IB · IB DIPLOMA PROGRAMME PHYSICS · FIRST ASSESSMENT 2025

Theme A · Space, time and motion

Kinematics, forces and momentum, work energy and power, and — at HL — rigid body mechanics and Galilean and special relativity.

SUGGESTED TIME	TOTAL MARKS	QUESTIONS	MULTIPLE CHOICE
60 minutes	**55**	**10**	**6**

SECTION	**A · Space, time and motion**
IN THE FORMAT OF	Paper 1A (multiple choice), Paper 1B (data-based), and Paper 2 (short answer and extended response)
ROUTES	SL only — 7 questions, 39 marks. SL and HL — the whole paper, 10 questions, 55 marks. Every question is tagged in the left margin.
DEMAND	**Routine 3 · Demanding 6 · Discriminating 1** *The command term sets the demand, and the papers are written that way. "State" earns one mark for one line; "explain" is not creditworthy without a mechanism; "discuss" and "evaluate" need both sides weighed before a conclusion is reached. The extended-response part that closes each Paper 2 question is where HL candidates separate from one another, and those parts are pitched there rather than at the level of the calculation before them.*
SYLLABUS POINTS	A.1 · A.2 · A.3 · A.4 · A.5

INSTRUCTIONS

- Answer all questions in the spaces provided.
- Show your working. Method marks are awarded even where the final answer is wrong.
- Give your answers to a sensible number of significant figures, with a unit.
- The mark scheme for this paper follows the last question.

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THE PAPER

Theme A · Space, time and motion

Answer all questions. 55 marks in 60 minutes.

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1 SL

MULTIPLE CHOICE · ROUTINE · A.1 **[1]**

A ball is launched from level ground at 20 m s^{-1} at an angle of 30° above the horizontal. Air resistance is negligible. How long does the ball take to reach its maximum height?

A 0.51 s

B 1.0 s

C 1.8 s

D 2.0 s

Answer ☐

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2 SL

MULTIPLE CHOICE · DEMANDING · A.2 **[1]**

A book rests on a table. Which pair of forces is a Newton's third law pair?

A the weight of the book and the normal force of the table on the book

B the weight of the book and the force of the book on the table

C the normal force of the table on the book and the force of the book on the table

D the weight of the book and the weight of the table

Answer ☐

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3 SL

MULTIPLE CHOICE · ROUTINE · A.2 **[1]**

A resultant force acts on a stationary object of mass 0.50 kg. The force–time graph is a triangle rising from zero at t = 0 to a peak of 40 N at t = 0.10 s and falling back to zero at t = 0.20 s. What is the speed of the object at t = 0.20 s?

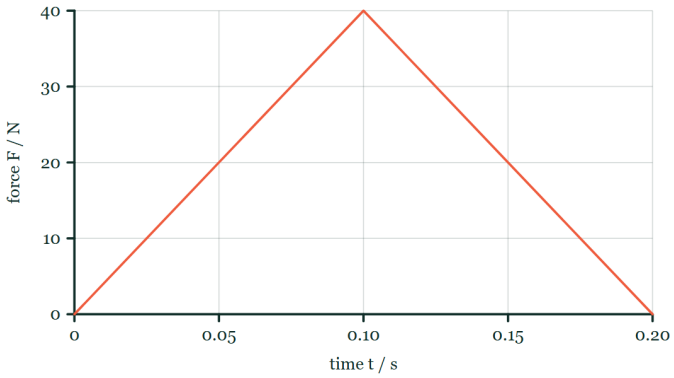

Figure 1 *A graph of force F / N against time t / s on gridded axes, the force axis marked 0 to 40 N and the time axis 0 to 0.20 s. The plotted line rises straight from the origin to 40 N at t = 0.10 s and falls straight back to zero at t = 0.20 s, so the trace is a triangle standing on the time axis.*

A 4.0 m s^{-1}

B 8.0 m s^{-1}

C 16 m s^{-1}

D 20 m s^{-1}

Answer ☐

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4 SL

MULTIPLE CHOICE · ROUTINE · A.3 **[1]**

A crane lifts a load of mass 250 kg through a vertical height of 12 m in 8.0 s at constant speed. What is the useful output power of the crane?

A 375 W

B 2.5 kW

C 3.7 kW

D 29 kW

Answer ☐

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5 HL

MULTIPLE CHOICE · DEMANDING · A.4 **[1]**

A disc of moment of inertia I rotates freely about a vertical axis at angular speed ω. A second, stationary disc of moment of inertia 2I is dropped onto it and the two rotate together. What is the new angular speed?

A ω/3

B ω/2

C 2ω/3

D 3ω

Answer

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6 HL

MULTIPLE CHOICE · DEMANDING · A.5 **[1]**

A spacecraft travels past Earth at 0.60c. A clock on board measures a time interval of 2.0 s between two events that occur at the same place on the spacecraft. What is the interval between those events as measured from Earth?

A 1.2 s

B 1.6 s

C 2.5 s

D 3.3 s

Answer

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7 SL

DATA ANALYSIS · DEMANDING · A.1 **[12]**

A student determines the acceleration of free fall using a simple pendulum. She measures the period T for several lengths L and processes the data as shown. Theory predicts $T = 2\pi\sqrt{(L/g)}$.

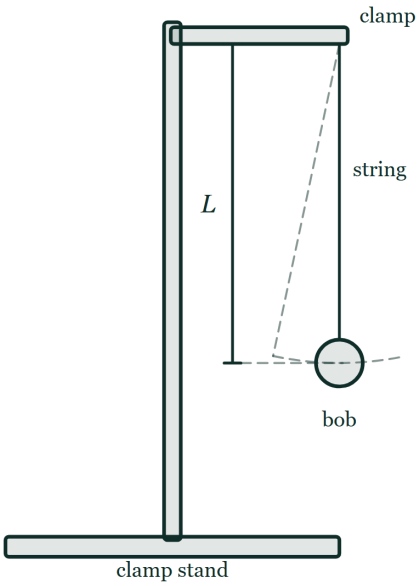

Figure 2 *Side view of the apparatus. A vertical rod in a heavy base carries a horizontal clamp arm, and a string hangs from the clamp jaws with a small spherical bob tied to its lower end. A dimension line beside the string marks the length L, running from the point of suspension down to the centre of the bob. A dashed line shows the string displaced to one side and a dashed arc through the bob shows the path it follows as it swings.*

The student's processed data

L / m	0.400	0.600	0.800	1.000	1.200
T / s	1.269	1.554	1.794	2.006	2.198
T^2 / s^2	1.610	2.415	3.219	4.024	4.829

(a) SHOW (THAT) **[3]**

Show that a graph of T^2 against L should be a straight line through the origin, and state an expression for its gradient.

(b) DETERMINE **[3]**

Determine the gradient of the line, and hence determine a value for g.

(c) OUTLINE **[3]**

The uncertainty in each value of L is ±0.005 m and the uncertainty in each value of T is ±0.002 s. Outline why the uncertainty in T^2 is not ±0.002 s^2, and determine the uncertainty in T^2 for the shortest pendulum.

(d) EVALUATE **[3]**

The student's line of best fit has a small positive intercept on the T^2 axis rather than passing through the origin. Evaluate two possible reasons for this.

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8 SL

STRUCTURED · DEMANDING · A.1 · A.2 **[11]**

A ball of mass 0.150 kg is thrown horizontally at 12 m s^{-1} from the top of a building 25 m high. Air resistance is negligible until part (d).

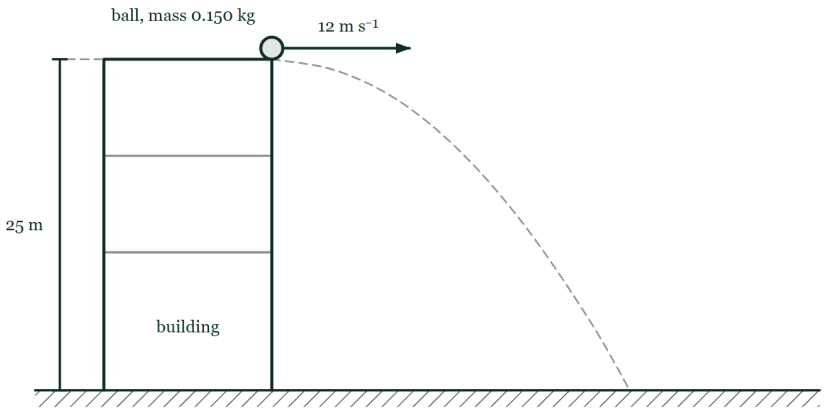

Figure 3 *Side view. A building stands on level hatched ground, its height marked by a dimension line labelled 25 m running from roof level down to the ground. A small ball, labelled as having mass 0.150 kg, sits at the right-hand edge of the roof, and a horizontal arrow from the ball labelled 12 m s^{-1} points away from the building. A faint dashed curve traces the path the ball follows from the roof edge down to the ground.*

(a) CALCULATE **[2]**

Calculate the time taken for the ball to reach the ground.

(b) DETERMINE **[3]**

Determine the speed of the ball as it reaches the ground.

(c) DETERMINE **[2]**

Determine the magnitude of the impulse delivered to the ball by gravity during its flight.

(d) EXPLAIN **[4]**

In reality air resistance is not negligible. Explain how the horizontal distance travelled and the time of flight each differ from the values calculated above.

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9 SL

STRUCTURED · DEMANDING · A.3 **[12]**

A cyclist and her bicycle have a combined mass of 78 kg. She rides up a straight road inclined at 4.0° to the horizontal at a constant speed of 5.5 m s^{-1}. The total resistive force opposing her motion is 25 N.

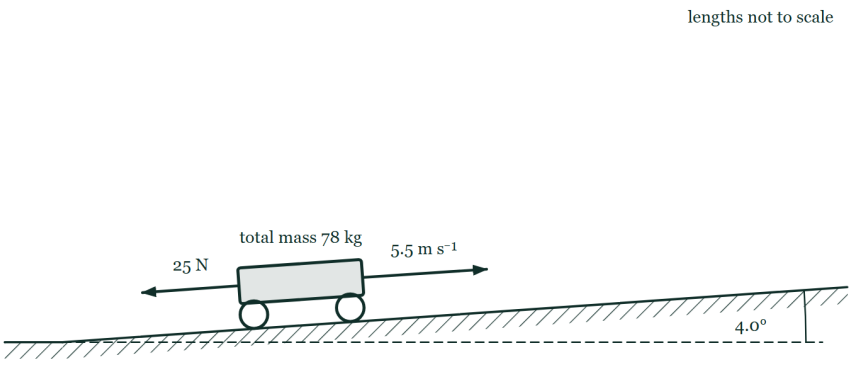

Figure 4 *Side view, drawn not to scale. A road climbs to the right from level ground, and the angle between the road and a dashed horizontal line drawn from the foot of the slope is marked 4.0°. The cyclist and bicycle are drawn as one wheeled body on the road, labelled total mass 78 kg. An arrow from the front of the body points up the slope and is labelled 5.5 m s^{-1}; a second arrow from the rear points down the slope and is labelled 25 N.*

(a) DEFINE **[1]**

Define power.

(b) DETERMINE **[2]**

Determine the component of the total weight acting down the slope.

(c) CALCULATE **[3]**

Calculate the useful power output of the cyclist.

(d) DETERMINE **[2]**

The cyclist's body converts chemical energy to mechanical work with an efficiency of 22%. Determine the rate at which she uses chemical energy.

(e) DISCUSS **[4]**

At the top of the hill the cyclist stops pedalling and freewheels down the other side, which has the same gradient. Discuss whether she reaches a constant speed, and what determines its value.

10 HL

STRUCTURED · DISCRIMINATING · A.4 · A.5 **[14]**

Part 1. A uniform solid cylinder of mass 2.0 kg and radius 0.15 m rolls without slipping down a slope, starting from rest at a height of 1.2 m above the bottom. The moment of inertia of a uniform solid cylinder about its axis is ½MR². Part 2. A spacecraft passes Earth at a constant speed of 0.80c. The spacecraft has a proper length of 90 m.

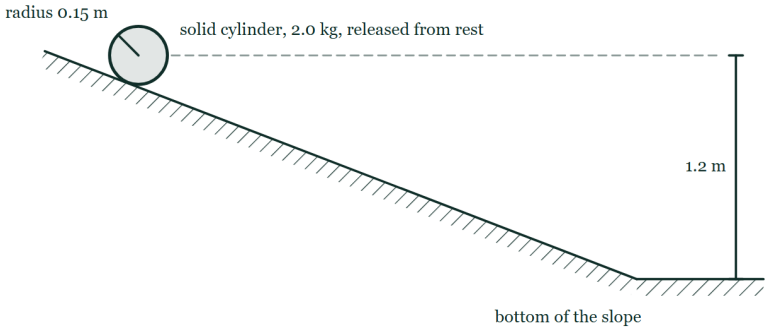

Figure 5 *Side view. A straight hatched slope runs down from the upper left to a horizontal surface at the lower right. A cylinder is drawn end-on resting on the slope near the top, labelled solid cylinder, 2.0 kg, released from rest, with a line from its centre to the rim labelled radius 0.15 m. A dashed horizontal line runs to the right from the level of the cylinder's centre, and a dimension line marks 1.2 m between that level and the horizontal surface at the bottom of the slope.*

(a) SHOW (THAT) **[4]**

Show that the translational speed of the cylinder at the bottom of the slope is about 4.0 m s^{-1}.

(b) DETERMINE **[3]**

Determine the fraction of the cylinder's total kinetic energy at the bottom that is rotational.

(c) CALCULATE **[3]**

Calculate the length of the spacecraft as measured by an observer on Earth.

(d) EXPLAIN **[4]**

An observer on the spacecraft claims that it is the Earth that is 0.80c and that Earth's distances are contracted, not the spacecraft's. Explain why both observers are correct, and outline what would have to change for one of them to be wrong.

MARK SCHEME

Theme A · Space, time and motion — mark scheme

One line per mark, as an examiner would award them. A note under a part is the error that part is set to catch.

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1 SL

MULTIPLE CHOICE · ROUTINE · A.1 **[1]**

A ball is launched from level ground at 20 m s⁻¹ at an angle of 30° above the horizontal. Air resistance is negligible. How long does the ball take to reach its maximum height?

KEY **B** **1.0 s**

C uses the horizontal component, 20 cos 30°, instead of the vertical one. D is the total time of flight rather than the time to the top.

A02

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2 SL

MULTIPLE CHOICE · DEMANDING · A.2 **[1]**

A book rests on a table. Which pair of forces is a Newton's third law pair?

KEY **C** **the normal force of the table on the book and the force of the book on the table**

A is chosen by most candidates because the two forces are equal and opposite — but they act on the same body and are of different types, so they are a balanced pair, not a third law pair. A third law pair acts on two different bodies and is always the same kind of force.

A02

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3 SL

MULTIPLE CHOICE · ROUTINE · A.2 **[1]**

A resultant force acts on a stationary object of mass 0.50 kg. The force–time graph is a triangle rising from zero at t = 0 to a peak of 40 N at t = 0.10 s and falling back to zero at t = 0.20 s. What is the speed of the object at t = 0.20 s?

KEY **B** **8.0 m s⁻¹**

The impulse is the area under the graph, ½ × 0.20 × 40 = 4.0 N s, and dividing by the mass gives 8.0 m s⁻¹. C treats the graph as a rectangle of height 40 N; A stops at the impulse and forgets to divide by the mass.

A02

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4 SL

MULTIPLE CHOICE · ROUTINE · A.3 **[1]**

A crane lifts a load of mass 250 kg through a vertical height of 12 m in 8.0 s at constant speed. What is the useful output power of the crane?

KEY **C** **3.7 kW**

D is the work done rather than the power, with the division by time omitted. B omits g.

A02

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5 HL

MULTIPLE CHOICE · DEMANDING · A.4 **[1]**

A disc of moment of inertia I rotates freely about a vertical axis at angular speed ω. A second, stationary disc of moment of inertia 2I is dropped onto it and the two rotate together. What is the new angular speed?

KEY **A** **ω/3**

No external torque acts about the axis, so Iω = (I + 2I)ω′ and ω′ = ω/3. B is the answer of a candidate who assumes the second disc is identical to the first.

A02

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6 HL

MULTIPLE CHOICE · DEMANDING · A.5 **[1]**

A spacecraft travels past Earth at 0.60c. A clock on board measures a time interval of 2.0 s between two events that occur at the same place on the spacecraft. What is the interval between those events as measured from Earth?

KEY **C** **2.5 s**

A and B are shorter than the proper time, which no observer can measure — the proper time is always the shortest interval between two events, so the Earth reading must be larger. With γ = 1.25, the answer is 2.5 s.

AO2

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7 SL

DATA ANALYSIS · DEMANDING · A.1 **[12]**

A student determines the acceleration of free fall using a simple pendulum. She measures the period T for several lengths L and processes the data as shown. Theory predicts $T = 2\pi\sqrt{(L/g)}$.

(a) SHOW (THAT) · AO2 **[3]**

Show that a graph of T^2 against L should be a straight line through the origin, and state an expression for its gradient.

1. squares the relationship: $T^2 = 4\pi^2 L/g$
2. this is of the form $y = mx$ with no constant term, so the line passes through the origin
3. gradient $= 4\pi^2/g$

(b) DETERMINE · AO2 **[3]**

Determine the gradient of the line, and hence determine a value for g.

1. gradient $= (4.829 - 1.610) / (1.200 - 0.400) = 3.219 / 0.800$
2. gradient $= 4.02\ s^2\ m^{-1}$
3. $g = 4\pi^2/4.02 = 9.8\ m\ s^{-2}$

(c) OUTLINE · AO4 **[3]**

The uncertainty in each value of L is ±0.005 m and the uncertainty in each value of T is ±0.002 s. Outline why the uncertainty in T^2 is not ±0.002 s^2, and determine the uncertainty in T^2 for the shortest pendulum.

1. squaring a quantity doubles its fractional (percentage) uncertainty, so the absolute uncertainty is not carried through unchanged
2. fractional uncertainty in T = 0.002/1.269 = 0.16%, so fractional uncertainty in T^2 = 0.32%
3. uncertainty in $T^2 = 0.0032 \times 1.610 = \pm 0.005\ s^2$

(d) EVALUATE · AO3 **[3]**

The student's line of best fit has a small positive intercept on the T^2 axis rather than passing through the origin. Evaluate two possible reasons for this.

1. a systematic error in the measurement of L — for example measuring to the top of the bob rather than to its centre, so every length is recorded too short
2. a systematic error in timing — for example consistently starting the stopwatch late, though this would need to affect longer pendulums proportionately less to produce an intercept rather than a change of gradient
3. evaluates which is more likely, noting that a constant offset in L produces exactly a constant intercept and is therefore the better explanation

   The third mark is for choosing between the two rather than listing both. "Evaluate" asks for a judgement, and answers that stop at a list earn two marks out of three.

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8 SL

STRUCTURED · DEMANDING · A.1 · A.2 **[11]**

A ball of mass 0.150 kg is thrown horizontally at 12 m s^{-1} from the top of a building 25 m high. Air resistance is negligible until part (d).

(a) CALCULATE · AO2 **[2]**

Calculate the time taken for the ball to reach the ground.

1 $25 = \frac{1}{2} \times 9.81 \times t^2$

2 $t = 2.26$ s

(b) DETERMINE · AO2 **[3]**

Determine the speed of the ball as it reaches the ground.

1 vertical component $v_y = 9.81 \times 2.26 = 22.2$ m s^{-1}

2 horizontal component is unchanged at 12 m s^{-1}

3 speed $= \sqrt{(12^2 + 22.2^2)} = 25$ m s^{-1}

(c) DETERMINE · AO2 **[2]**

Determine the magnitude of the impulse delivered to the ball by gravity during its flight.

1 impulse = change in momentum = m × change in vertical velocity = 0.150 × 22.2

2 impulse = 3.3 N s, directed vertically downwards

(d) EXPLAIN · AO3 **[4]**

In reality air resistance is not negligible. Explain how the horizontal distance travelled and the time of flight each differ from the values calculated above.

1 air resistance acts opposite to the velocity, so it has both a horizontal and a vertical component throughout the flight

2 the horizontal component decelerates the ball, so the horizontal velocity is no longer constant and the horizontal distance is smaller

3 the vertical component acts upward as the ball falls, reducing the downward acceleration below g

4 so the ball takes longer to fall the same 25 m, and the time of flight increases

The commonest wrong answer says the time of flight is unchanged because "horizontal and vertical motions are independent". That independence is a consequence of the only force being vertical, and it fails as soon as a velocity-dependent force acts.

9 SL

STRUCTURED · DEMANDING · A.3 **[12]**

A cyclist and her bicycle have a combined mass of 78 kg. She rides up a straight road inclined at 4.0° to the horizontal at a constant speed of 5.5 m s^{-1}. The total resistive force opposing her motion is 25 N.

(a) DEFINE · AO1 **[1]**

Define power.

1 the rate at which work is done, or the rate at which energy is transferred

(b) DETERMINE · AO2 **[2]**

Determine the component of the total weight acting down the slope.

1 component = mg sin θ = 78 × 9.81 × sin 4.0°

2 = 53 N

(c) CALCULATE · AO2 **[3]**

Calculate the useful power output of the cyclist.

1 at constant speed the driving force balances the weight component and the resistive force: F = 53 + 25 = 78 N

2 P = Fv = 78 × 5.5

3 P = 4.3 × 10^2 W

(d) DETERMINE · AO2 **[2]**

The cyclist's body converts chemical energy to mechanical work with an efficiency of 22%. Determine the rate at which she uses chemical energy.

1 input power = 429 / 0.22

2 = 1.9 × 10^3 W

(e) DISCUSS · AO3 **[4]**

At the top of the hill the cyclist stops pedalling and freewheels down the other side, which has the same gradient. Discuss whether she reaches a constant speed, and what determines its value.

1 on the way down, the component of weight along the slope now acts in the direction of motion and accelerates her

2 the resistive force increases with speed, mainly because air resistance rises steeply with speed

3 she reaches a constant speed when the resistive force has grown to equal the 53 N component of weight down the slope

4 the value of that speed is set by how quickly the resistive force grows with speed — by her frontal area, her posture and the air density, not by her mass alone

10 HL

STRUCTURED · DISCRIMINATING · A.4 · A.5 **[14]**

Part 1. A uniform solid cylinder of mass 2.0 kg and radius 0.15 m rolls without slipping down a slope, starting from rest at a height of 1.2 m above the bottom. The moment of inertia of a uniform solid cylinder about its axis is $\frac{1}{2}MR^2$. Part 2. A spacecraft passes Earth at a constant speed of 0.80c. The spacecraft has a proper length of 90 m.

(a) SHOW (THAT) · AO2 **[4]**

Show that the translational speed of the cylinder at the bottom of the slope is about 4.0 m s^{-1}.

1. $Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2$, with $I = \frac{1}{2}MR^2$
2. applies the rolling condition $\omega = v/R$, so $\frac{1}{2}I\omega^2 = \frac{1}{4}Mv^2$
3. $Mgh = \frac{3}{4}Mv^2$, so $v = \sqrt{(4gh/3)}$
4. $v = \sqrt{(4 \times 9.81 \times 1.2 / 3)} = 3.96 \approx 4.0$ m s^{-1}

(b) DETERMINE · AO2 **[3]**

Determine the fraction of the cylinder's total kinetic energy at the bottom that is rotational.

1. rotational KE = $\frac{1}{4}Mv^2$, translational KE = $\frac{1}{2}Mv^2$
2. total = $\frac{3}{4}Mv^2$
3. fraction rotational = $(\frac{1}{4})/(\frac{3}{4}) = 1/3$

The fraction is the same for every uniform solid cylinder, whatever its mass, radius or the height of the slope — a point worth making, because it is what the cancellation in part (a) was telling you.

(c) CALCULATE · AO2 **[3]**

Calculate the length of the spacecraft as measured by an observer on Earth.

1. $\gamma = 1/\sqrt{(1 - 0.80^2)} = 1/0.60 = 1.67$
2. $L = L_0/\gamma = 90/1.67$
3. $L = 54$ m

(d) EXPLAIN · AO3 **[4]**

An observer on the spacecraft claims that it is the Earth that is 0.80c and that Earth's distances are contracted, not the spacecraft's. Explain why both observers are correct, and outline what would have to change for one of them to be wrong.

1. both frames are inertial, and the principle of relativity states that the laws of physics are the same in all inertial frames
2. there is no experiment either observer can do to establish that they are the one "really" moving, so neither frame is privileged
3. each measures the other's length as contracted because they disagree about which events are simultaneous, and a length measurement requires locating both ends at the same time
4. the symmetry would be broken only if one observer accelerated — an accelerating frame is not inertial, and that observer would feel the acceleration and know it

The best-discriminating part on the paper. Relativity of simultaneity is the mark that separates a candidate who has understood the argument from one who has memorised the formulae.

THE CHEAPEST MARKS ON ANY PAPER

What the command words are asking for

Every board publishes these and marks to them. A candidate who explains where the question said state has spent four minutes earning one mark; one who states where it said explain has earned none.

Define	Give the precise meaning of a word, phrase, concept or physical quantity.
State	Give a specific name, value or other brief answer without explanation or calculation.
Calculate	Obtain a numerical answer, showing the relevant stages in the working.
Describe	Give a detailed account.
Determine	Obtain the only possible answer, from the data or by reasoning.
Outline	Give a brief account or summary.
Compare	Give an account of the similarities between two or more items, referring to both throughout.
Discuss	Offer a considered and balanced review that includes a range of arguments, factors or hypotheses, supported by appropriate evidence.
Evaluate	Make an appraisal by weighing up the strengths and limitations.
Explain	Give a detailed account including reasons or causes.
Show (that)	Give the steps in a calculation or derivation.
Sketch	Represent by means of a graph showing a line and labelled but unscaled axes, with important features clearly identifiable.
Suggest	Propose a solution, hypothesis or other possible answer.

WHAT IS BEING TESTED

IB assessment objectives

Paper 1 has two parts: 1A is multiple choice, and 1B is data-based questions drawn from the experimental work of the course, with no recall in it at all. Paper 2 is short-answer and extended-response across the whole syllabus. HL papers are longer and reach the HL-only sub-topics. The data booklet is provided in every paper, so no question tests whether you can remember an equation.

AO1
1 MARK · 2%

Demonstrate knowledge

Recall facts, concepts and terminology, and state methodologies and techniques used in the course.

AO2
36 MARKS · 65%

Understand and apply knowledge

Apply concepts, terminology and techniques to familiar and unfamiliar situations, including numerical work.

AO3
15 MARKS · 27%

Analyse, evaluate and construct

Analyse and evaluate data, methods, claims and explanations, and construct a reasoned argument or conclusion.

AO4
3 MARKS · 5%

Demonstrate the application of skills

Design and evaluate investigations, handle raw and processed data, treat uncertainties, and communicate results.