A Level Mechanics
Practice Test 3: Kinematics

Instructions:
Answer all questions. Show your working clearly.
Calculators may be used unless stated otherwise.
Draw diagrams where appropriate to illustrate your solutions.
Time allowed: 2 hours 40 minutes

Section A: Advanced Mathematical Motion [30 marks]

Question 1 [**18 marks**] A particle moves along a straight line such that its acceleration at time t seconds is given by $a = 6t - 18$ m/s^2. At t = 0, the particle has velocity 10 m/s and is at position s = 5 m.

(a) Find the velocity of the particle at time t. [**4 marks**]

(b) Determine the position of the particle at time t. [**4 marks**]

(c) Calculate when the particle is momentarily at rest. [**3 marks**]

(d) Find the position of the particle when it is at rest. [**2 marks**]

(e) Determine when the acceleration is zero. [**2 marks**]

(f) Calculate the total distance traveled between t = 0 and t = 6 seconds. [**3 marks**]

Question 2 [**12 marks**] The displacement-time graph of a particle shows the following motion over 10 seconds: - Starts at s = 0 - Increases linearly to s = 20 m at t = 4 s - Remains constant at s = 20 m from t = 4 s to t = 7 s - Decreases linearly to s = 8 m at t = 10 s

(a) Sketch the corresponding velocity-time graph. [**4 marks**]

(b) Calculate the velocity during each phase of motion. [**3 marks**]

(c) Determine the average velocity over the entire 10 seconds. [**2 marks**]

(d) Calculate the total distance traveled. [**3 marks**]

Section B: Multi-Stage Motion Analysis [35 marks]

Question 3 [**20 marks**] A train journey consists of four stages: 1. Accelerates from rest at 0.8 m/s^2 for 30 seconds 2. Travels at constant speed for 5 minutes 3. Decelerates at 0.6 m/s^2 for 40 seconds 4. Travels at the new constant speed for 3 minutes

(a) Calculate the speed reached after stage 1. [**2 marks**]

(b) Find the distance covered in stage 1. [**3 marks**]

(c) Calculate the distance covered in stage 2. **[2 marks]**

(d) Determine the final speed after stage 3. **[3 marks]**

(e) Find the distance covered in stage 3. **[3 marks]**

(f) Calculate the distance covered in stage 4. **[2 marks]**

(g) Determine the total distance for the entire journey. **[2 marks]**

(h) Calculate the average speed for the entire journey. **[3 marks]**

Question 4 [15 marks] Two particles A and B start from the same point at t = 0. Particle A moves with constant velocity 12 m/s. Particle B starts from rest and accelerates at 1.5 m/s² for 10 seconds, then moves with constant velocity.

(a) Write displacement equations for both particles for t 10 s. **[3 marks]**

(b) Find when particle A is furthest ahead of particle B during the first 10 seconds. **[4 marks]**

(c) Calculate the maximum separation between the particles. **[3 marks]**

(d) Determine when particle B catches up with particle A. **[5 marks]**

Section C: Vertical Motion and Collision Analysis [30 marks]

Question 5 [18 marks] From the top of a tower 60 m high, one ball is dropped while another is thrown vertically downward with initial velocity 8 m/s. Both balls are released simultaneously.

(a) Write height equations for both balls. **[4 marks]**

(b) Calculate when each ball hits the ground. **[6 marks]**

(c) Find the velocities of both balls just before impact. **[4 marks]**

(d) Determine the vertical separation between the balls after 2 seconds. **[4 marks]**

Question 6 [12 marks] A ball is thrown vertically upward from ground level. It passes a window 15 m above the ground twice - once on the way up after 1.5 seconds, and once on the way down.

(a) Calculate the initial velocity of the ball. **[4 marks]**

(b) Find the maximum height reached by the ball. **[3 marks]**

(c) Determine when the ball passes the window on the way down. **[3 marks]**

(d) Calculate the total time of flight. **[2 marks]**

Section D: Complex Inclined Plane Motion [25 marks]

Question 7 [15 marks] A particle slides up a smooth inclined plane that makes an angle of 18° with the horizontal. The particle has an initial velocity of 16 m/s up the plane.

(a) Calculate the deceleration of the particle up the plane. **[3 marks]**

(b) Find how far up the plane the particle travels before coming to rest. **[4 marks]**

(c) Calculate the time taken to reach the highest point. **[3 marks]**

(d) Determine the particle's velocity after sliding back down for 3 seconds. **[3 marks]**

(e) Find the particle's position relative to its starting point after 8 seconds total. **[2 marks]**

Question 8 **[10 marks]** A block is placed on an inclined plane 25° to the horizontal. Due to friction, the block accelerates down the plane at 2.8 m/s² when released from rest.

(a) Calculate the coefficient of friction between the block and plane. **[5 marks]**

(b) If the plane is 10 m long, find the speed at the bottom. **[3 marks]**

(c) Calculate the time taken to reach the bottom. **[2 marks]**

Section E: Advanced Projectile Motion [40 marks]

Question 9 **[25 marks]** A golf ball is hit from ground level with initial velocity 45 m/s at an angle of 25° above the horizontal. The ball lands on a green that is 8 m above the level of the tee.

(a) Calculate the horizontal and vertical components of initial velocity. **[3 marks]**

(b) Write parametric equations for the ball's position. **[3 marks]**

(c) Find the time when the ball reaches its maximum height. **[3 marks]**

(d) Calculate the maximum height above the tee level. **[3 marks]**

(e) Determine the two times when the ball is at height 8 m above the tee. **[6 marks]**

(f) Calculate the horizontal distances for both times in part (e). **[4 marks]**

(g) Find the velocity components when the ball first reaches the green level. **[3 marks]**

Question 10 **[15 marks]** A projectile is launched from the edge of a cliff 35 m high with initial velocity 24 m/s at 50° below the horizontal.

(a) Calculate the horizontal and vertical components of initial velocity. **[3 marks]**

(b) Write equations for the projectile's position. **[3 marks]**

(c) Find when the projectile hits the ground. **[4 marks]**

(d) Calculate the horizontal distance from the cliff base where it lands. **[2 marks]**

(e) Determine the velocity components just before impact. **[3 marks]**

Section F: Vector Motion and Relative Velocity [25 marks]

Question 11 **[15 marks]** Ship A is traveling due east at 15 m/s while ship B is traveling northwest at 12 m/s. At t = 0, ship A is at the origin and ship B is at position (800 m, 600 m).

(a) Write position vector equations for both ships. **[4 marks]**

(b) Calculate the velocity of ship B relative to ship A. **[4 marks]**

(c) Find when the ships are closest together. **[4 marks]**

(d) Determine the minimum distance between the ships. **[3 marks]**

Question 12 **[10 marks]** A pilot wants to fly from airport A to airport B, which is 200 km due north of A. The aircraft's airspeed is 180 km/h and there is a wind of 40 km/h from the west.

(a) In what direction should the pilot head to fly directly from A to B? **[4 marks]**

(b) Calculate the ground speed for this direct flight. **[3 marks]**

(c) Find the time taken for the journey. **[2 marks]**

(d) If the pilot heads due north instead, how far east of airport B will the aircraft be after flying for the same time? **[1 mark]**

Section G: Comprehensive Motion Problems [25 marks]

Question 13 [25 marks] A ball is thrown from point A on the ground with velocity 20 m/s at 60° to the horizontal. At the same instant, another ball is thrown vertically upward from point B (which is 25 m horizontally from A) with initial velocity 18 m/s.

(a) Write position equations for both balls. **[4 marks]**

(b) Calculate when ball A reaches its maximum height. **[2 marks]**

(c) Find the maximum height reached by ball A. **[3 marks]**

(d) Determine when ball B reaches its maximum height. **[2 marks]**

(e) Calculate the maximum height reached by ball B. **[3 marks]**

(f) Find if and when the balls are at the same height. **[5 marks]**

(g) Calculate the horizontal separation between the balls when they are at the same height. **[3 marks]**

(h) Determine which ball hits the ground first and by how much time. **[3 marks]**

Physics Data and Formulae

Calculus and Motion:

$v = \frac{ds}{dt}$, $a = \frac{dv}{dt} = \frac{d^2s}{dt^2}$

$v = \int a\,dt + C$, $s = \int v\,dt + C$

SUVAT Equations:

$v = u + at$

$s = ut + \frac{1}{2}at^2$

$v^2 = u^2 + 2as$

$s = \frac{u+v}{2}t$

$s = vt - \frac{1}{2}at^2$

Projectile Motion:

Horizontal: $x = x_0 + u_x t$ (where $u_x = u\cos\theta$)

Vertical: $y = y_0 + u_y t - \frac{1}{2}gt^2$ (where $u_y = u\sin\theta$)

Velocity components: $v_x = u_x$, $v_y = u_y - gt$

Resultant velocity: $v = \sqrt{v_x^2 + v_y^2}$

Direction: $\tan\alpha = \frac{v_y}{v_x}$

Inclined Plane Motion:

Component down plane: $mg\sin\theta - \mu mg\cos\theta = ma$

For smooth plane: $a = g\sin\theta$

With friction: $a = g(\sin\theta - \mu\cos\theta)$

Vector Analysis:

Position vector: $\vec{r} = x\hat{i} + y\hat{j}$

Velocity vector: $\vec{v} = \frac{d\vec{r}}{dt}$

Relative velocity: $\vec{v}_{AB} = \vec{v}_A - \vec{v}_B$

Magnitude: $|\vec{v}| = \sqrt{v_x^2 + v_y^2}$

Constants:

Acceleration due to gravity: $g = 9.8$ m/s^2

Trigonometric Values:

$\sin 18 = 0.309$, $\cos 18 = 0.951$

$\sin 25 = 0.423$, $\cos 25 = 0.906$

$\sin 50 = 0.766$, $\cos 50 = 0.643$

$\sin 60 = 0.866$, $\cos 60 = 0.500$

$\sin 45 = 0.707$, $\cos 45 = 0.707$ (for northwest direction)

END OF TEST

Total marks: 210

Grade boundaries: A* 189, A 168, B 147, C 126, D 105, E 84

For more resources and practice materials, visit:
stepupmaths.co.uk