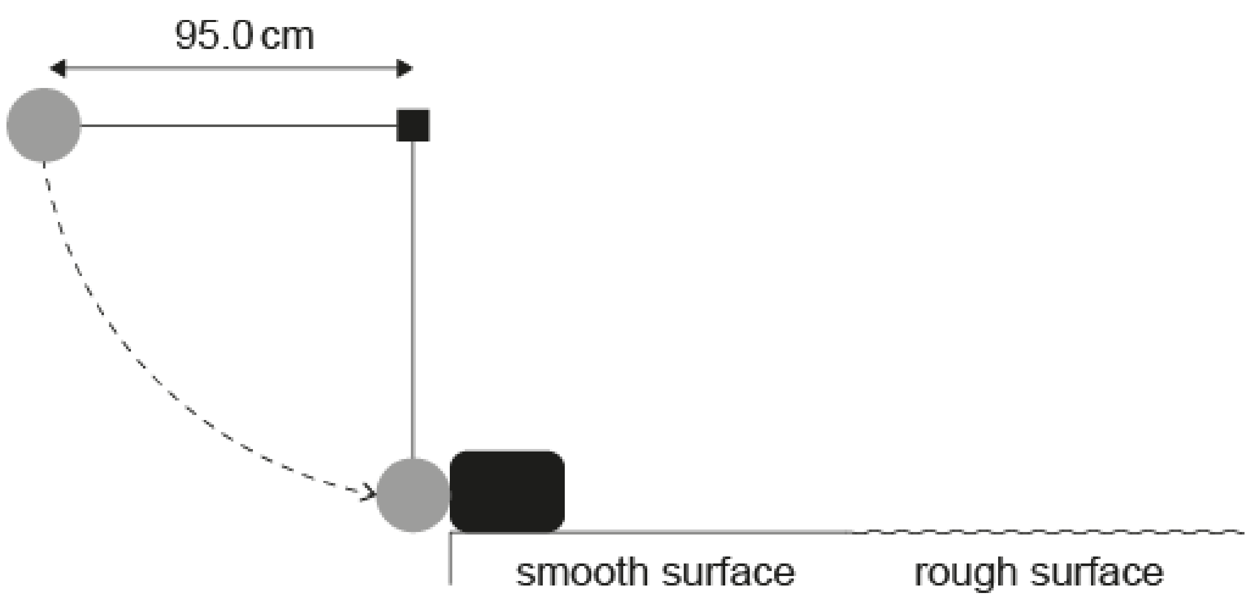
(f) The speed of the tram is measured by detecting a beam of microwaves of wavelength 2.8 cm reflected from the rear of the tram as it moves away from the station. Predict the change in wavelength of the microwaves at the stationary microwave detector in the station.

[2]

Wavelengths of microwaves at stationary microwave detector increase as detected frequency from train decreases.

3. 23M.2.SL.TZ1.1

A ball of mass 0.800 kg is attached to a string. The distance to the centre of the mass of the ball from the point of support is 95.0 cm. The ball is released from rest when the string is horizontal. When the string becomes vertical the ball collides with a block of mass 2.40 kg that is at rest on a horizontal surface.



(a) Just before the collision of the ball with the block,

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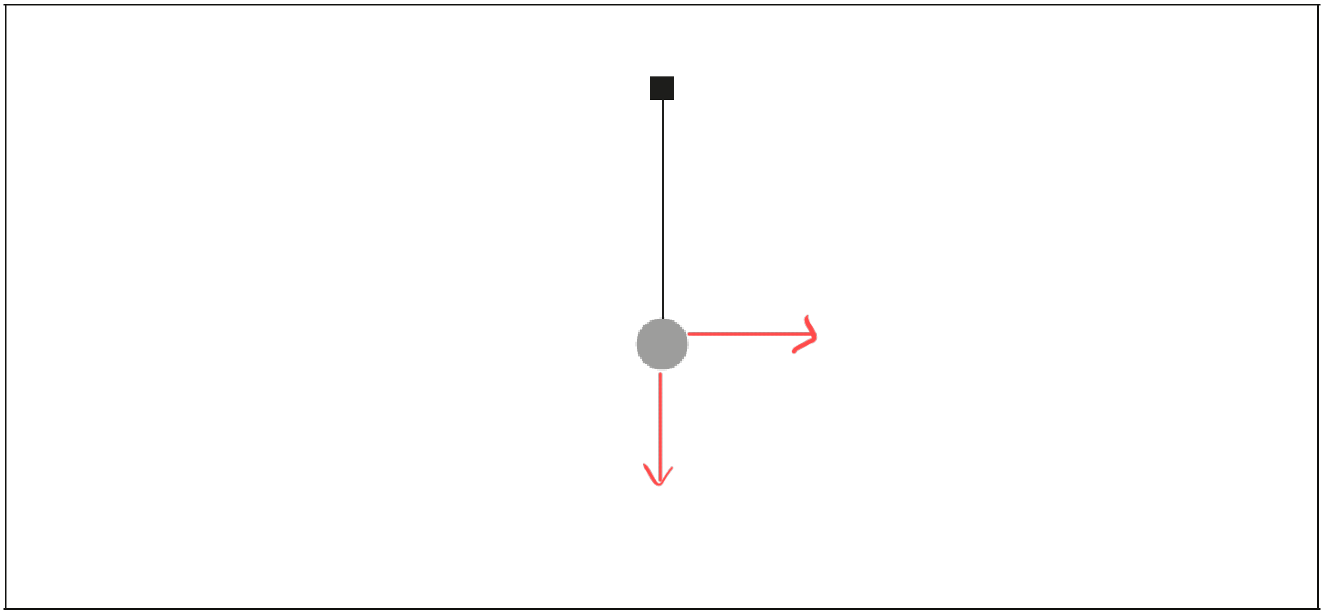
(a.i) draw a free-body diagram for the ball.



[2]

(a.ii) show that the speed of the ball is about 4.3 m s^{-1}.

[1]

$\frac{1}{2}\cancel{m}v^2 = \cancel{m}g(0.95)$

$\frac{1}{2}v^2 = 0.95g$

$v = \sqrt{1.9g}$

$v \approx 4.32\ ms^{-1}$

(a.iii) determine the tension in the string.

[2]

$T = F = ma$
$T = (0.8)(9.81)$
$T \approx 7.85\,N$

(b) After the collision, the ball rebounds and the block moves with speed 2.16 m s^{-1}.

[[N/A]]

(b.i) Show that the collision is elastic.

[4]

$0.8 \cdot 4.3 = 0.8 \cdot V + 2.4 \cdot 2.16$
$3.44 = 0.8v + 5.184$
$-1.744 = 0.8V$
$V = -2.18$

$\frac{1}{2}(0.8)(4.3)^2 = \frac{1}{2}(0.8)(-2.18)^2 + \frac{1}{2}(2.4)(2.16)^2$
$7.396 = 7.396$

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(b.ii) Calculate the maximum height risen by the centre of the ball.

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$\theta = \frac{s}{r}$

$0 = (-2.18)^2 + 2(9.81)s$?

$-4.7524 = 19.62s$

$s = 0.242\ \text{m}$

$\theta = \frac{0.242}{0.95} \approx 0.255\ \text{m}$

(c) The coefficient of dynamic friction between the block and the rough surface is 0.400.

Estimate the distance travelled by the block on the rough surface until it stops.

[3]

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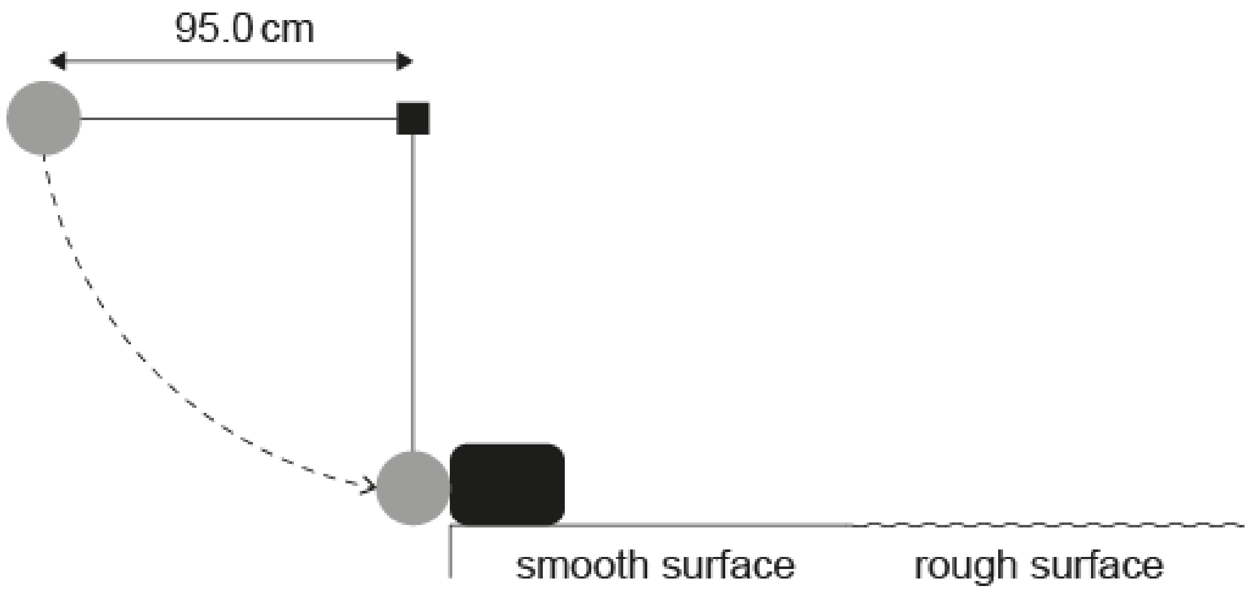
4. 23M.2.HL.TZ1.1

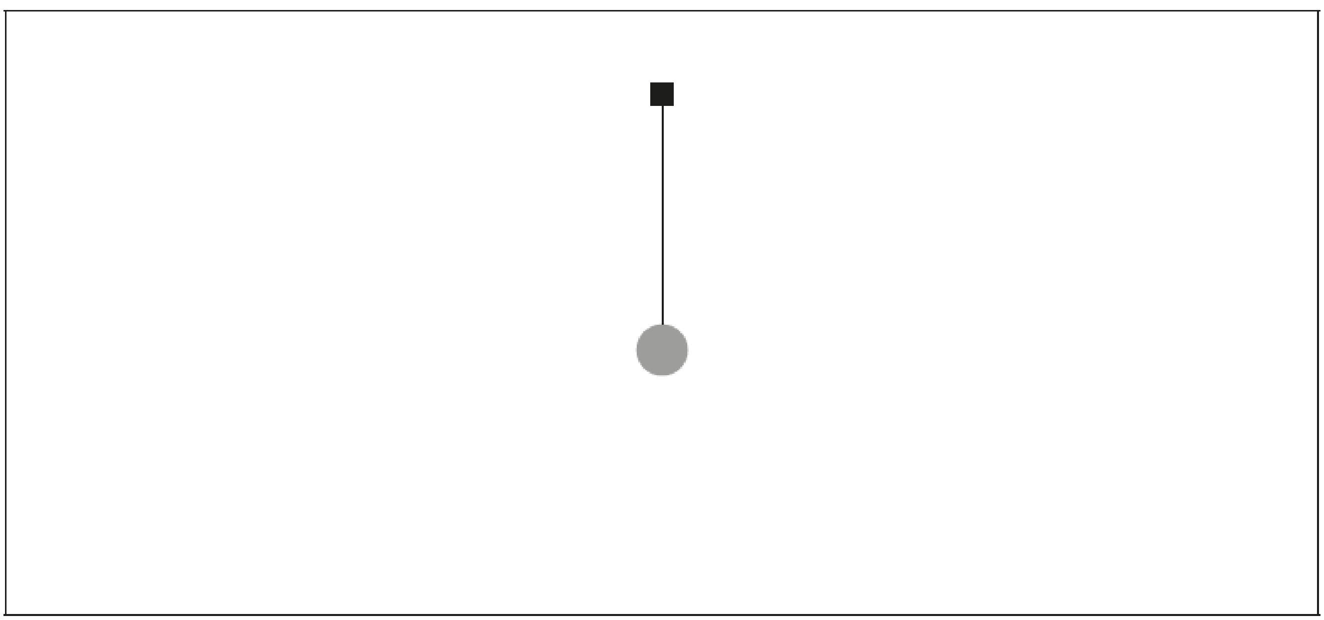
A ball of mass 0.800 kg is attached to a string. The distance to the centre of the mass of the ball from the point of support is 95.0 cm. The ball is released from rest when the string is horizontal. When the string becomes vertical the ball collides with a block of mass 2.40 kg that is at rest on a horizontal surface.



(a) Just before the collision of the ball with the block,

[[N/A]]

(a.i) draw a free-body diagram for the ball.



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(a.ii) show that the speed of the ball is about 4.3 m s^{-1}.

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(a.iii) determine the tension in the string.

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(b) After the collision, the ball rebounds and the block moves with speed $2.16\,\mathrm{m\,s^{-1}}$.

[[N/A]]

(b.i) Show that the collision is elastic.

[4]

(b.ii) Calculate the maximum height risen by the centre of the ball.

[2]

(c) The coefficient of dynamic friction between the block and the rough surface is 0.400.

Estimate the distance travelled by the block on the rough surface until it stops.

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5. 23M.2.SL.TZ1.a

The moment of inertia of the rod about the axis is 0.180 kg m^2. Show that the moment of inertia of the rod–particle system is about 0.25 kg m^2.

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6. 23M.2.SL.TZ1.a

The moment of inertia of the rod about the axis is 0.180 kg m^2. Show that the moment of inertia of the rod–particle system is about 0.25 kg m^2.

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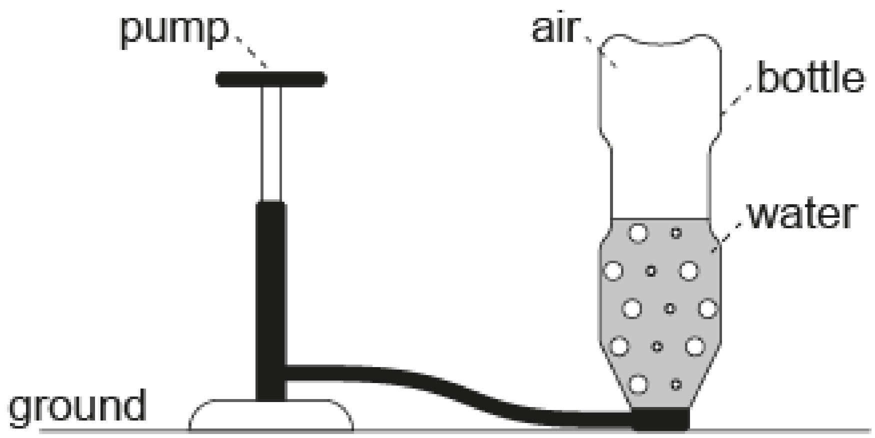
7. 23M.2.HL.TZ2.1

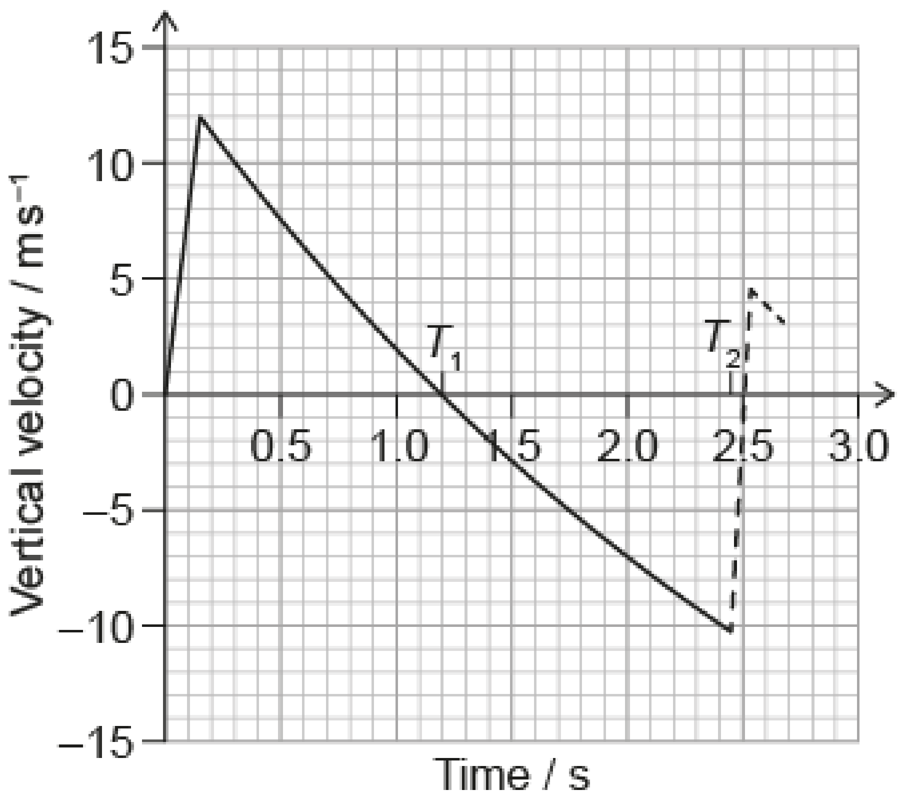
A toy rocket is made from a plastic bottle that contains some water.

Air is pumped into the vertical bottle until the pressure inside forces water and air out of the bottle. The bottle then travels vertically upwards.



The air–water mixture is called the propellant.

The variation with time of the vertical velocity of the bottle is shown.



The bottle reaches its highest point at time T_1 on the graph and returns to the ground at time T_2. The bottle then bounces. The motion of the bottle after the bounce is shown as a dashed line.

(a) Estimate, using the graph, the maximum height of the bottle.

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(b) Estimate the acceleration of the bottle when it is at its maximum height.

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(c) The bottle bounces when it returns to the ground.

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(c.i) Calculate the fraction of the kinetic energy of the bottle that remains after the bounce.

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(c.ii) The mass of the bottle is 27 g and it is in contact with the ground for 85 ms.

Determine the average force exerted by the ground on the bottle. Give your answer to an appropriate number of significant figures.

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(d) The maximum height reached by the bottle is greater with an air–water mixture than with only high-pressure air in the bottle.

Assume that the speed at which the propellant leaves the bottle is the same in both cases.

Explain why the bottle reaches a greater maximum height with an air–water mixture.

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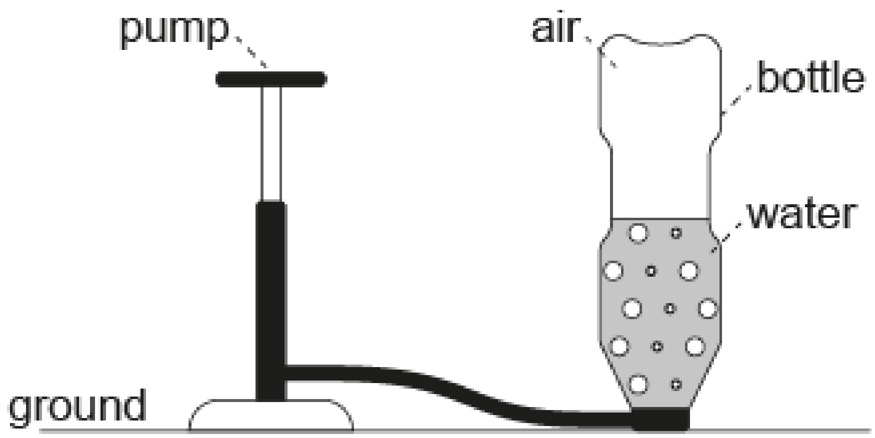
8. 23M.2.SL.TZ2.1

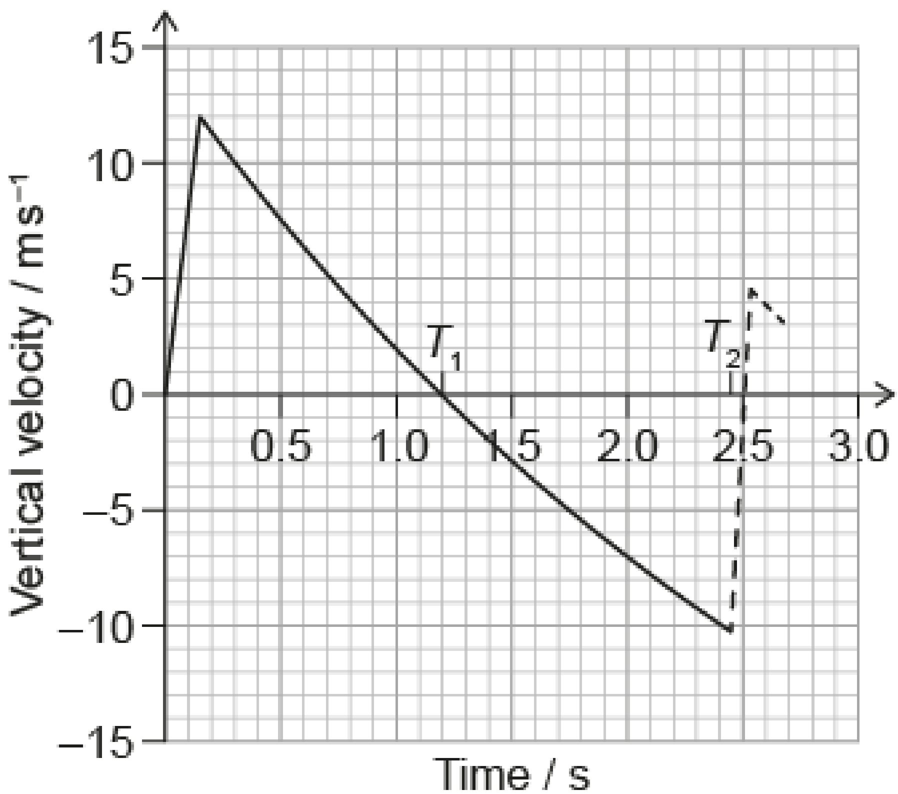
A toy rocket is made from a plastic bottle that contains some water.

Air is pumped into the vertical bottle until the pressure inside forces water and air out of the bottle. The bottle then travels vertically upwards.



The air–water mixture is called the propellant.

The variation with time of the vertical velocity of the bottle is shown.



The bottle reaches its highest point at time T_1 on the graph and returns to the ground at time T_2. The bottle then bounces. The motion of the bottle after the bounce is shown as a dashed line.

(a) Estimate, using the graph, the maximum height of the bottle.

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(b) Estimate the acceleration of the bottle when it is at its maximum height.

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(c) The bottle bounces when it returns to the ground.

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(c.i) Calculate the fraction of the kinetic energy of the bottle that remains after the bounce.

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(c.ii) The mass of the bottle is 27 g and it is in contact with the ground for 85 ms.

Determine the average force exerted by the ground on the bottle. Give your answer to an appropriate number of significant figures.

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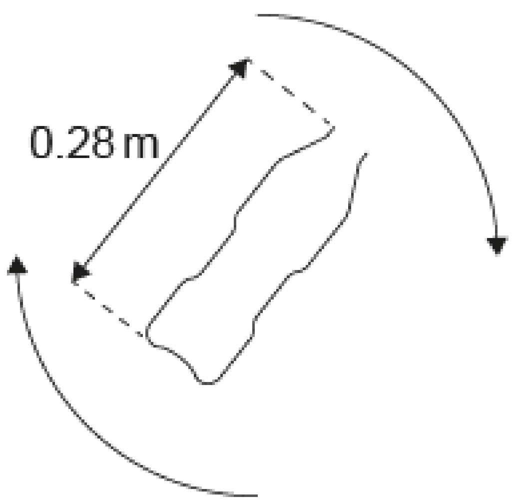
(d) After a second bounce, the bottle rotates about its centre of mass. The bottle rotates at 0.35 revolutions per second.



The centre of mass of the bottle is halfway between the base and the top of the bottle. Assume that the velocity of the centre of mass is zero.

Calculate the linear speed of the top of the bottle.

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(e) The maximum height reached by the bottle is greater with an air–water mixture than with only high-pressure air in the bottle.

Assume that the speed at which the propellant leaves the bottle is the same in both cases.

Explain why the bottle reaches a greater maximum height with an air–water mixture.

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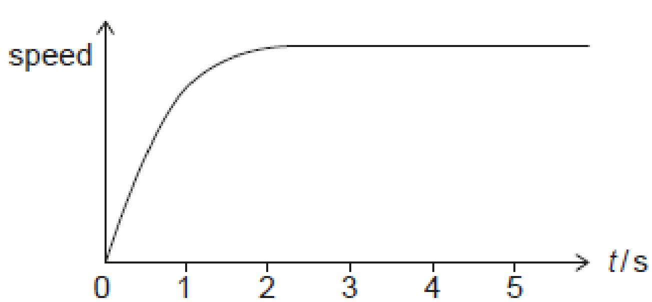
9. 22N.2.SL.TZ0.1

A raindrop falls vertically from rest.

The graph shows how the speed of the raindrop varies with time t.



During the first 3.0 s of motion, the raindrop falls a distance of 21 m and reaches a speed of 9.0 m s^{-1}. The mass of the raindrop is 34 mg. The temperature of the raindrop does not change.

(a) State the initial acceleration of the raindrop.

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(b) Explain, by reference to the vertical forces, how the raindrop reaches a constant speed.

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(c.i) Determine the energy transferred to the air during the first 3.0 s of motion. State your answer to an appropriate number of significant figures.

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(c.ii) Describe the energy change that takes place for $t > 3.0$ s.

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10. 22N.2.SL.TZ0.6

Polonium-210 (Po-210) decays by alpha emission into lead-206 (Pb-206).

The following data are available.

Nuclear mass of Po-210 = 209.93676 u

Nuclear mass of Pb-206 = 205.92945 u

Mass of the alpha particle = 4.00151 u

(a) Outline, by reference to nuclear binding energy, why the mass of a nucleus is less than the sum of the masses of its constituent nucleons.

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(b.i) Calculate, in MeV, the energy released in this decay.

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(b.ii) The polonium nucleus was stationary before the decay.

Show, by reference to the momentum of the particles, that the kinetic energy of the alpha particle is much greater than the kinetic energy of the lead nucleus.

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(b.iii) In the decay of polonium-210, alpha emission can be followed by the emission of a gamma photon.

State and explain whether the alpha particle or gamma photon will cause greater ionization in the surrounding material.

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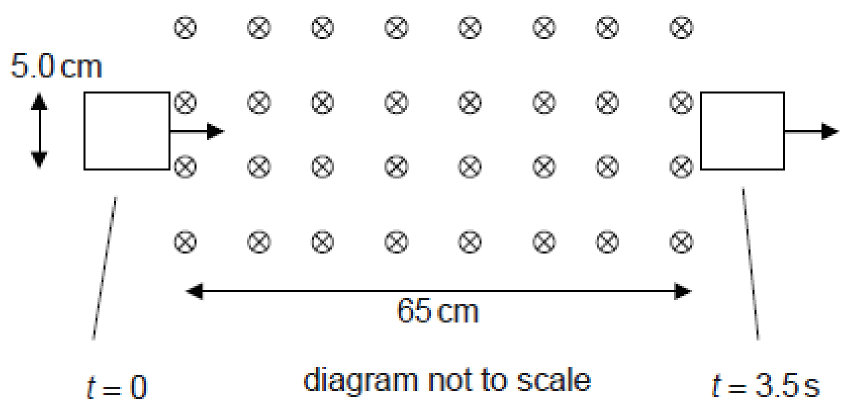
11. 21N.2.HL.TZ0.5

A square loop of side 5.0 cm enters a region of uniform magnetic field at t = 0. The loop exits the region of magnetic field at t = 3.5 s. The magnetic field strength is 0.94 T and is directed into the plane of the paper. The magnetic field extends over a length 65 cm. The speed of the loop is constant.



(a) Show that the speed of the loop is 20 cm s^{-1}.

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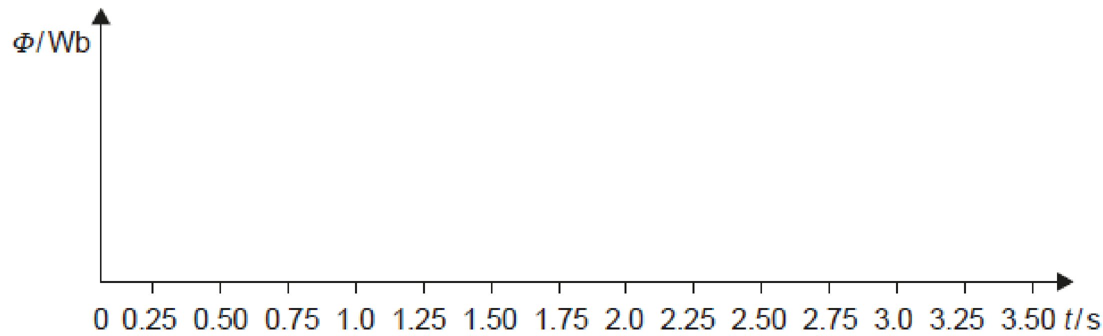
(b.i) Sketch, on the axes, a graph to show the variation with time of the magnetic flux linkage Φ in the loop.



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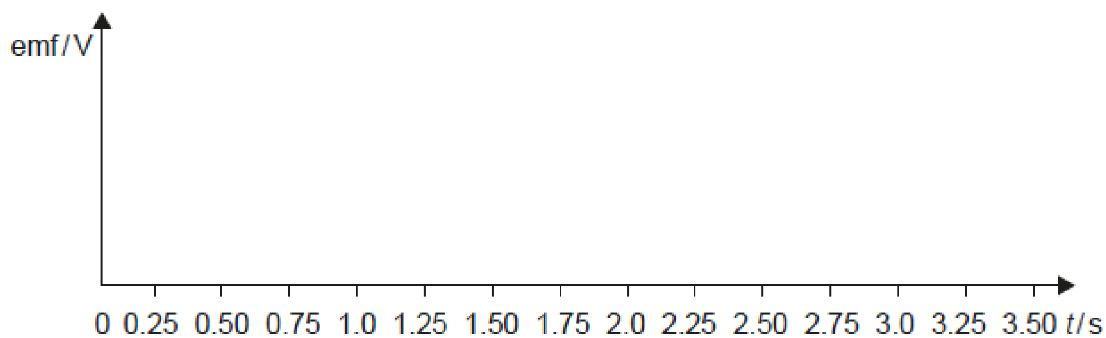
(b.ii) Sketch, on the axes, a graph to show the variation with time of the magnitude of the emf induced in the loop.



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(c.i) There are 85 turns of wire in the loop. Calculate the maximum induced emf in the loop.

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(c.ii) The resistance of the loop is 2.4 Ω. Calculate the magnitude of the magnetic force on the loop as it enters the region of magnetic field.

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(d.i) Show that the energy dissipated in the loop from $t = 0$ to $t = 3.5$ s is 0.13 J.

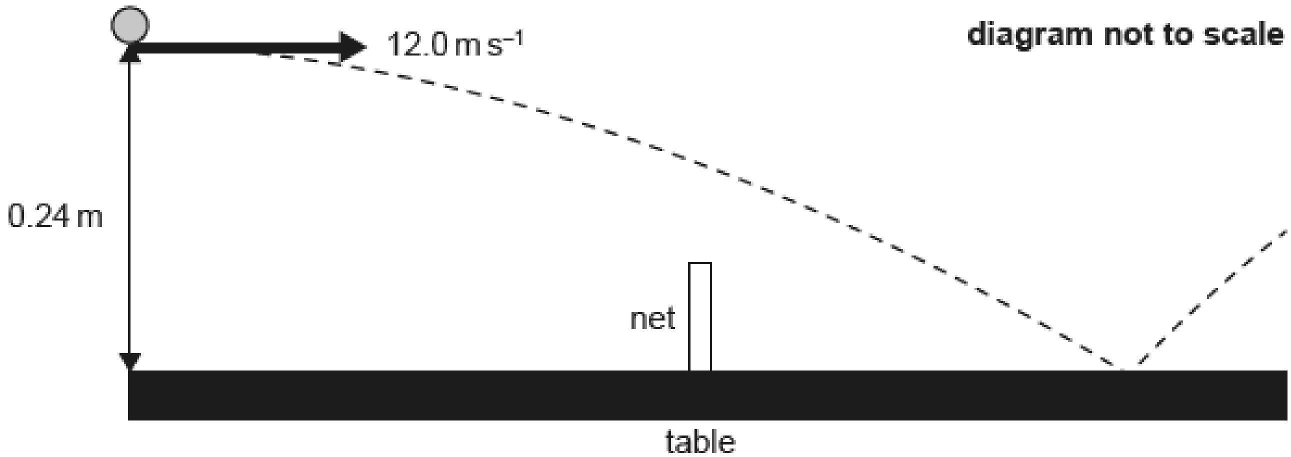
[2]

(d.ii) The mass of the wire is 18 g. The specific heat capacity of copper is 385 J kg^{-1} K^{-1}. Estimate the increase in temperature of the wire.

[2]

12. 21M.2.SL.TZ1.1

Two players are playing table tennis. Player A hits the ball at a height of 0.24 m above the edge of the table, measured from the top of the table to the bottom of the ball. The initial speed of the ball is 12.0 m s^{-1} horizontally. Assume that air resistance is negligible.



The ball bounces and then reaches a peak height of 0.18 m above the table with a horizontal speed of 10.5 m s^{-1}. The mass of the ball is 2.7 g.

(a) Show that the time taken for the ball to reach the surface of the table is about 0.2 s.

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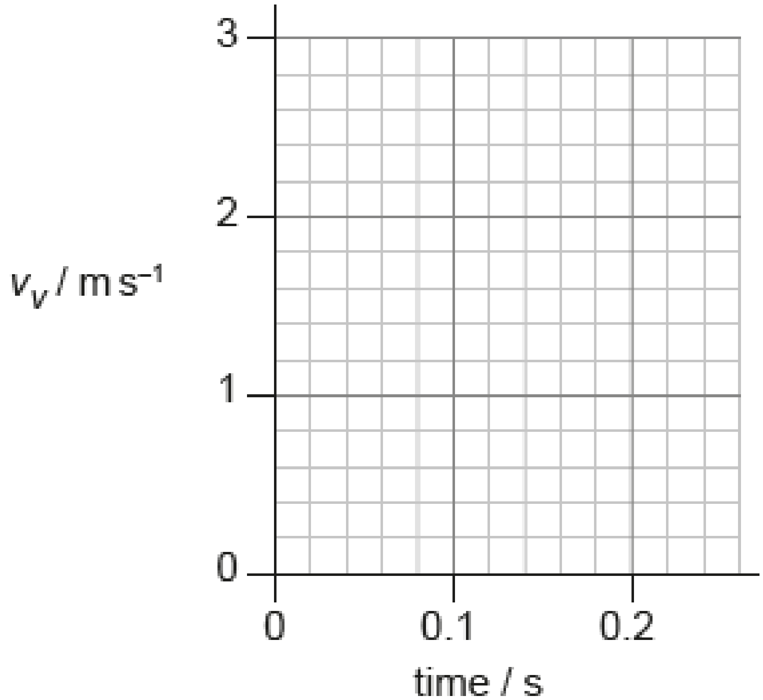
(b) Sketch, on the axes, a graph showing the variation with time of the vertical component of velocity v_v of the ball until it reaches the table surface. Take g to be +10 m s^{-2}.



[2]

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(c) The net is stretched across the middle of the table. The table has a length of 2.74 m and the net has a height of 15.0 cm.

Show that the ball will go over the net.

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(d.i) Determine the kinetic energy of the ball immediately after the bounce.

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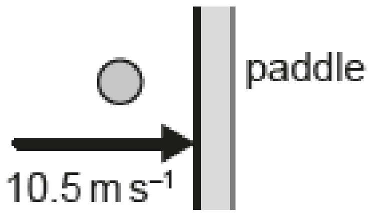
(d.ii) Player B intercepts the ball when it is at its peak height. Player B holds a paddle (racket) stationary and vertical. The ball is in contact with the paddle for 0.010 s. Assume the collision is elastic.



Calculate the average force exerted by the ball on the paddle. State your answer to an appropriate number of significant figures.

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13. 21M.2.SL.TZ2.6

A photovoltaic cell is supplying energy to an external circuit. The photovoltaic cell can be modelled as a practical electrical cell with internal resistance.

The intensity of solar radiation incident on the photovoltaic cell at a particular time is at a maximum for the place where the cell is positioned.

The following data are available for this particular time:

Operating current = 0.90 A
Output potential difference to external circuit = 14.5 V
Output emf of photovoltaic cell = 21.0 V
Area of panel = 350 mm × 450 mm

(a) Explain why the output potential difference to the external circuit and the output emf of the photovoltaic cell are different.

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(b) Calculate the internal resistance of the photovoltaic cell for the maximum intensity condition using the model for the cell.

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(c) The maximum intensity of sunlight incident on the photovoltaic cell at the place on the Earth's surface is $680\,\mathrm{W\,m^{-2}}$.

A measure of the efficiency of a photovoltaic cell is the ratio

$$\frac{\text{energy available every second to the external circuit}}{\text{energy arriving every second at the photovoltaic cell surface}}.$$

Determine the efficiency of this photovoltaic cell when the intensity incident upon it is at a maximum.

[3]

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(d) State **two** reasons why future energy demands will be increasingly reliant on sources such as photovoltaic cells.

Reason 1: . . . .

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Reason 2: . . . .

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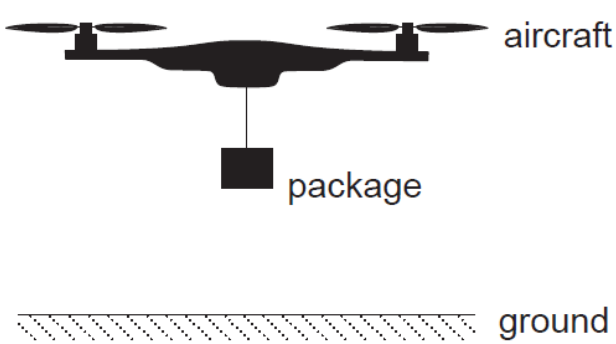
14. 20N.2.HL.TZ0.1

A company delivers packages to customers using a small unmanned aircraft. Rotating horizontal blades exert a force on the surrounding air. The air above the aircraft is initially stationary.



The air is propelled vertically downwards with speed v. The aircraft hovers motionless above the ground. A package is suspended from the aircraft on a string. The mass of the aircraft is 0.95 kg and the combined mass of the package and string is $0.45\ kg$. The mass of air pushed downwards by the blades in one second is $1.7\ kg$.

(a(i)) State the value of the resultant force on the aircraft when hovering.

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(a(ii)) Outline, by reference to Newton's third law, how the upward lift force on the aircraft is achieved.

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(a(iii)) Determine v. State your answer to an appropriate number of significant figures.

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(a(iv)) Calculate the power transferred to the air by the aircraft.

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(b) The package and string are now released and fall to the ground. The lift force on the aircraft remains unchanged. Calculate the initial acceleration of the aircraft.

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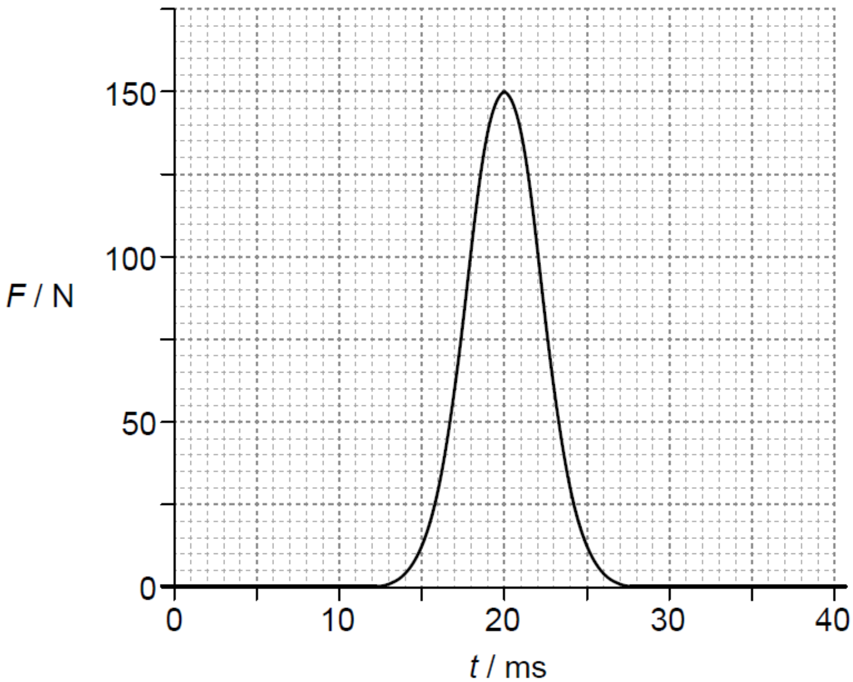
15. 19N.2.SL.TZ0.1

The graph shows the variation with time t of the horizontal force F exerted on a tennis ball by a racket.



The tennis ball was stationary at the instant when it was hit. The mass of the tennis ball is 5.8×10^{-2} kg. The area under the curve is 0.84 N s.

(a) Calculate the speed of the ball as it leaves the racket.

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(b) Show that the average force exerted on the ball by the racket is about 50 N.

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(c) Determine, with reference to the work done by the average force, the horizontal distance travelled by the ball while it was in contact with the racket.

[3]

(d) Draw a graph to show the variation with t of the horizontal speed v of the ball while it was in contact with the racket. Numbers are **not** required on the axes.

[2]

16. 19N.2.SL.TZ0.7

A stationary nucleus of uranium-238 undergoes alpha decay to form thorium-234.

The following data are available.

Energy released in decay	4.27 MeV
Binding energy per nucleon for helium	7.07 MeV
Binding energy per nucleon for thorium	7.60 MeV

(a) Radioactive decay is said to be "random" and "spontaneous". Outline what is meant by each of these terms.

Random:

Spontaneous:

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(b(i)) Calculate the binding energy per nucleon for uranium-238.

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(b(ii)) Calculate the ratio $\frac{kinetic\ energy\ of\ alpha\ particle}{kinetic\ energy\ of\ thorium\ nucleus}$.

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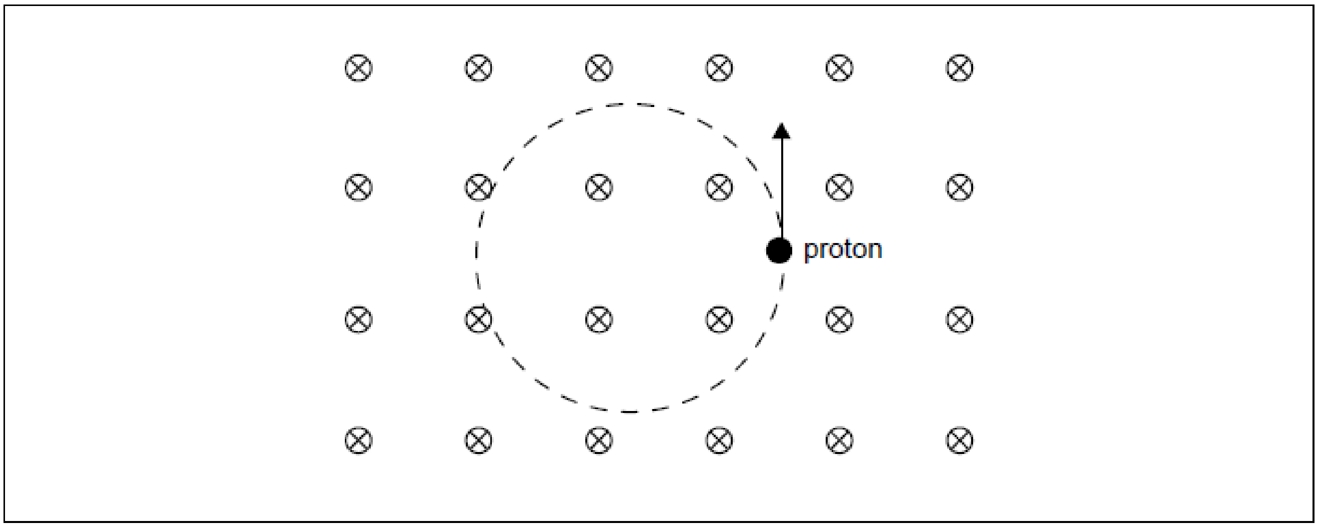
17. 19N.2.SL.TZ0.4

A proton is moving in a region of uniform magnetic field. The magnetic field is directed into the plane of the paper. The arrow shows the velocity of the proton at one instant and the dotted circle gives the path followed by the proton.



The speed of the proton is 2.0×10^6 m s^{-1} and the magnetic field strength B is 0.35 T.

(a) Explain why the path of the proton is a circle.

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(b(i)) Show that the radius of the path is about 6 cm.

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(b(ii)) Calculate the time for **one** complete revolution.

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(c) Explain why the kinetic energy of the proton is constant.

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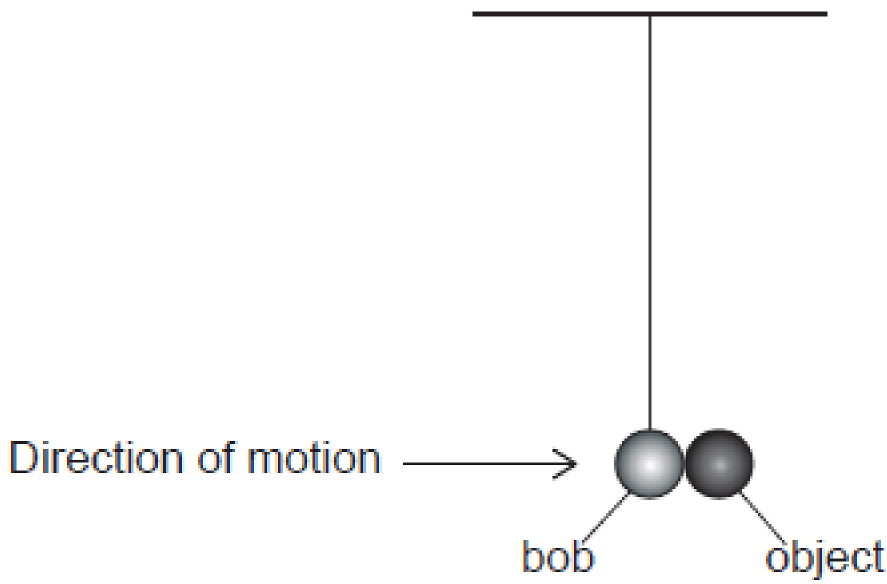
18. 19M.2.SL.TZ1.5

A small metal pendulum bob of mass 75 g is suspended at rest from a fixed point with a length of thread of negligible mass. Air resistance is negligible. The bob is then displaced to the left.

At time t = 0 the bob is moving horizontally to the right at 0.8 m s^{-1}. It collides with a small stationary object also of mass 75 g. Both objects then move together with motion that is simple harmonic.



(a) Calculate the speed of the combined masses immediately after the collision.

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(b) Show that the collision is inelastic.

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(c) Describe the changes in gravitational potential energy of the oscillating system from $t = 0$ as it oscillates through one cycle of its motion.

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19. 19M.2.HL.TZ1.5

The moon Phobos moves around the planet Mars in a circular orbit.

(a.i) Outline the origin of the force that acts on Phobos.

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(a.ii) Outline why this force does no work on Phobos.

[1]

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(b.i) The orbital period *T* of a moon orbiting a planet of mass *M* is given by

$$\frac{R^3}{T^2} = kM$$

where *R* is the average distance between the centre of the planet and the centre of the moon.

Show that $k = \frac{G}{4\pi^2}$

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(b.ii) The following data for the Mars–Phobos system and the Earth–Moon system are available:

Mass of Earth = 5.97×10^{24} kg

The Earth–Moon distance is 41 times the Mars–Phobos distance.

The orbital period of the Moon is 86 times the orbital period of Phobos.

Calculate, in kg, the mass of Mars.

[2]

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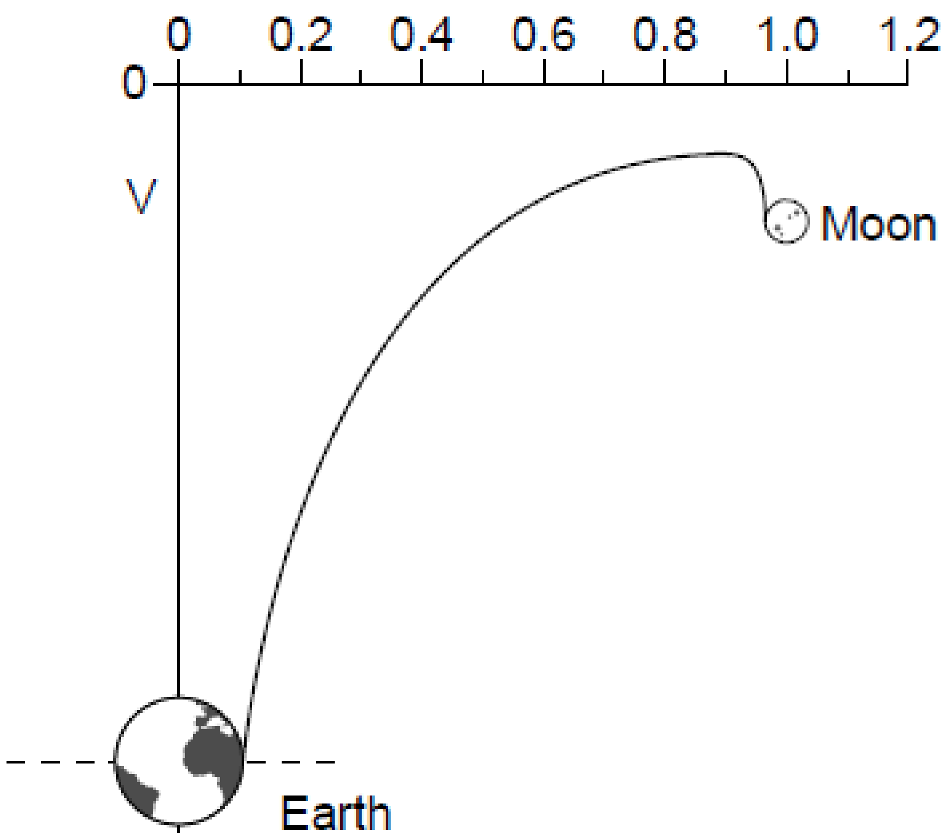
(c) The graph shows the variation of the gravitational potential between the Earth and Moon with distance from the centre of the Earth. The distance from the Earth is expressed as a fraction of the total distance between the centre of the Earth and the centre of the Moon.



Determine, using the graph, the mass of the Moon.

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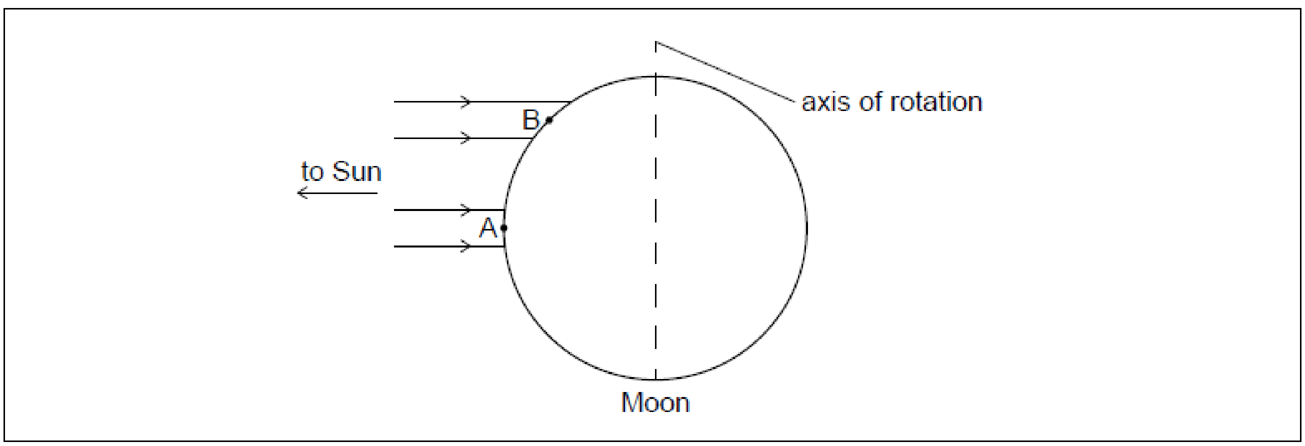
20. 19M.2.SL.TZ1.6

The Moon has no atmosphere and orbits the Earth. The diagram shows the Moon with rays of light from the Sun that are incident at 90° to the axis of rotation of the Moon.



(a.i) A black body is on the Moon’s surface at point A. Show that the maximum temperature that this body can reach is 400 K. Assume that the Earth and the Moon are the same distance from the Sun.

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(a.ii) Another black body is on the Moon’s surface at point B.

Outline, without calculation, why the aximum temperature of the black body at point B is less than at point A.

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(b) The albedo of the Earth’s atmosphere is 0.28. Outline why the maximum temperature of a black body on the Earth when the Sun is overhead is less than that at point A on the Moon.

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(c.i) Outline why a force acts on the Moon.

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(c.ii) Outline why this force does no work on the Moon.

[1]

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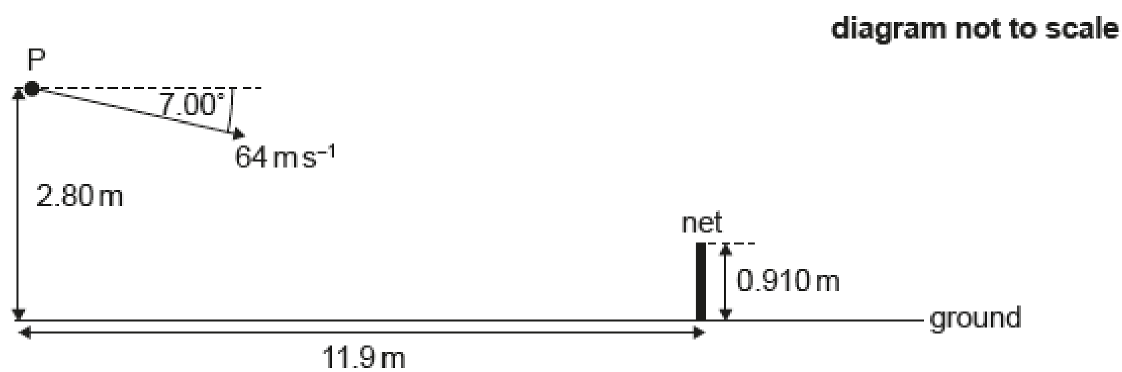
21. 19M.2.SL.TZ2.1

A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of 64 m s^{-1}. The ball has a mass of 0.058 kg and the contact between the ball and the racquet lasts for 25 ms.

The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of 7.00° to the horizontal.



The following data are available.

Height of P = 2.80 m

Distance of student from net = 11.9 m

Height of net = 0.910 m

Initial speed of tennis ball = 64 m s^{-1}

(ai) Calculate the average force exerted by the racquet on the ball.

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(aii) Calculate the average power delivered to the ball during the impact.

[2]

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(bi) Calculate the time it takes the tennis ball to reach the net.

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(bii) Show that the tennis ball passes over the net.

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(biii) Determine the speed of the tennis ball as it strikes the ground.

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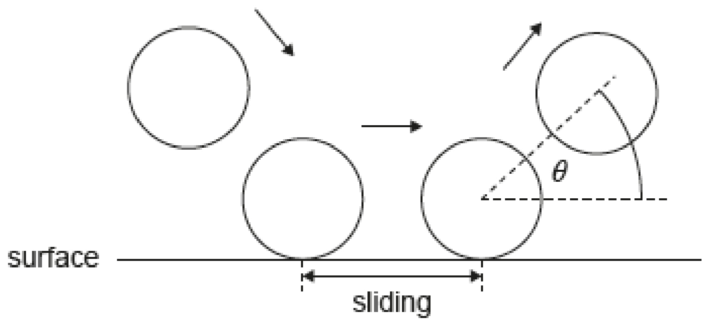
(c) The student models the bounce of the tennis ball to predict the angle θ at which the ball leaves a surface of clay and a surface of grass.



The model assumes

• during contact with the surface the ball slides.
• the sliding time is the same for both surfaces.
• the sliding frictional force is greater for clay than grass.
• the normal reaction force is the same for both surfaces.

Predict for the student's model, without calculation, whether θ is greater for a clay surface or for a grass surface.

[3]

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22. 19M.2.SL.TZ2.2

A container of volume 3.2 × 10-6 m^3 is filled with helium gas at a pressure of 5.1×10^5 Pa and temperature 320 K. Assume that this sample of helium gas behaves as an ideal gas.

A helium atom has a volume of 4.9×10^{-31} m^3.

(a) The molar mass of helium is 4.0 g mol^{-1}. Show that the mass of a helium atom is 6.6×10^{-27} kg.

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(b) Estimate the average speed of the helium atoms in the container.

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(c) Show that the number of helium atoms in the container is about 4×10^{20}.

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(di) Calculate the ratio $\frac{\text{total volume of helium atoms}}{\text{volume of helium gas}}$.

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(dii) Explain, using your answer to (d)(i) and with reference to the kinetic model, why this sample of helium can be assumed to be an ideal gas.

[2]

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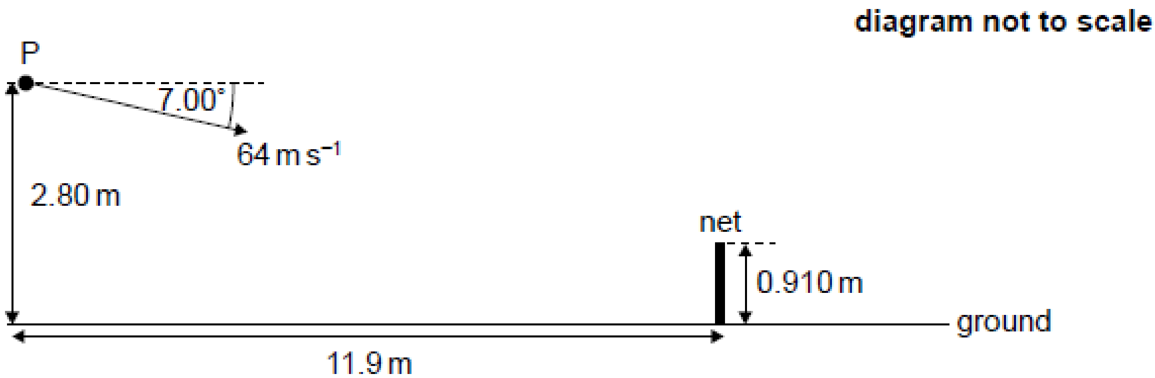
23. 19M.2.HL.TZ2.1

A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of 64 m s^{-1}. The ball has a mass of 0.058 kg and the contact between the ball and the racquet lasts for 25 ms.

The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of 7.00° to the horizontal.



The following data are available.

Height of P = 2.80 m
Distance of student from net = 11.9 m
Height of net = 0.910 m
Initial speed of tennis ball = 64 m s^{-1}

(ai) Calculate the average force exerted by the racquet on the ball.

[2]

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(aii) Calculate the average power delivered to the ball during the impact.

[2]

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(bi) Calculate the time it takes the tennis ball to reach the net.

[2]

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(bii) Show that the tennis ball passes over the net.

[3]

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(biii) Determine the speed of the tennis ball as it strikes the ground.

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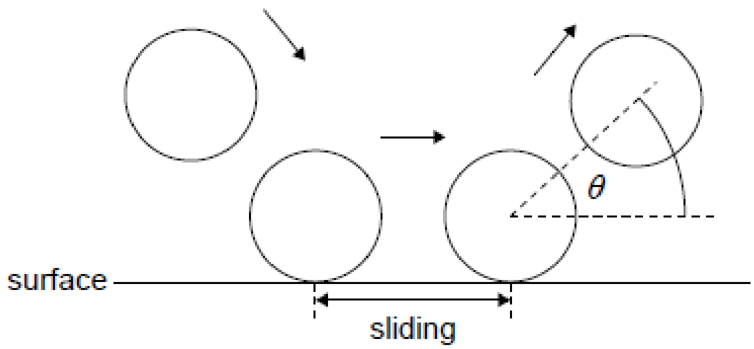
(c) A student models the bounce of the tennis ball to predict the angle θ at which the ball leaves a surface of clay and a surface of grass.



The model assumes

- during contact with the surface the ball slides.
- the sliding time is the same for both surfaces.
- the sliding frictional force is greater for clay than grass.
- the normal reaction force is the same for both surfaces.

Predict for the student’s model, without calculation, whether θ is greater for a clay surface **or** for a grass surface.

[3]

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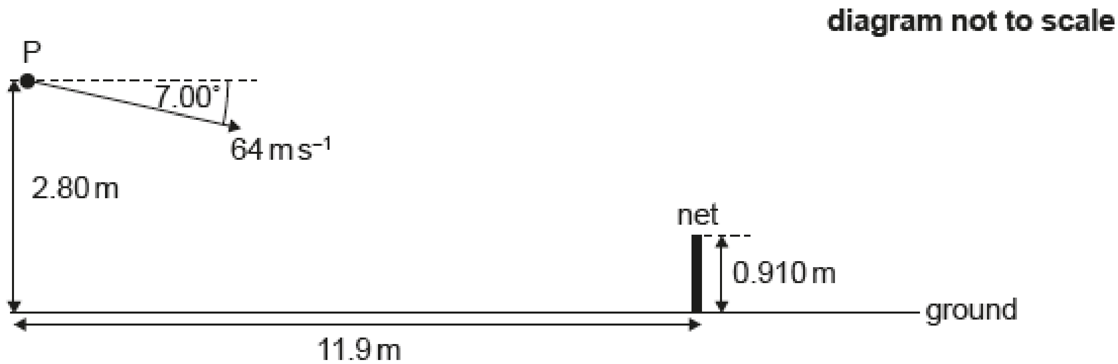
24. 19M.2.SL.TZ2.1

A student strikes a tennis ball that is initially at rest so that it leaves the racquet at a speed of 64 m s^{-1}. The ball has a mass of 0.058 kg and the contact between the ball and the racquet lasts for 25 ms.

The student strikes the tennis ball at point P. The tennis ball is initially directed at an angle of 7.00° to the horizontal.



The following data are available.

Height of P = 2.80 m

Distance of student from net = 11.9 m

Height of net = 0.910 m

Initial speed of tennis ball = 64 m s^{-1}

(ai) Calculate the average force exerted by the racquet on the ball.

[2]

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(aii) Calculate the average power delivered to the ball during the impact.

[2]

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(bi) Calculate the time it takes the tennis ball to reach the net.

[2]

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(bii) Show that the tennis ball passes over the net.

[3]

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(biii) Determine the speed of the tennis ball as it strikes the ground.

[2]

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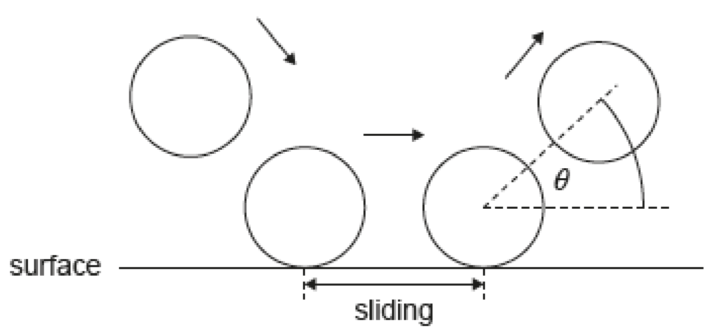
(c) The student models the bounce of the tennis ball to predict the angle θ at which the ball leaves a surface of clay and a surface of grass.



The model assumes

- during contact with the surface the ball slides.
  - the sliding time is the same for both surfaces.
  - the sliding frictional force is greater for clay than grass.
  - the normal reaction force is the same for both surfaces.

Predict for the student's model, without calculation, whether θ is greater for a clay surface or for a grass surface.

[3]

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