# A Level Mechanics
# Practice Test 2: Statics and Dynamics of Particles

**Instructions:**
Answer all questions. Show your working clearly.
Calculators may be used unless stated otherwise.
Draw clear diagrams where appropriate to illustrate your solutions.
Time allowed: 2 hours 30 minutes

## Section A: Equilibrium of Particles [30 marks]

**Question 1** [**12 marks**] A particle is in equilibrium under the action of three forces: 15 N acting horizontally to the right, 20 N acting at 60° above the horizontal, and a third force F.

(a) Resolve the 20 N force into horizontal and vertical components. [**3 marks**]

(b) Calculate the horizontal component of force F required for equilibrium. [**2 marks**]

(c) Calculate the vertical component of force F required for equilibrium. [**2 marks**]

(d) Find the magnitude and direction of force F. [**4 marks**]

(e) Verify your answer by showing that the sum of all forces is zero. [**1 mark**]

**Question 2** [**18 marks**] A chandelier of mass 50 kg is suspended from the ceiling by three cables. Cable A is vertical, cable B makes an angle of 25° with the vertical, and cable C makes an angle of 40° with the vertical. Cables B and C are attached to the same point on the chandelier.

(a) Draw a force diagram showing all forces acting at the attachment point. [**3 marks**]

(b) If the tension in cable A is 300 N, calculate the weight supported by this cable. [**2 marks**]

(c) Write equilibrium equations for the horizontal and vertical directions at the attachment point. [**3 marks**]

(d) Calculate the tension in cable B. [**5 marks**]

(e) Calculate the tension in cable C. [**3 marks**]

(f) Find the total weight of the chandelier and verify this equals the given mass. [**2 marks**]

## Section B: Particles on Inclined Planes [40 marks]

**Question 3** [**20 marks**] A crate of mass 18 kg rests on a rough inclined plane that makes an angle of 28° with the horizontal. The coefficient of static friction is 0.65 and the coefficient of kinetic friction is 0.45.

(a) Calculate the component of weight acting down the inclined plane. [**3 marks**]

(b) Find the normal reaction force between the crate and the plane. **[3 marks]**

(c) Calculate the maximum static friction force available. **[3 marks]**

(d) Determine whether the crate will remain stationary on the plane. Show your reasoning clearly. **[4 marks]**

(e) If a horizontal force of 80 N is applied to push the crate up the plane, calculate the component of this force parallel to the plane. **[3 marks]**

(f) For the situation in part (e), determine whether the crate will move up the plane and calculate its acceleration if it does. **[4 marks]**

**Question 4 [20 marks]** A skier of mass 70 kg slides down a slope inclined at 15° to the horizontal. The coefficient of kinetic friction between the skis and snow is 0.12.

(a) Draw a force diagram showing all forces acting on the skier. **[3 marks]**

(b) Calculate the component of the skier's weight parallel to the slope. **[3 marks]**

(c) Find the normal reaction force from the slope. **[3 marks]**

(d) Calculate the friction force acting on the skier. **[3 marks]**

(e) Determine the net force acting down the slope. **[2 marks]**

(f) Calculate the acceleration of the skier down the slope. **[3 marks]**

(g) If the skier starts from rest, find the velocity after sliding 50 m down the slope. **[3 marks]**

## Section C: Systems of Connected Particles [50 marks]

**Question 5 [25 marks]** Two blocks A and B have masses 8.0 kg and 12 kg respectively. They are connected by a light inextensible string passing over a smooth pulley. Block A rests on a rough horizontal table with coefficient of kinetic friction 0.25, while block B hangs freely.

(a) Draw separate force diagrams for both blocks. **[4 marks]**

(b) Calculate the weight of block B. **[2 marks]**

(c) Find the maximum static friction force on block A if the coefficient of static friction is 0.30. **[3 marks]**

(d) Determine whether the system will remain in equilibrium or start to move. **[3 marks]**

(e) Write the equation of motion for block A in the horizontal direction. **[3 marks]**

(f) Write the equation of motion for block B in the vertical direction. **[2 marks]**

(g) Calculate the acceleration of the system. **[5 marks]**

(h) Find the tension in the string. **[3 marks]**

**Question 6 [25 marks]** A particle P of mass 4.0 kg is connected by a light inextensible string to particle Q of mass 6.0 kg. Particle P rests on a smooth inclined plane at 35° to the horizontal, while particle Q rests on a rough inclined plane at 20° to the horizontal (coefficient of kinetic friction 0.4). The string passes over a smooth pulley at the junction of the two planes.

(a) Draw force diagrams for both particles. **[4 marks]**

(b) For particle P, calculate the component of weight down the inclined plane. **[3 marks]**

(c) For particle Q, calculate:

(i) The component of weight down the inclined plane. **[2 marks]**

(ii) The normal reaction force. **[2 marks]**

(iii) The maximum friction force available. **[2 marks]**

(d) Determine the direction of motion of the system by comparing the driving forces. **[3 marks]**

(e) Write equations of motion for both particles and solve for the acceleration. **[6 marks]**

(f) Calculate the tension in the string. **[3 marks]**

## Section D: Motion with Resistance [25 marks]

**Question 7 [15 marks]** A particle of mass 3.0 kg moves in a straight line under the action of a driving force F = (20 - 4t) N, where t is time in seconds. The particle also experiences a constant resistance force of 5.0 N.

(a) Write an expression for the net force acting on the particle at time t. **[2 marks]**

(b) Calculate the acceleration of the particle when t = 2.0 s. **[3 marks]**

(c) If the particle starts from rest, derive an expression for velocity as a function of time. **[5 marks]**

(d) Find the velocity of the particle when t = 3.0 s. **[2 marks]**

(e) Calculate the displacement of the particle during the first 3.0 seconds. **[3 marks]**

**Question 8 [10 marks]** A ball of mass 0.5 kg falls vertically through air. The air resistance force is proportional to the square of the velocity and is given by $R = 0.02v^2$ N, where v is the velocity in m/s.

(a) Write the equation of motion for the ball when falling. **[3 marks]**

(b) Calculate the terminal velocity of the ball. **[4 marks]**

(c) If the ball has reached 80% of its terminal velocity, calculate the acceleration at this instant. **[3 marks]**

## Section E: Projectile Motion [35 marks]

**Question 9 [20 marks]** A stone is thrown horizontally from the top of a building 80 m high with an initial velocity of 15 m/s.

(a) Write expressions for the horizontal and vertical positions as functions of time. **[4 marks]**

(b) Calculate the time taken for the stone to reach the ground. **[3 marks]**

(c) Find the horizontal distance traveled when the stone hits the ground. **[3 marks]**

(d) Calculate the horizontal and vertical components of velocity just before impact. **[4 marks]**

(e) Find the magnitude and direction of the velocity just before impact. **[4 marks]**

(f) At what time is the stone 30 m above the ground? **[2 marks]**

**Question 10 [15 marks]** A golf ball is struck from ground level at an angle of 42° above the horizontal with an initial speed of 28 m/s.

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

(b) Find the maximum height reached by the ball. **[4 marks]**

(c) Calculate the time of flight of the ball. **[4 marks]**

(d) Determine the horizontal range of the ball. **[2 marks]**

(e) Find the velocity components when the ball is at half its maximum height on the way up. **[2 marks]**

## Section F: Complex Particle Problems [30 marks]

**Question 11 [18 marks]** A particle of mass 2.0 kg is in equilibrium under five forces: 25 N due north, 18 N due east, 30 N at 60° west of north, 20 N due south, and an unknown force F.

(a) Set up a coordinate system with east as positive x-direction and north as positive y-direction. **[1 mark]**

(b) Resolve each known force into x and y components. **[6 marks]**

(c) Calculate the sum of x-components and y-components of all known forces. **[3 marks]**

(d) Find the x and y components of force F required for equilibrium. **[3 marks]**

(e) Calculate the magnitude and direction of force F. **[4 marks]**

(f) Verify equilibrium by checking that the sum of all forces equals zero. **[1 mark]**

**Question 12 [12 marks]** A bead of mass 0.8 kg can slide on a smooth vertical circular wire of radius 1.2 m. The bead is in equilibrium under the action of its weight and a horizontal force P applied at the center of the circle.

(a) If the bead is positioned at 30° from the vertical, draw a force diagram showing all forces. **[3 marks]**

(b) Calculate the normal reaction force from the wire on the bead. **[4 marks]**

(c) Find the magnitude of the horizontal force P required for equilibrium. **[3 marks]**

(d) Determine the direction in which force P must act. **[2 marks]**

**Physics Data and Formulae**

**Forces and Equilibrium:**

For particle equilibrium: $\sum F_x = 0$ and $\sum F_y = 0$

Force resolution: $F_x = F\cos\theta$, $F_y = F\sin\theta$

Resultant magnitude: $R = \sqrt{F_x^2 + F_y^2}$

Resultant direction: $\tan\alpha = \frac{F_y}{F_x}$

**Newton's Laws:**

First Law: $\sum F = 0$ (equilibrium)

Second Law: $\sum F = ma$

Third Law: Action and reaction forces are equal and opposite

**Friction:**

Static friction: $f_s \leq \mu_s N$ (maximum: $f_{s,max} = \mu_s N$)

Kinetic friction: $f_k = \mu_k N$

**Inclined Planes:**

Component parallel to plane: $mg\sin\theta$ (down the plane)

Component perpendicular to plane: $mg\cos\theta$ (into the plane)

Normal reaction: $N = mg\cos\theta$ (for particle on plane)

**Kinematics:**

$v = u + at$

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

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

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

**Projectile Motion:**

Horizontal: $x = u_x t$ (constant velocity)

Vertical: $y = u_y t - \frac{1}{2}gt^2$

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

Maximum height: $h_{max} = \frac{u_y^2}{2g}$

Time of flight: $T = \frac{2u_y}{g}$

Range: $R = \frac{u_x \cdot 2u_y}{g}$

**Energy and Work:**

Kinetic energy: $KE = \frac{1}{2}mv^2$

Potential energy: $PE = mgh$

Work done: $W = Fs\cos\theta$

**Constants:**

Acceleration due to gravity: $g = 9.81$ m/s²

**Trigonometric Values:**

$\sin 15 = 0.259$, $\cos 15 = 0.966$, $\tan 15 = 0.268$

$\sin 20 = 0.342$, $\cos 20 = 0.940$, $\tan 20 = 0.364$

$\sin 25 = 0.423$, $\cos 25 = 0.906$, $\tan 25 = 0.466$

$\sin 28 = 0.469$, $\cos 28 = 0.883$, $\tan 28 = 0.532$

$\sin 30 = 0.500$, $\cos 30 = 0.866$, $\tan 30 = 0.577$

$\sin 35 = 0.574$, $\cos 35 = 0.819$, $\tan 35 = 0.700$

$\sin 40 = 0.643$, $\cos 40 = 0.766$, $\tan 40 = 0.839$

$\sin 42 = 0.669$, $\cos 42 = 0.743$, $\tan 42 = 0.900$

$\sin 60 = 0.866$, $\cos 60 = 0.500$, $\tan 60 = 1.732$

**END OF TEST**

Total marks: 210

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

**END OF TEST**

Total marks: 90

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