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|  | |  |  | | --- | --- | | **Physics A**  **Motion and Uncertainty Analysis practise questions** |  | | Please note that you may see slight differences between this paper and the original.  Candidates answer on the Question paper.  **OCR supplied materials:** Additional resources may be supplied with this paper.  **Other materials required:** •   Pencil •   Ruler (cm/mm) | **Duration:** 2 hours | |  | | |  |

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## INSTRUCTIONS TO CANDIDATES

•   Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.  
•   Use black ink. HB pencil may be used for graphs and diagrams only.  
•   Answer **all** the questions, unless your teacher tells you otherwise.  
•   Read each question carefully. Make sure you know what you have to do before starting your answer.  
•   Where space is provided below the question, please write your answer there.  
•   You may use additional paper, or a specific Answer sheet if one is provided, but you must clearly show your candidate number, centre number  
    and question number(s).

## INFORMATION FOR CANDIDATES

•   The quality of written communication is assessed in questions marked with either a pencil or an asterisk. In History and Geography   
    a *Quality of extended response* question is marked with an asterisk, while a pencil is used for questions in which *Spelling, punctuation and  
    grammar and the use of specialist terminology* is assessed.  
•   The number of marks is given in brackets **[ ]** at the end of each question or part question.  
•   The total number of marks for this paper is **100**.  
•   The total number of marks may take into account some 'either/or' question choices.

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|  | |  |  | | --- | --- | |  |  | | **1.** | A student has plotted a velocity against time graph for a trolley moving down a ramp.  Which of the following pair of quantities can be determined from the gradient of the graph and the area under the graph?     |  |  | | --- | --- | | **A** | acceleration, displacement | | **B** | acceleration, impulse | | **C** | displacement, kinetic energy | | **D** | force, work done |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **2.** | The table below shows the measurements recorded by a student for a solid metal sphere. The absolute uncertainties in the mass of the sphere and in its radius are also shown.     |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | |  | |  |  | | --- | --- | | mass | 100 ± 6 g | | radius | 1.60 ± 0.08 cm | |  |   What is the percentage uncertainty in the density of the sphere?   1. 1% 2. 11% 3. 16% 4. 21%   Your answer       |  | | --- | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **3.** | A person in a buggy is attached to a large parakite by a rope, as shown below.    Strong wind acting on the parakite moves the buggy along horizontal ground.  The rope makes an angle of 55° to the horizontal. The total mass of the buggy and person is 150 kg.  The velocity v against time t graph for the buggy is shown below.    Calculate the horizontal distance travelled by the buggy from t = 0 to t = 8.0 s.     |  | | --- | | horizontal distance = ..................................................... m **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **4.** | A length x is 50 mm ± 2 mm. Length y is 100 mm ± 6 mm. The length z is given by z = y − x.  What is the best estimate of the uncertainty in z?   1. ± 1 mm 2. ± 4 mm 3. ± 5 mm 4. ± 8 mm   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **5.** | The table shows some data for a car travelling on a straight road with an initial speed of 13 m s–1.     |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  | | --- | --- | | **Thinking distance / m** | **9.0** | | **Braking distance / m** | 14 | | **Stopping distance / m** | **23** | |  |   The car has a constant deceleration when the brakes are applied. What is the magnitude of the deceleration of the car during braking?     |  |  | | --- | --- | | **A** | 0.46 m s–2 | | **B** | 3.7 m s–2 | | **C** | 6.0 m s–2 | | **D** | 9.4 m s–2 |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **6.** | An object is moving in a straight line.  The displacement s against time *t* graph for this object is shown below.     |  | | --- | |  |   At which point **A, B, C** or **D**, does the object have the greatest speed?     |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **7.** | A student is determining the acceleration of free fall g using a metal sphere on a ramp. The sphere is released from the ramp at different heights. The speed v of the sphere at the bottom of the ramp is determined.  The acceleration of free fall g is given by the expression , where d is the initial height of the sphere and v is speed of the sphere at the bottom of the ramp.  The student records the following data.   * d = 0.100 ± 0.002m * v = 1.4 ± 0.1ms−1   Calculate the absolute uncertainty in g. Write your answer to **2** significant figures.     |  | | --- | | absolute uncertainty = ............................... ms−2 **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **8.** | Droplets of water drip at a constant rate from a tap.  The diagram below shows this dripping tap.     |  | | --- | |  |   Explain how you can deduce that the droplets are accelerating.    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **9.** | A driver sees an obstacle ahead in the road at time t = 0 and then applies the brakes. The velocity v against time t graph for the car is shown below.     |  | | --- | |  |   Which row is correct?     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  |  | | --- | --- | --- | |  | **Reaction time of driver / s** | **Braking distance of car / m** | | **A** | 0.5 | 15.0 | | **B** | 0.5 | 17.5 | | **C** | 3.5 | 15.0 | | **D** | 3.5 | 17.5 | |  |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **10.** | The velocity v against time t graphs for four objects **A** , **B** , **C** and **D** are shown below.      Which object travels the greatest distance between t = 0 and t = T?     |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **11(a).** | A car is travelling at a constant speed of 20 m s−1 along a straight road. The driver sees a hazard ahead in the road, applies the brakes and brings the car to a stop. The graph below shows the displacement s against time t for the car from the time that the driver sees the hazard to when the car stops.    The braking force F acting on the car is constant. The mass of the car is 950 kg. The reaction time of the driver is 0.75 s.  Explain how you can deduce from the graph that the brakes are applied at time t = 0.75s.      **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Draw a tangent to the graph at time t = 1.75 s. Use this tangent to show that the speed of the car at t = 1.75 s is about 12 m s−1.     |  | | --- | | **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | Describe and explain the variation of the displacement with time when the same driver applies the brakes in the same car when the initial speed of the car is 10 m s−1.            **[3]** | |

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|  | |  |  | | --- | --- | |  |  | | **(d).** | State the gradient of the graph when t = 0.     |  | | --- | | gradient = ........................................................ m s−1 **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **12.** | \* A metal ball leaves a horizontal surface with velocity v. A student investigates the horizontal distance R that the ball travels before it hits the ground.    It is suggested that the relationship between R and v is given by    where g is the acceleration of free fall and Q is a constant.     |  | | --- | | Describe with the aid of a suitable diagram how an experiment can be safely conducted, and how the data can be analysed, to determine Q. |                                           **[6]** | |

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|  | |  |  | | --- | --- | |  |  | | **13.** | A car is travelling along a straight road at 18 m s−1. The driver sees an obstacle and after 0.50 s applies the brakes. The **stopping** distance of the car is 38 m.  Calculate the magnitude of the deceleration of the car when the brakes are applied.     |  | | --- | | deceleration = ................................................ m s−2 **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **14(a).** | A metal ball is released from rest. It falls vertically towards the ground. Fig. 22 shows the variation with time t of the displacement s of the ball.     |  | | --- | | **Fig. 22** |   Air resistance has negligible effect on the motion of the ball.  The ball hits the ground at t = 0.50 s. During the collision, the ball is in contact with the ground for a time of 1.8 ms. The mass of the ball is 56 g.  Use an equation of motion to show that the speed of the ball is 4.9 ms–1 just before it hits the ground.     |  | | --- | | **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Draw a suitable tangent to the curve in Fig. 22 and show that the **rebound** speed of the ball is about 3.5 ms–1.     |  | | --- | | **[3]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | Calculate the average resultant force acting on the ball during the collision.     |  | | --- | | force = ..................................................... N **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **15.** | A metre rule is being used to measure the length ℓ of a section of wire. The end of the ruler is displaced from the start of the wire.    What is the nature of the errors associated with the length measurement?   1. There are random errors but no systematic errors. 2. There are systematic errors but no random errors. 3. There are both systematic and random errors. 4. There is no overall error because the random and systematic errors cancel out.   Your answer       |  | | --- | | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **16.** | A ball of diameter 2.50 cm is held above the ground. The bottom of the ball is 10.2 cm above the ground. The ball is released from rest. Air resistance has negligible effect on the motion of the ball.  What is the time taken for the ball to reach the ground?     |  |  | | --- | --- | | **A** | 0.021 s | | **B** | 0.144 s | | **C** | 0.152 s | | **D** | 0.161 s |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **17.** | A car is dripping oil at a steady rate on a straight road. The road is divided into four sections **A**, **B**, **C**, and **D**.     |  | | --- | |  |   Which section of the road shows the car travelling at a constant speed?     |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **18.** | An object is dropped from rest at time t = 0. It falls vertically through the air. The variation of the velocity v with time t is shown below.    Which statement is correct about this object?     |  |  | | --- | --- | | **A** | It has constant acceleration. | | **B** | It experiences zero drag at t = 30 s. | | **C** | It has an acceleration of 9.81 m s–2 at t = 0 s. | | **D** | It travels the same distance in every successive 10 s. |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **19(a).** | A student is carrying out an experiment in the laboratory to determine the acceleration of free fall g. The student drops a small steel ball from rest and records the time t taken for the ball to fall through a vertical distance h.  The results for different vertical distances are shown in the table below.     |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **h** / **m** | **t / s** | **t2 / s2** |  | |  | 0.660 | 0.365 | 0.133 |  | |  | 0.720 | 0.385 | 0.148 |  | |  | 0.780 | 0.400 | 0.160 |  | |  | 0.840 | 0.415 | 0.172 |  | |  | 0.900 | 0.430 |  |  | |  | 0.960 | 0.445 | 0.198 |  |      |  |  | | --- | --- | | Complete the table for the missing value of t2. | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig. 3 shows the graph of t2 (y-axis) against h (x-axis).     |  |  |  | | --- | --- | --- | | (i) | Plot the missing data point and draw the straight line of best fit. | **[2]** | | **Fig. 3** | | |      |  |  | | --- | --- | | (ii) | Determine the gradient of the straight line of best fit. |        |  |  |  | | --- | --- | --- | | gradient = |  | s2 m−1 **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(c).** | 1. Use the equations of motion for constant acceleration to show that the relationship between t and h is      |  |  |  | | --- | --- | --- | |  |  |  |   where g is the acceleration of free fall.     |  | | --- | | **[1]** |  1. Use your answer to **(c)(ii)** to determine the experimental value for g.      |  |  |  | | --- | --- | --- | | g = |  | m s−2 **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(d).** | Describe and explain how the student could use standard laboratory equipment to make accurate measurements of h and t.            **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **20(a).** | A trolley is placed on a long ramp and is released from rest from the top of the ramp. It travels to the bottom of the ramp with a constant acceleration.  Describe how a metre rule and a stopwatch can be used to determine the **final** velocity v of the trolley at the bottom of the ramp.        **[2]** | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | A motion sensor is used to determine the velocity of the trolley at points **X** and **Y**, as shown in Fig. 21.  **Fig. 21 (not to scale)**  The distance between **X** and **Y** is 1.10 m. The trolley has velocity 1.3 ms−1 at **X** and velocity 2.5 ms−1 at **Y**.   1. Calculate the acceleration a of the trolley.      |  |  |  |  |  | | --- | --- | --- | --- | --- | | a = |  |  | m s−2 | **[2]** |  1. The frictional forces acting on the trolley are negligible. The acceleration of the trolley down the ramp is equal to the component of the acceleration of free fall parallel to the ramp. Use your answer to **(i)**to calculate the angle θ between the ramp and the horizontal.      |  |  |  |  |  | | --- | --- | --- | --- | --- | | θ = |  |  | ° | **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **21.** | The cross-sectional area of a wire is recorded as 0.14 ± 0.01 mm2. The length of the wire is recorded as 100 ± 1 mm.  What is the percentage uncertainty in the volume of the wire?     |  |  | | --- | --- | | **A** | 1.0 % | | **B** | 4.6 % | | **C** | 7.1 % | | **D** | 8.1 % |   Your answer    **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **22.** | A car is driven at constant velocity until the driver sees an obstruction ahead at time t = 0. The velocity against time graph below shows the motion of the car as the driver brings it to a stop.    The thinking distance is 10 m. What is the stopping distance for the car?     |  |  | | --- | --- | | **A** | 20 m | | **B** | 30 m | | **C** | 40 m | | **D** | 50 m |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **23.** | The graph below shows the variation of displacement s with time t for an object.    At which point, **A**, **B**, **C** or **D**, does the object have maximum velocity?     |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **24.** | Define what is meant by the stopping distance of a vehicle.      **[1]** | |

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|  | |  |  | | --- | --- | |  |  | | **25.** | Which is **not** an International System (S.I.) base unit?     |  |  | | --- | --- | | **A** | second (s) | | **B** | kelvin (K) | | **C** | kilogram (kg) | | **D** | coulomb (C) |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **26.** | The braking distance of a car is directly proportional to its initial kinetic energy.  The braking distance of a car is 18 m when its initial speed is 10 m s−1.  What is the braking distance of the car, under the same conditions, when its initial speed is 25 ms−1?     |  |  | | --- | --- | | **A** | 7.2 m | | **B** | 45 m | | **C** | 113 m | | **D** | 222 m |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **27.** | A ball is dropped from rest above the ground. Air resistance has negligible effect on the motion of the ball.  The speed of the ball is v after it has fallen a distance h from its point of release.  Which graph is correct for this falling ball?     |  |  | | --- | --- | | **A** |  | | **B** |  | | **C** |  | | **D** |  |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **28(a).** | A student uses a motion sensor to investigate the motion of a trolley crashing into a soft barrier. Fig. 21 shows the displacement s against time t graph for the trolley in one experiment.     |  |  |  | | --- | --- | --- | |  |  |  | |  | **Fig. 21** |  |   The student assumes that the deceleration of the trolley is constant during the crash. Use Fig. 21 to determine the magnitude of the deceleration.     |  |  | | --- | --- | |  | deceleration = ......................................... m s−2 **[2]** | | |

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|  | |  |  | | --- | --- | |  |  | | **(b).** | Use Fig. 21 to describe and explain the variation of the velocity of the trolley from t = 0 to t = 1.0 s.              **[4]** | |

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|  | |  |  | | --- | --- | |  |  | | **29.** | A projectile is fired in a horizontal direction at time t = 0. Ignore air resistance.  Which graph correctly shows the horizontal component of the velocity VH of the projectile against time t?     |  |  | | --- | --- | | **A** |  | | **B** |  | | **C** |  | | **D** |  |      |  |  |  | | --- | --- | --- | | Your answer |  | **[1]** | | |

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|  | |  |  | | --- | --- | |  |  | | **30.** | In a hockey match a hockey ball is hit 18.0 m from the front of the goal. The ball leaves the hockey stick with initial velocity v at an angle θ to the horizontal ground. The ball passes over the goal at a maximum height of 2.0 m as shown in Fig. 3.    **Fig. 3**  The initial vertical component of the velocity of the ball is 6.3 m s−1. Air resistance has negligible effect on the motion of the ball.   1. Show that the time t taken for the ball to reach the maximum height is about 0.6 s.   **[1]**   1. Use the answer to **(i)** and **Fig. 3** to show that the horizontal component of the velocity of the ball as it leaves the hockey stick is about 30 m s−1.   **[1]**   1. Calculate the magnitude of the initial velocity v of the ball.   v = ........................................................... m s−1 **[2]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **31(a).** | A ball is held above level ground. It is then dropped from rest at time *t* = 0. Fig. 1.1 shows the velocity *v* against time *t* graph for this ball bouncing vertically. Ignore the effect of air resistance.     1. Explain why the gradient of the line **DE** is the same as the gradient of the line **AB**.  *In your answer, you should use appropriate technical terms spelled correctly.*     **[1]**   1. Explain why the area of triangle **ABC** is not the same as the area of triangle **CDE**.         **[2]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **(b).** | The ball, of mass 0.13 kg, was dropped from an initial height of 1.7 m. It remained in contact with the ground for 75 ms while experiencing a mean upward force of 16 N.  Calculate   1. the speed of the ball immediately before impact with the ground   speed = ........................................................... m s−1 **[1]**   1. the speed of the ball immediately at **D**   speed = ........................................................... m s−1 **[2]**   1. the maximum height reached after the first bounce.   height = ........................................................... m **[1]** | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **32.** | The table below shows how the braking distance x for a car depends on its initial speed u.     |  |  |  |  |  | | --- | --- | --- | --- | --- | | **u / m s−1** | 5.0 | 10 | 20 | 40 | | **x / m** | 2.0 | 8.0 | 32 | 128 |  1. State the relationship between x and u.     **[1]**   1. The reaction time of a driver is 0.60 s. Calculate the **stopping distance** of the car when u is 30 m s−1.   distance = ...........................................................m **[3]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **33(a).** | Fig. 1.1 shows the graph of velocity v against time t for a moving object.    **Fig. 1.1**   1. Describe the motion of the object from  **1**   t = 0 to t = 2 s     **[1]**  **2**   t = 2 s to t = 7 s.    **[1]**   1. Explain how Fig. 1.1 shows that the distance travelled by the object from t = 0 to t = 2 s is **shorter** than the distance travelled from t = 2 s to t = 7 s.       **[1]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **(b).** | Define acceleration.    **[1]** | |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **34(a).** | A group of students are conducting an experiment in the laboratory to determine the acceleration of free g using a simple pendulum as shown below.    The pendulum bob is released from **rest** from a height h. The speed of the pendulum bob as it passes through the vertical position is v. The speed v is measured using a light-gate and a computer. The results from the students are shown in a table.     |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  | |  |  |  | | --- | --- | --- | | h / m | v / m s−1 | v2 / m2 s−2 | | 0.052 | 1.0 ± 0.1 | 1.0 ± 0.2 | | 0.100 | 1.4 ± 0.1 | 2.0 ± 0.3 | | 0.151 | 1.7 ± 0.1 | 2.9 ± 0.3 | | 0.204 | 1.9 ± 0.1 |  | | 0.250 | 2.2 ± 0.1 | 4.8 ± 0.4 | | 0.302 | 2.4 ± 0.1 | 5.8 ± 0.5 | |  |   Complete the missing value of v2 in the table.  **[1]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **(b).** | Fig. 24 shows the graph of v2 against h.     1. Plot the missing data point and error bar on Fig. 24.   **[1]**   1. \* Explain how Fig. 24 can be used to determine the acceleration of free fall g. Find the value of g and include the uncertainty in your answer.                       **[6]** | |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | |  |  | | --- | --- | |  |  | | **35.** | The initial temperature T1 of water in a beaker was 20.1 °C ± 0.2 °C. After the water had been heated for some time, the final temperature T2 was 27.3 °C ± 0.3 °C. The temperature increase ΔAT is given by ΔT = T2 − T1  What is the best estimate of the uncertainty in ΔT?   1. ± 0.05 °C 2. ± 0.1 °C 3. ± 0.25 °C 4. ± 0.5 °C   Your answer    **[1]** | |

**END OF QUESTION PAPER**

# Mark scheme

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Question** | | | **Answer/Indicative content** | **Marks** | **Guidance** |
| 1 |  |  | **A** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 2 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 3 |  |  | distance = area under the graph/suvat equations  ½ (4.0 + 10.0) × 3.0 / 10.0 × 5.0  horizontal distance = 71 (m) | C1 C1 A1 | **Allow** any attempt to calculate part of the area under the graph or suvat equations **Allow** any correct calculation of part of the area under the graph/suvat eqn e.g. 9, 12, 20, 21, 30, 32, 50 (m) **Examiner’s Comments**  Most candidates performed well on this question by achieving at least 1 or 2 marks for either correctly identifying that the distance travelled = area under the graph and/or attempting to calculate a distance from the area. Nearly two thirds of candidates scored 3 marks for correctly calculating the total distance travelled. |
|  |  |  | **Total** | **3** |  |
| 4 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 5 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 6 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 7 |  |  | or or   (2 × 0.071 ...+ 0.02) or 0.1628 ... or 16.3 %  absolute uncertainty = 1.6 (m s-2)  **OR**  or   range = 3.2 (m s-2)  absolute uncertainty = 1.6 (m s-2) | C1  C1 A1 C1 C1 A1 | **Allow** 1SF answers here for uncertainties **Not** g = 9.8 for this C1 mark; must see working  **Allow** 0.16 or 16%  **Note**: The answer must be given to 2 SF **Ignore** value of g given on the answer line, e.g. 9.8 土 1.6  **Note**: The answer must be given to 2 SF |
|  |  |  | **Total** | **3** |  |
| 8 |  |  | Separation between droplets increases (further down) | B1 |  |
|  |  |  | **Total** | **1** |  |
| 9 |  |  | **A** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 10 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 11 | a |  | (After 0.75 s) gradient decreases with time Indicating velocity is decreasing / deceleration | M1 A1 | **Examiner’s Comments** In part (b) some candidates were vague in their responses, for example, stating that the gradient changes rather than stating that the gradient decreases. In part (c) most candidates were able to draw a reasonable tangent. Parts (d) and (e) were harder to answer. Part (d) required the correct time interval to be applied by interpreting the braking time and not including the thinking time. In part (e), high achieving candidates applied the halving of the initial speed to the effect this had on the thinking distance, the thinking time, the braking distance and the braking time. |
|  | b |  | Tangent drawn at t = 1.75 s (judge by eye)   Gradient in the range 11.0 (m s−1) to 13.0 (m s−1) | B1   B1 |  |
|  | c |  | Maximum of two from:  (thinking) time is the same  (braking) time is halved / 1.25 s  total time is 2 s  **AND**   maximum of two from:  (thinking) distance / displacement travelled (before braking) halved / 7.5 m  (braking) distance / displacement quarters / 6.25 m  total distance / displacement = 13.75 m | B1 ×3 |  |
|  | d |  | 20 (m s−1) | B1 |  |
|  |  |  | **Total** | **8** |  |
| 12 |  |  | **Level 3 (5–6 marks)** Detailed procedure including labelled diagram and measurements to be taken **and** detailed analysis  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.   **Level 2 (3–4 marks)** A diagram, some procedure, some measurements and some analysis **or**  detailed analysis and limited procedure with limited diagram **or**  detailed procedure including diagram and measurements to be taken and limited analysis  There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.   **Level 1 (1–2 marks)** Limited procedure and limited measurements **or** limited analysis  There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.  **0 marks** No response or no response worthy of credit. | B1 ×6 | **Indicative scientific points may include:**   **Diagram and procedure**   * labelled diagram * horizontal surface supported * description of procedure * method to release ball * method to identify position ball hits the ground * repeats experiment for each v * method to prevent ball rolling on floor in laboratory   **Measurements**   * measuring instruments to determine v * measurements to determine v e.g. mgh conversion or one light gate with diameter of ball measured or two light gates with distance between light gates measured * use of ruler to measure R.   **Analysis**   * equation to determine v * appropriate graph, e.g. plot R against v or plot R2 against v2 * Expect straight line passing through origin * Q = g × gradient2 or Q = g × gradient   **Examiner’s Comments** In Question 4, candidates were required to plan an experiment. A diagram should have been drawn which should indicate a workable experimental set-up. In this particular case, it was expected that candidates would include a method of support for the horizontal surface, a method to release the ball (e.g. a curved slope or a horizontal spring) and a method to determine the velocity as the ball left the horizontal surface. Most candidates indicated a rule to measure distance R. Candidates should also describe the method – perhaps indicating that R would be measured several times for same v and an average calculated. Safety precautions should also be included. Some candidates suggested good methods of identifying where the ball would land, e.g. use sand or add paint to the ball. High achieving candidates clearly described how the velocity of the ball as it left the horizontal surface could be determined. Some used an energy conversion either of gravitational potential energy to kinetic energy or elastic strain energy to kinetic energy. Others suggested the use of either one or two light gates connected to a data-logger. In the case of using one light, the diameter of the ball would need to be determined while for two light gates, the gates should be positioned close to each other and the distance between the two light gates would need to be measured. Most candidates suggested an appropriate graph to plot and then described how Q could be calculated using the gradient. |
|  |  |  | **Total** | **6** |  |
| 13 |  |  | |  |  |  | | --- | --- | --- | | 18 x 0.5 | or | 9(.0) m |      |  |  |  | | --- | --- | --- | |  |  | (Any subject) |   Deceleration = 5.6 (m s-2) | C1 C1 A1 | **Allow** 1 mark max for 4.26 or 4.3; (38 m used instead of 29 m) **Allow** 1 mark max for 3.4 or 3.45; (47 m used instead of 29 m) **Ignore** minus sign  **Examiner’s Comments**  Many candidates use the stopping distance for the braking distance of the car, giving a deceleration that was too low and scoring 1 mark only. More successful candidates remembered to calculate the thinking distance involved (9 m) and subtract this from the stopping distance to give a braking distance of 29 m. Algebraic rearrangement, substitution and evaluation from then on was excellent. |
|  |  |  | **Total** | **3** |  |
| 14 | a |  | (s =) 1.23 (m) **or** (**t** =) 0.50 (s)   v2 = 2 × 9.81 × 1.23 **or** 1.23 = 0.50  **or** 1.23 = v × 0.50 – ½ × 9.81 × 0.502 **or** v = 9.81 × 0.50 **or** 1.23 = ½ × 9.81 × t2; t = 0.50 (s) **and** v = 9.81 × 0.50    v = 4.9 (m s-1) | C1   C1          A0 | **Note** there are no marks for gradient calculations here  **Allow** s between 1.22 (m) and 1.26 (m) **Allow** t between 0.495 (s) and 0.505 (s)  Substitution into v2 = u2 + 2as with u = 0 Substitution into with u = 0 Substitution into s = vt – ½ at2 Substitution into v = u + at with u = 0 Substitution into s = vt – ½ at2 and v = u + at with u = 0 **Allow** g = 9.8 **Not** g = 10, unless already penalised in **21(c)(ii)**   **Examiner’s Comments**  This question was generally well-answered with candidates using a range of equations of motion to show the speed to be 4.9 m s-1. The most popular route was:  v = 0 + (9.81 × 0.50) = 4.905 m s-1. |
|  | b |  | Correct tangent at t = 0.50 s with positive gradient  Attempt at calculating the gradient of a tangent     Gradient calculated in the range 3.20 to 3.80 (m s-1) | B1   M1      A1 | **Note** must evidence for Δs and Δt values either here or on Fig. 22 **Allow** this M1 mark for tangent not drawn at t = 0.50 s   **Note** this mark can only be scored if the tangent is drawn at t = 0.50 s and the calculated value falls in this range   **Examiner’s Comments**  In this question, candidates had clear instructions on what to do. Most candidates drew adequate tangents at t = 0.50 s and did the correct analysis to determine the rebound speed of the ball. Most responses were in the range required (3.20 to 4.00 m s-1) and most candidates scored 3 marks. About a quarter of the candidates drew tangents at times other than t = 0.50 s. This meant that they could only score a maximum of 1 mark for correctly calculating the gradient of their tangent. |
|  | c |  | (Δv =) 4.9 + 3.5 **or** (Δv =) 8.4 (ms-1)    force = 260 (N) | C1     A1 | Possible ECF from **(c)**  **Allow** (Δρ =) (4.9 + 3.5) × 0.056 **or** (Δρ =) 0.47 (kg ms-1)    **Allow** 1 mark for 44 (N); Δv = 4.9 - 3.5 used **Ignore** sign   **Examiner’s Comments**  The correct answer of 260 N eluded even many of the top-end candidates. The vector nature of velocity, or momentum, was overlooked, with many candidates calculating the magnitude of the force as follows:    The magnitude of the change in the velocity of the ball 0.056(4.5 + 3.5), which would have given the correct answer of 260 N.     |  |  | | --- | --- | |  | **Misconception** |   Some examples of **incorrect** physics were:   * force = weight of the ball = 0.056 × 9.81 * Using Δt = 0.50 s instead of 1.8 ms. * Using either 4.9 m s-1 or 3.5 m s-1 to calculate the force. |
|  |  |  | **Total** | **7** |  |
| 15 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 16 |  |  | **B** | 1 | **Examiner’s Comments**  This question required knowledge and understanding of equations of motions. The simplest route to getting the correct answer was the equation s = ½ at2 with the displacement s = 0.102 m. About two thirds of the candidates got the correct answer B. All the other distractors were based on using incorrect values for s. For example, the answer would have been D for s = 12.7 cm. The exemplar 3 below shows a typical working for a correct answer.  **Exemplar 3**    This exemplar illustrates relevant scribbling in a multiple choice answer can lead to the correct response. It is good to see that the candidate has focused on the correct distance of 0.102 m. The equation is there, as are the key numbers. The candidate had saved some time by finishing off the calculation on his/her calculator. A perfect technique from this candidate. |
|  |  |  | **Total** | **1** |  |
| 17 |  |  | C | 1 |  |
|  |  |  | **Total** | **1** |  |
| 18 |  |  | **C** | **1** |  |
|  |  |  | **Total** | **1** |  |
| 19 | a |  | 0.185 (s2) | **B1** | **Examiner’s Comments**  This question was well answered. Since the raw data was given to three significant figures the calculated data should also have been given to three significant figures. Candidates did not score the mark for writing 0.1849 (four significant figures or 0.184 (truncating the data). |
|  | b | i | Plots one missing plot to less than a half small square  Draws straight line of best fit | **B1   B1** | **Allow** ECF from **(b)**   **Allow** ECF  Expect to be balance of points about line of best-fit. Judge straightness by eye.  **Not** thick lines, multiple lines  **Examiner’s Comments**  This question was again well answered with the majority of the candidates plotting the data point correctly. Sometimes the straight line of best fit did not have the points balanced.  Candidates should be encouraged to plot graphs using a sharp pencil. It is helpful to use a clear 30 cm rule to draw the straight line of best fit. Thick plots and/or lines do not score marks. |
|  |  | ii | Determines gradient correctly and gradient in the range 0.210 to 0.225 | **B1** | Ignore significant figures.  **Examiner’s Comments**  To determine the gradient of the straight line of best fit candidates are expected to identify two points (x1, y1) and (x2, y2) which are on the line and substitute them     |  |  | | --- | --- | | into |  |   The two points should be at least half the length of the drawn line apart. The advantage of this method is that it automatically allows for negative gradients.  Common errors included the use data points from the table which are not on the line or just using one data point and assuming that the line passed through the origin. |
|  | c | i | Evidence of use of (and  u = 0)   Manipulation leading to | **B1** | **Examiner’s Comments**  For this type of question, candidates should start the answer by quoting the relevant equation of motion. It was then expected that candidates would state that u (or ut) = 0, that a = g and s = h. Some lower ability candidates did not clearly rearrange the equation correctly. **Exemplar 2**    This shows a reasoned answer with the relevant terms defined and clear working to demonstrate the rearrangement. |
|  |  | ii | and given to 2 or 3 s.f. | **B1  10** | **Note:** Possible ecf from (c)(ii)  **Ignore** rounding  **Examiner’s Comments**  Candidates were required to identify from the equation given at the beginning of  (d) (i) that the gradient was equal to 2/g. Candidates then needed to use the gradient value they calculated in 2 (c) (ii) to determine g. Some candidates incorrectly substituted data points from the table of results.  To improve this skill candidates should practise comparing the x and y values from graphs with the equation of a straight line and then identifying the gradient and y-intercept values. |
|  | d |  | h measured with a metre rule/ruler   (electronic) timer/data logger (started and stopped electronically)   Method to start timer (and release ball), e.g. electromagnet or light gate to start timer   Method to stop timer, e.g. trap door, second light gate | **B1   B1    B1     B1** | **Allow** metre stick, tape measure   **Not** stopwatch    **Allow** one mark for use light gates without reference to timer/starting/stopping        **Examiner’s Comments**  This question assessed candidates’ knowledge and understanding of the techniques and procedures used to determine the acceleration of freefall. Most candidates were able to explain how the vertical distance could be measured using a metre rule. To measure the time, to the nearest 0.001 s, it was expected that candidates would describe either a method using an electromagnet and trap door or the use of light gates with a timer. Many candidates did not realise that the times were recorded to the nearest 0.001 s.  Many candidates were vague in their responses, e.g. “use light gates” without an explanation. It was expected that candidates would state that the light gates would be connected to a timer or datalogger or computer and that the timer would start when the ball interrupts the first light beam and stops when the second light beam is crossed.  Candidates should experience and be able to describe the techniques to determine velocity and acceleration using light gates |
|  |  |  | **Total** | **10** |  |
| 20 | a |  | Distance / displacement / length measured using the (metre) rule **and** time measured using the stopwatch  (S = ½ [ v + u]t and u = 0)  v = 2 × average velocity | **B1      B1** | **Allow** this mark even if the measurements are taken after trolley has left the ramp     **Note** v must be the subject **Allow** v = 2 × average speed **Allow** v = 2x/t without the terms defined (x can be d, D or s) **Not** s = ½ vt **Allow** v = x/t, where x = distance travelled along horizontal surface assuming it is smooth / negligible friction **Allow** 1 mark for the following where there is no mention of timing / stopwatch:     |  |  | | --- | --- | |  | Measure height / vertical distance with a (metre) rule **and** use v = √2gh (no need to define the terms) |   **Examiner’s Comments**  Most candidates struggled to gain full marks in this opening question. The first mark, for using a ruler to measure the length of the ramp and the stopwatch for the time taken to travel the length of the ramp, was gained by just over half of the candidates. The second mark required a clear statement that the **final** velocity was twice the **mean** velocity of the trolley. Equivalent statements were allowed. Unfortunately, many candidates opted to describe light-gates arrangements or using inappropriate equations of motion. |
|  | b | i | (v2 = u2 + 2as)     |  |  | | --- | --- | | 2.52 = 1.32 + 2 × 1.10 × a | (Any subject) |   a = 2.1 (m s−2) | **C1  A1** | **Allow** other methods   **Allow** this mark for t = 0.58 (s)  **Note** answer to 3 SF is 2.07 (m s−2)  **Examiner’s Comments**  Most candidates demonstrated excellent understanding and application of equations of motion. The solutions were often well represented, calculations done correctly and the answer written to the correct number of significant figures (SF). A variety of routes were possible, but the most popular method was using the equation v2 = u2 + 2as.  **Exemplar 5**   This exemplar from a grade E candidate shows flawless technique. The known and unknown quantities are written on the left-hand side. The equation is clear, as is the substitution and the final answer for the acceleration. |
|  |  | ii | ma = mg sinθ **or** a = g sinθ **or** 2.07 = 9.81 × sinθ     θ = 12° | **C1      A1** | **Allow** 2.1 (m s−1) **Allow** g = 9.8 **Note** using tan−1(2.07/9.81) is **wrong physics**.  Possible ECF from **(b)(i)** **Allow** g = 10 here; it gives the same answer to 2 SF **Allow** 1 mark for 78° |
|  |  |  | **Total** | **6** |  |
| 21 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |
| 22 |  |  | **B** | 1 | **Examiner’s Comments**  This question required understanding of *thinking, braking* and *stopping* distances together with an appreciation of the learning outcome 3.1.1(d). The total area under this velocity–time graph is equal to stopping distance. The area of the ‘rectangle’ is equal to thinking distance and the area of the ‘triangle’ is equal to the braking distance. The correct answer is **B**. The popular distractor was **A**, which just represented the braking distance.  **Exemplar 4**   This exemplar illustrates how minimal work in a multiple–choice answer can produce dividends. The candidate has used the thinking distance and the ‘reaction time’ of 0.5 s to determine the initial speed of the car (20 m s−1). This has then been used to calculate the braking distance. No interim values of distances are shown, but the candidate has done all the hard work by the substitution shown and labelling the vertical axis. A model answer from this high performing candidate. |
|  |  |  | **Total** | **1** |  |
| 23 |  |  | **B** | 1 |  |
|  |  |  | **Total** | **1** |  |
| 24 |  |  | Sum of thinking distance and the braking distance | **B1** | **Allow** the (total) distance travelled from when the driver sees a hazard to the vehicle stopping wtte  **Examiner’s Comments** The first question was incorrectly answered by a large number of candidates. The common error was only referring to braking distance. |
|  |  |  | **Total** | **1** |  |
| 25 |  |  | **D** | **1** |  |
|  |  |  | **Total** | **1** |  |
| 26 |  |  | **C** | 1 | **Examiner’s Comments** This question was slightly more challenging. |
|  |  |  | **Total** | **1** |  |
| 27 |  |  | **A** | 1 | **Examiner’s Comments** This question was more challenging still. In this question, it was expected that candidates would use the idea that v2 = u2 + 2aS, hence realising that v2 was directly proportional to the drop height, h, giving option A as the correct answer. |
|  |  |  | **Total** | **1** |  |
| 28 | a |  | |  |  |  | | --- | --- | --- | | s = 0.5 (m) | / | t = 0.5 (s) |      |  |  |  | | --- | --- | --- | |  | or | 0 = 2.02 + 2 × a × 0.5 |   deceleration = (−) 4.0 (m s−2) | **C1    A1** | **Allow** other correct methods  Possible ECF from **(b)**    **Allow** 1 sf answer **Ignore** sign  **Examiner’s Comments** Most candidates were aware of what equation to use but only about half managed to gain one or two marks for their calculation. The simplest answers occupied a single line and the complex ones recalculated the initial velocity of the trolley from the graph and then used the equation v2 = u2 + 2as. There were no marks for using incorrect values for the time, or the displacement, during the deceleration stage. A significant number of candidates took the time for stopping to be either 0.80 s or 1.0 s. |
|  | b |  | Constant velocity from 0 to 0.3(0 s) / up to 0.3(0 s) / up to the crash / at the start  Velocity decreases / deceleration from 0.3(0 s) to 0.8(0 s)  Zero velocity / stationary after 0.8 (s) / towards the end  gradient (of the graph) = velocity | **B1   B1   B1   B1** | **Allow** speed instead of velocity **Allow** 0.30 to 0.40   **Allow** 0.30 to 0.40 and 0.76 to 0.80 **Allows** slows down  Possible ECF   **Allow** slope instead of gradient **Allow** gradient is 2.0 (m s−1) / gradient is constant (up to 0.30 s) / straight line (up to 0.30 s), so velocity / speed is constant **Allow** gradient decreases (between 0.30 s and 0.80 s), so velocity / speed decreases **Allow** gradient is zero (after 0.80 s), so velocity / speed is zero  **Examiner’s Comments** Most candidates gained two or more marks. Answers were often longer than required, but most candidates managed to analyse the displacement-time graph of the trolley extremely well. A few candidates lost marks for incorrect physics such as ‘the trolley decelerates at a constant speed between 0.3 s and 0.8 s’. The top-end candidates scored full marks for their descriptions and recognised that the velocity was equal to the gradient. A small number of candidates spoilt their answers by suggesting that the trolley ‘bounced back’. |
|  |  |  | **Total** | **6** |  |
| 29 |  |  | **B** | **1** |  |
|  |  |  | **Total** | **1** |  |
| 30 |  | i |  | M1 | **Allow** other correct methods, e.g: |
|  |  | i | (t = ) 0.6(42....s) | A0 | **Not** a = 10 m s−2 **Note** t must be the unknown   **Examiner's Comments**  There were some convoluted answers. A number of candidates gained credit but wasted time by solving a quadratic equation. Some candidates assumed that the vertical velocity was an average and determined the time and then just multiplied by two without explanation – this did not gain credit. Clear explanations of the method are used to answer these types of “show” questions. |
|  |  | ii |  | M1 | **Note** v must be the unknown |
|  |  | ii | (vH =) 28 (m s−1) or 30 (m s−1) | A0 | **Examiner's Comments**  This part was answered better although some candidates tried using an equation with acceleration. |
|  |  | iii |  | C1 | **Allow** trigonometry methods |
|  |  | iii | v = 31 (m s−1) | A1 | v = 29 (m s−1) **Note** 940 scores one mark   **Examiner's Comments**  A pleasing number of candidates determined the magnitude of the velocity correctly, Some correctly used trigonometry methods. |
|  |  |  | **Total** | **4** |  |
| 31 | a | i | Gradient / It is the **acceleration** which is the same (for both) (AW) | B1 | **Note: acceleration** must be spelled correctly for this mark **Allow**: Gradient / It is the **acceleration** and **acceleration** is free fall/*g/9.8 (1)*  **Examiner's Comments**  This question was generally answered fairly well although a significant minority could not be awarded the mark as they did not specifically link the gradient to acceleration of the ball. |
|  |  | ii | Collision is inelastic / kinetic energy is lost (on impact with the ground) | B1 |  |
|  |  | ii | Idea that area is height (above ground) / Height (at E) is less (than height of A) (AW) | B1 | **Not** heights are not the same **Allow:** displacement or distance travelled by ball for height  **Examiner's Comments**  Although the underlying physics was fairly well known, this became a discriminating question because a large proportion of candidates did not specifically refer to the change in kinetic energy on impact. |
|  | b | i | *u2* = 2×9.8(1)2×1.7 (=33.32) *u* = 5.8 (ms−1) | B1 | **Not** *g* = 10 **Note** answer to 3 sf is 5.78 (m s−1)  **Examiner's Comments**  This synoptic question caused little difficulty to the majority of candidates |
|  |  | ii | **EITHER** *F* Δt=m(v-u) **and** *F* Δt = 16×75×10−3 16×75×10−3=0.13×[*v*−(−5.78)] *v* = 3.5 (ms−1) | C1 | **Allow** ECF from (i) **Allow** (from graph for C1 mark) |
|  |  | ii | **OR** *a* = *F/m* = 16/0.13 (*a* =123) (upwards positive) v = −5.78 +123 × 75 × 10−3 = 3.5 (m s−1) | A1 | **Note:** answer to 3 sf is 3.46 (ms−1) Using u = −5.8 leads to *v* = 3.4 scores 2/2 Using u = +5.78 leads to *v* = 15 scores 1/2 Using equation of motion with a = 9.8(1) is WP score 0/2  **Examiner's Comments**  While most candidates linked this question to impulse and were able to score the first mark, it was only a minority that appreciated the vector nature of the problem and were thus able to complete the calculation correctly. Only a small minority attempted to solve the problem by using ratios from the graph or by determining the mean acceleration of the ball during impact. |
|  |  | iii | *h* = 0.61 (m) | B1 | **NO ECF** **Allow** graphical method using *h ∞ v2* **Allow** answer in range 0.59 − 0.63 (m)  **Examiner's Comments**  A number of candidates gave answers which were larger than the initial height of release. Largely these were a result of errors in previous answers. It is always advisable to reflect on the value of answers which are dependent on earlier working. |
|  |  |  | **Total** | **7** |  |
| 32 |  | i | *x* ∝ *u* 2 or doubling the speed increases the distance by a factor of 4 | B1 | **Examiner's Comments**  Around half the candidates scored this mark. Common errors were to write that *u* is directly proportional to *x*, or that *u* is directly proportional to x2 - the reverse of the correct answer. |
|  |  | ii | thinking distance = 30 × 0.6 or 18 (m) | C1 |  |
|  |  | ii | braking distance = 0.08 × *u* 2 or 0.08 × 302 or 72 (m) | C1 |  |
|  |  | ii | stopping distance = 18 + 72 |  |  |
|  |  | ii | stopping distance = 90 (m) | A1 | **Examiner's Comments**  Whilst the calculation of thinking distance was usually done correctly, the calculation of braking distance was a more complex calculation that produced excellent discrimination between the different quartiles. Interestingly many who had incorrectly written ‘*u* is directly proportional to x2’ went on to calculate the correct value of braking distance in this question. |
|  |  |  | **Total** | **4** |  |
| 33 | a | i | **1**    Increasing acceleration | B1 | **Not:** answers using rate of acceleration - for either mark   **Examiner's Comments**  Candidates had difficulty with this question. Many knew the motion of the object was not uniform acceleration and wrote ‘non-uniform acceleration’, which was insufficient for the mark. Many included the word rate in their answer in such a way that they negated a possibly correct answer. The correct way to have used rate to score the mark would be to write ‘increasing rate of change of velocity’, which a few candidates did. |
|  |  | i | **2**    Constant deceleration | B1 | **Not**: Constant acceleration **Allow**: constant negative acceleration **Allow:** uniform /steady deceleration   **Examiner's Comments**  Twice as many candidates answered this part correctly. Again, incorrect inclusion of the word rate penalised some candidates. |
|  |  | ii | The area under the graph from t = 0 to t = 2 s is smaller (AW) | B1 | **Examiner's Comments**  It was well understood that the area beneath a velocity time graph gives distance. A small number of candidates tried to answer this question with reference to gradients or the length of the base line - but omitted to mention area. A few candidates used incompatible adjectives such as ‘it has a shorter area’. |
|  | b |  | (Acceleration =) rate of change of velocity | B1 | **Allow**: Equations and as long as labels, *v, u*, Δ*v* and *t* are defined. **Not**: ‘speed’ instead of ‘velocity’  **Examiner's Comments**  Candidates answered this opening question well with the vast majority writing a succinct and correct definition. A noticeable incorrect answer was ‘the rate of change of velocity per unit time’; candidates need to be aware that in dynamics the term ‘rate’ includes per unit time. |
|  |  |  | **Total** | **4** |  |
| 34 | a |  | 3.6 ± 0.4 (m2 s−2) | B1 |  |
|  | b | i | Data point and error bar correctly plotted | B1 | **Allow** ecf from previous part. |
|  |  | ii | \* **Level 3 (5–6 marks)** Detailed analysis of the graph clearly linked to the principle of conservation of energy, including determination of the value of g and the related uncertainty in the answer.  There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.  **Level 2 (3–4 marks)** Analysis of the graph linked to kinetic energy and / or potential energy, with an attempt to find the value of g. Mention of where one would find uncertainties in the answer but without analysis.  There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.  **Level 1 (1–2 marks)** Line of best fit drawn and gradient attempted. Mention of energy and / or where uncertainties may occur.  The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.  **0 marks** No response or no response worthy of credit. | B1 × 6 | **Explanation**   1. Principle of conservation of energy used to derive relationship. 2. mgh = ½ mv2 or v2 = 2gh 3. A graph of v2 against h will be a straight line (through the origin). 4. Gradient of line = 2g.   **Determination**   1. Line of best fit drawn through all data points. 2. Gradient in the range 17 to 21 (m2 s−2). 3. g determined correctly from the gradient.   **Uncertainty**   1. Worst line of fit drawn. 2. Correct attempt to determine the uncertainty. |
|  |  |  | **Total** | **8** |  |
| 35 |  |  | D | 1 |  |
|  |  |  | **Total** | **1** |  |