MEGA LECTURE

IB DP PHYSICS

Theme A · Space, Time and Motion

TOPICAL WORKSHEET

A.1 Kinematics · A.2 Forces and Momentum · A.3 Work, Energy and Power
A.4 Rigid Body Mechanics (HL) · A.5 Relativity (HL)

Standard and Higher Level · Syllabus 2025

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Original exam-style questions written for the IB Diploma Programme Physics course (first assessment 2025)

Section A — Multiple Choice (15 marks)

Circle the letter of the best answer to each question. Each question is worth 1 mark.

1. A ball is thrown vertically upward at 15 m s^{-1}. Taking g = 9.8 m s^{-2} and ignoring air resistance, what is its velocity after 2.0 s? **[1]**

A 4.6 m s^{-1} upward

B 4.6 m s^{-1} downward

C 34.6 m s^{-1} downward

D 0 m s^{-1}

2. Which feature of a displacement–time graph gives the instantaneous velocity at a point? **[1]**

A The area under the graph up to that point

B The gradient of the tangent to the curve at that point

C The y-intercept of the graph

D The curvature (rate of change of gradient) at that point

3. A car accelerates uniformly from 4.0 m s^{-1} to 22 m s^{-1} over a distance of 130 m. What is its acceleration? **[1]**

A 0.72 m s^{-2}

B 1.4 m s^{-2}

C 1.8 m s^{-2}

D 2.6 m s^{-2}

4. A 5.0 kg box on a frictionless surface is pushed by a resultant force of 15 N. What is its acceleration? **[1]**

A 0.33 m s^{-2}

B 3.0 m s^{-2}

C 5.0 m s^{-2}

D 15 m s^{-2}

5. Newton's third law action–reaction pairs act **[1]**

A on the same object, in the same direction

B on two different objects, are the same type of force, and are equal and opposite

C on two different objects but are always different types of force

D only during collisions, not for objects at rest

6. A trolley of mass 2.0 kg moving at 3.0 m s^{-1} collides and sticks to a stationary 4.0 kg trolley. What is their common velocity after the collision? **[1]**

A 0.50 m s^{-1}

B 1.0 m s^{-1}

C 1.5 m s^{-1}

D 2.0 m s^{-1}

7. A crane lifts a 500 kg mass at a constant 2.0 m s^{-1}. What power must the crane's motor deliver (ignoring losses)? **[1]**

A 0.98 kW

B 4.9 kW

C 9.8 kW

D 19.6 kW

8. Which quantity is conserved in a perfectly elastic collision but not in an inelastic collision? **[1]**

A Momentum

B Total kinetic energy

C Total energy

D Mass

9. A spring of force constant k = 200 N m^{-1} is compressed by 0.15 m. How much elastic potential energy is stored? **[1]**

A 1.5 J

B 2.25 J

C 3.0 J

D 4.5 J

10. A force of 20 N is applied perpendicular to a spanner at a distance of 0.30 m from the pivot bolt. What torque does it produce? **[1]**

A 3.0 N m

B 6.0 N m

C 9.0 N m

D 12 N m

11. What is the moment of inertia of a uniform solid sphere of mass 3.0 kg and radius 0.20 m about an axis through its centre (**I** = ■⁄■mr^2)? **[1]**

A 0.012 kg m^2

B 0.024 kg m^2

C 0.048 kg m^2

D 0.096 kg m^2

12. Angular momentum of a system is conserved whenever **[1]**

A the net external torque on the system is zero

B the net external force on the system is zero

C the total kinetic energy is constant

D it is always conserved, with no condition

13. A spaceship moves at $v = 0.60c$ relative to Earth. What is the Lorentz factor γ? **[1]**

A 0.80

B 1.00

C 1.25

D 1.67

14. According to an observer on Earth, a clock moving at high speed relative to them runs **[1]**

A faster than an identical clock at rest on Earth

B slower than an identical clock at rest on Earth

C at exactly the same rate

D faster or slower depending only on its direction of motion

15. The "proper length" of an object is the length measured **[1]**

A by an observer for whom the object is moving

B in the rest frame of the object itself

C by any observer, since length is invariant

D only when the object moves at $v = c$

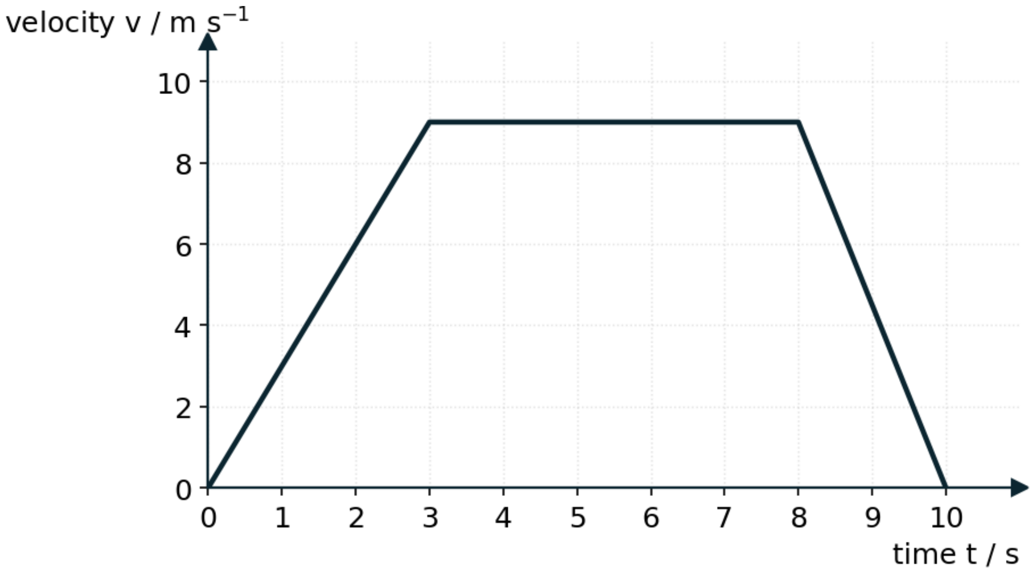
Section B — Structured Questions (70 marks)

Answer all questions in the space provided. Working must be shown for full marks.

A.1 Kinematics

Question 1 [7 marks]

A sprinter accelerates uniformly from rest to a maximum speed, holds that speed, then decelerates uniformly to rest. The graph below shows her velocity during the run.



Velocity–time graph for the sprint (values on the axes are the given data for this question).

(a) Calculate the sprinter's acceleration during the first 3.0 s. **[2]**

(b) Show that the total distance covered during the 10 s run is about 68 m. **[3]**

(c) Calculate her average velocity for the whole 10 s run. **[2]**

Question 2 [7 marks]

A stone is kicked horizontally at 12 m s^{-1} from the top of a cliff of height 20 m. Air resistance is negligible; take g = 9.8 m s^{-2}.

(a) Calculate the time taken for the stone to reach the ground. **[2]**

(b) Calculate the horizontal distance travelled before landing. **[2]**

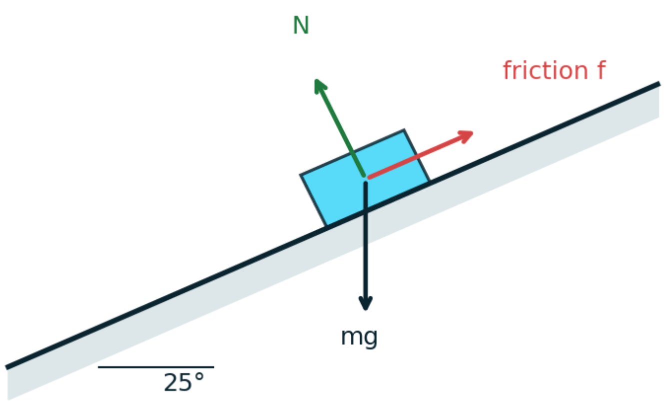
(c) Calculate the stone's speed as it hits the ground. **[3]**

A.2 Forces and Momentum

Question 3 [7 marks]

A 12 kg box rests on a rough incline at 25° to the horizontal, as shown. The coefficient of static friction between the box and the incline is 0.40. Take g = 9.8 m s^{-2}.

12 kg box on a rough incline (μ = 0.40)



Forces on the box: weight mg, normal force N, and friction f acting up the slope.

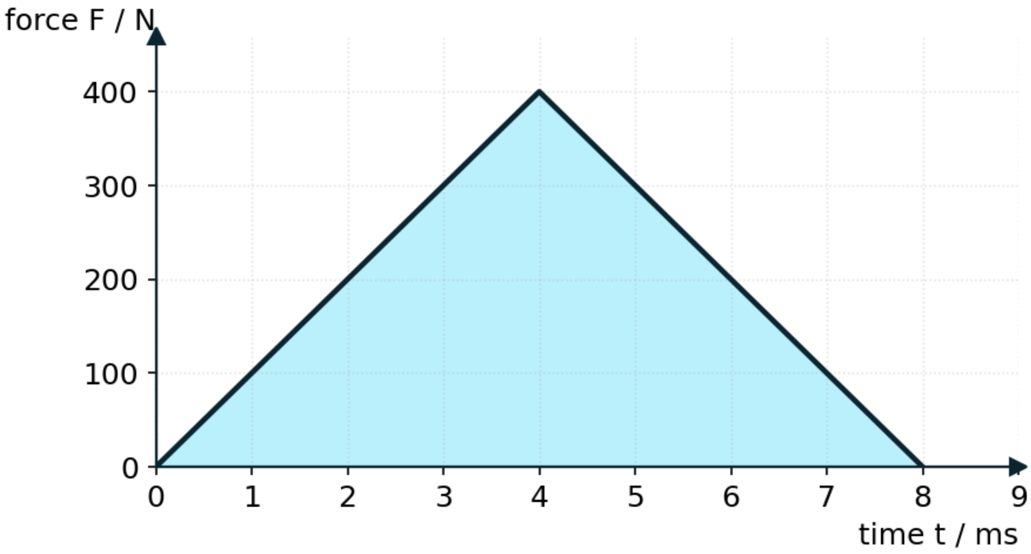
(a) Calculate the component of the box's weight acting along the incline (down the slope). **[2]**

(b) Calculate the normal force acting on the box. **[2]**

(c) Determine, showing your reasoning, whether the box remains stationary or begins to slide. **[3]**

Question 4 [6 marks]

A 0.50 kg ball is struck by a bat. The graph shows how the force on the ball varies during the 8.0 ms contact time.



Force–time graph for the bat–ball impact (given data).

(a) Calculate the impulse delivered to the ball during the impact. **[2]**

(b) Calculate the change in the ball's velocity, assuming it was at rest just before impact. **[2]**

(c) Calculate the average force exerted on the ball during the impact. **[2]**

A.3 Work, Energy and Power

Question 5 [8 marks]

A skier of mass 65 kg starts from rest at the top of a slope of vertical height 40 m. Take g = 9.8 m s^{-2}.

(a) Calculate the loss in gravitational potential energy as the skier descends to the bottom. **[2]**

(b) Assuming no energy is lost to friction or air resistance, calculate the skier's speed at the bottom of the slope. **[3]**

(c) In reality the skier's speed at the bottom is measured to be 24 m s^{-1}. Calculate the energy transferred to thermal energy by friction and air resistance. **[3]**

Question 6 [6 marks]

An electric motor lifts a 15 kg load a vertical height of 6.0 m in 8.0 s, moving at constant speed. The electrical energy supplied to the motor during this time is 1500 J. Take g = 9.8 m s^{-2}.

(a) Calculate the useful work done in lifting the load. **[2]**

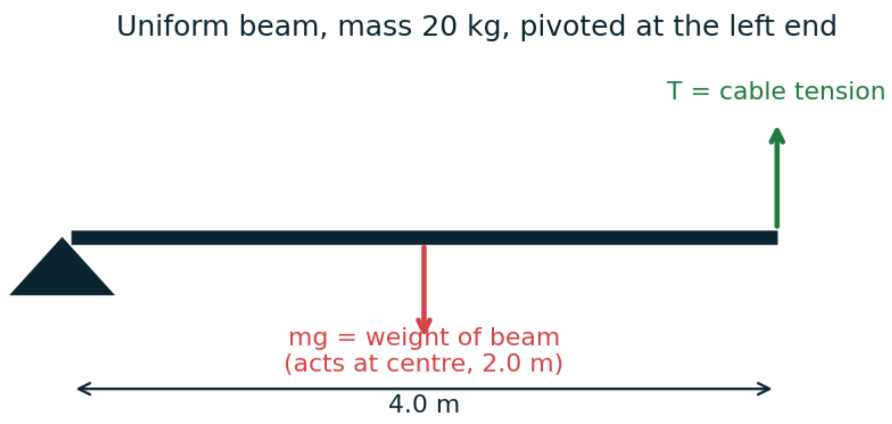
(b) Calculate the efficiency of the motor. **[2]**

(c) Calculate the useful power output of the motor. **[2]**

A.4 Rigid Body Mechanics (HL)

Question 7 [8 marks]

A uniform beam of length 4.0 m and mass 20 kg is pivoted (hinged) at one end and held horizontal by a vertical cable attached at its far end, as shown. Take g = 9.8 m s^{-2}.



Uniform beam in rotational equilibrium about the pivot.

(a) Calculate the torque produced about the pivot by the beam's own weight. **[2]**

(b) Hence calculate the tension T in the cable, which acts vertically at the far end of the beam, 4.0 m from the pivot. **[3]**

(c) An additional 10 kg mass is now hung from the far end of the beam. Calculate the new tension in the cable. **[3]**

Question 8 [8 marks]

A solid cylinder of mass 2.0 kg and radius 0.10 m (**I** = ½mr^2 for a solid cylinder about its central axis) rolls without slipping from rest down a slope, reaching the bottom with a linear speed of 4.0 m s^{-1}. Take g = 9.8 m s^{-2}.

(a) Calculate the cylinder's angular velocity at the bottom of the slope. **[2]**

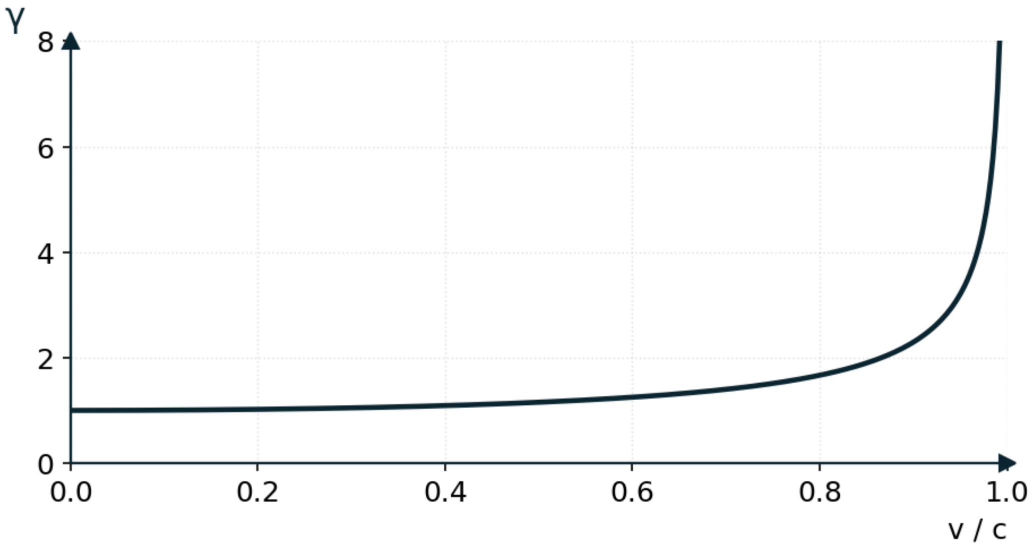
(b) Show that the cylinder's total kinetic energy at the bottom is about 24 J. **[3]**

(c) Assuming no energy is lost to friction, calculate the vertical height of the slope. **[3]**

A.5 Relativity (HL)

Question 9 [7 marks]

A muon is created in the upper atmosphere and travels toward the Earth's surface at v = 0.98c. In the muon's own rest frame, its (proper) lifetime is 2.2 μs. The graph below shows how the Lorentz factor γ varies with speed v/c.



γ as a function of v/c (reference curve — read off approximately, then verify by calculation in part (a)).

(a) Calculate the Lorentz factor γ for the muon. **[2]**

(b) Calculate the muon's lifetime as measured by an observer on the ground. **[2]**

(c) Using this dilated lifetime, calculate the distance (in the Earth's frame) that the muon travels before it decays. **[3]**

Question 10 [6 marks]

A spacecraft has a proper length of 120 m. It travels past the Earth at $v = 0.80c$.

(a) Calculate the Lorentz factor γ for the spacecraft's motion. **[2]**

(b) Calculate the spacecraft's length as measured by an observer on Earth. **[2]**

(c) The crew measure a journey time of 100 s using the spacecraft's own clock. Calculate the time for the same journey as measured by an observer on Earth. **[2]**