MOMENTUM

IB Physics HL

Kinematics - Set 1 - Markscheme

A.1 | First assessment 2025 | Higher Level

Independent examination-style practice material

10 original problems

Task 01 - Reading a velocity-time record

Paper 1A style | IB code A.1 | Total [1]

Part	Marking guidance	Marks
Answer	C. The total distance is 62.67 m, including the small distance travelled after v changes sign. Average speed = 62.67 / 9.0 = 6.96 m s^{-1}.	**1**

Task 02 - Crossing a river without drift

Paper 1A style | IB code A.1 | Total [1]

Part	Marking guidance	Marks
Answer	B. The upstream component must be 1.20 m s^{-1}, so sin(θ) = 1.20 / 2.50 and θ = 28.7 degrees. The across-river component is 2.19 m s^{-1}, giving t = 180 / 2.19 = 82.1 s.	**1**

Task 03 - Acceleration from optical-gate data

Paper 1B style | IB code A.1 | Total [8]

Part	Marking guidance	Marks
(a)	Uses $x = ut + (1/2)at^2$ with $u = 0$; identifies gradient of x against t^2 as $a/2$.	**2**
(b)	Calculates t^2 values; obtains a best-fit gradient about 0.80 m s^{-2}; hence $a = 2$(gradient) = 1.60 m s^{-2}. Accept 1.55 to 1.65 m s^{-2} with a defensible fit.	**4**
(c)	Best-fit intercept is approximately 0.005 m. This is comparable with the stated ± 0.006 m position uncertainty, so there is no significant evidence of a non-zero offset.	**2**

Task 04 - Testing a projectile model with video data

Paper 1B style | IB code A.1 | Total [9]

Part	Marking guidance	Marks
(a)	Gradient of x against t is constant; $v_x = 1.919 / 0.60 = 3.20$ m s^{-1}, within rounding uncertainty.	**2**
(b)	For equal time steps, $\Delta^2 y = a_y(\Delta t)^2$. The second differences are about -0.098 m, giving a_y about -9.8 m s^{-2}; magnitude 9.8 m s^{-2}.	**3**
(c)	From $y = 3.40t - 4.90t^2$, $v_y = 3.40 - 9.80t$. Thus $t_{max} = 0.347$ s and $y_{max} = 0.590$ m.	**2**
(d)	The x-t data are linear and the vertical second differences are constant within measurement uncertainty. There is no measurable departure from the no-drag model in these data.	**2**

Task 05 - A delayed pursuit

Paper 2 style | IB code A.1 | Total [7]

Part	Marking guidance	Marks
(a)	Motorcycle acceleration time = 18.0 / 2.40 = 7.50 s. Its distance is 0.5(2.40)(7.50)^2 = 67.5 m. At that instant the cyclist has travelled 8.00(10.50) = 84.0 m, so no catch occurs during acceleration.	**3**
(b)	Gap after acceleration = 16.5 m. Relative speed = 18.0 - 8.00 = 10.0 m s^{-1}, requiring 1.65 s. Total time after the cyclist passes = 3.00 + 7.50 + 1.65 = 12.15 s.	**3**
(c)	x = 8.00(12.15) = 97.2 m.	**1**

Task 06 - Projectile motion above a descending slope

Paper 2 style | IB code A.1 | Total [8]

Part	Marking guidance	Marks
(a)	Uses $x = u\cos(25)t$ and $y = u\sin(25)t - gt^2/2$ with $y = -x\tan(12)$. Solving after cancelling t gives $t = 2u[\sin(25) + \cos(25)\tan(12)]/g = 2.26$ s.	**3**
(b)	Horizontal distance $x = 18.0\cos(25)(2.26) = 36.8$ m. Distance along slope $= x / \cos(12) = 37.6$ m.	**2**
(c)	$v_x = 16.3$ m s^{-1} and $v_y = 18.0\sin(25) - 9.81(2.26) = -14.5$ m s^{-1}. Speed $= 21.8$ m s^{-1}. Velocity is 41.7 degrees below horizontal, hence 29.7 degrees below the slope.	**3**

Task 07 - A bouncing ball recorded by a microphone

Paper 2 style | IB code A.1 | Total [8]

Part	Marking guidance	Marks
(a)	Each complete flight interval is 2u/g, where u is the rebound speed. Successive rebound speeds are in the ratio e, so successive intervals are also in the ratio e.	**2**
(b)	Ratios are approximately 1.01/1.26 = 0.802, 0.81/1.01 = 0.802 and 0.65/0.81 = 0.802. Therefore e about 0.80.	**2**
(c)	First rebound speed u_1 = g(1.26)/2 = 6.18 m s^{-1}. Speed just before the first impact is u_1/e = 7.73 m s^{-1}. Release height h = v^2/(2g) = 3.04 m.	**3**
(d)	Δt_next = e(0.65) about 0.52 s.	**1**

Task 08 - Kinematics of a rotating camera arm

Paper 2 style | IB code A.1 | Total [7]

Part	Marking guidance	Marks
(a)	$\theta(2.00) = 2.40$ rad. Differentiation gives $\omega = 1.20t^2 - 2.40t + 2.00$, so $\omega = 2.00$ rad s^{-1}. $\alpha = 2.40t - 2.40$, so $\alpha = 2.40$ rad s^{-2}.	**3**
(b)	Tangential acceleration $a_t = r\alpha = 1.92$ m s^{-2}. Radial acceleration $a_r = r\omega^2 = 3.20$ m s^{-2} inward.	**2**
(c)	$a = \sqrt{(1.92^2 + 3.20^2)} = 3.73$ m s^{-2}. Angle from the inward radial direction is arctan(1.92/3.20) = 31.0 degrees towards the direction of motion.	**2**

Task 09 - Aircraft navigation in a crosswind

Paper 2 style | IB code A.1 | Total [8]

Part	Marking guidance	Marks
(a)	East component = 72.0 sin(20.0) - 18.0 = 6.63 m s^{-1}; north component = 72.0 cos(20.0) = 67.7 m s^{-1}. Ground speed = 68.0 m s^{-1} at 5.59 degrees east of north.	**3**
(b)	For 1080 s: east displacement = 7.16 km and north displacement = 73.1 km. The displacement magnitude is 73.4 km at 5.59 degrees east of north.	**2**
(c)	For zero east ground component, 72.0 sin(θ) = 18.0, giving θ = 14.5 degrees east of north. North ground speed = 72.0 cos(14.5) = 69.7 m s^{-1}. Time = 100000 / 69.7 = 1.43 x 10^3 s = 23.9 min.	**3**

Task 10 - Displacement and distance from an acceleration graph

Paper 2 style | IB code A.1 | Total [9]

Part	Marking guidance	Marks
(a)	For $0 <= t <= 4$, $a = 1.50t$ and $v = -5.00 + 0.750t^2$. Setting $v = 0$ gives $t = 2.58$ s.	**2**
(b)	Acceleration becomes zero at $t = 7.00$ s, so velocity is maximal there. $v(4) = -5.00$ + area 0-4 = 7.00 m s^{-1}. Area 4-7 is 9.00 m s^{-1}, hence $v_{max} = 16.0$ m s^{-1}.	**3**
(c)	For 0-4, integrating $v = -5 + 0.75t^2$ gives displacement -4.00 m. For 4-8, integrating $v = 14t - t^2 - 33$ gives 54.67 m. Total displacement = 50.7 m.	**2**
(d)	At the reversal, $x = -5t + 0.25t^3 = -8.61$ m. Distance = 8.61 m to the reversal plus 50.67 - (-8.61) m afterwards = 67.9 m.	**2**