A Level Mechanics
Practice Test 1: 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 45 minutes

Section A: Forces and Equilibrium [35 marks]

Question 1 [10 marks]

(a) Define what is meant by a particle being in equilibrium. **[2 marks]**

(b) State the condition for equilibrium of a particle in terms of forces. **[2 marks]**

(c) Explain what is meant by concurrent forces and why the principle of moments does not apply to particles. **[3 marks]**

(d) A particle is acted upon by forces of 8 N east and 6 N north. Calculate the magnitude and direction of the third force needed for equilibrium. **[3 marks]**

Question 2 [12 marks] A particle of mass 5.0 kg is suspended by two light inextensible strings. String A makes an angle of 30° with the vertical, and string B makes an angle of 45° with the vertical.

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

(b) Write down the equilibrium equations in the horizontal and vertical directions. **[2 marks]**

(c) Calculate the tension in string A. **[4 marks]**

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

Question 3 [13 marks] A traffic light of weight 200 N is suspended from a cable that passes over two support points. The cable makes angles of 20° and 35° with the horizontal at the two support points.

(a) Draw a diagram showing the forces acting at the point where the traffic light is attached. **[3 marks]**

(b) Calculate the tension in the section of cable making 20° with the horizontal. **[5 marks]**

(c) Calculate the tension in the section of cable making 35° with the horizontal. **[3 marks]**

(d) Find the horizontal force exerted on each support point. **[2 marks]**

Section B: Forces on Inclined Planes [40 marks]

Question 4 [15 marks] A block of mass 8.0 kg rests on a smooth inclined plane that makes an angle of 25° with the horizontal. The block is held in equilibrium by a force F acting parallel to the inclined plane.

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

(b) Resolve the weight of the block into components parallel and perpendicular to the inclined plane. **[4 marks]**

(c) Calculate the magnitude of force F required to keep the block in equilibrium. **[3 marks]**

(d) Calculate the normal reaction force from the inclined plane. **[3 marks]**

(e) If the force F were applied horizontally instead of parallel to the plane, calculate the new magnitude required for equilibrium. **[2 marks]**

Question 5 [25 marks] A package of mass 12 kg rests on an inclined conveyor belt that makes an angle of 30° with the horizontal. The coefficient of static friction between the package and belt is 0.6, and the coefficient of kinetic friction is 0.4.

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

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

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

(d) Determine whether the package will remain stationary on the belt when the belt is not moving. Show your working clearly. **[4 marks]**

(e) If the belt moves upward at constant speed, calculate the actual friction force acting on the package. **[3 marks]**

(f) The belt now accelerates upward at 2.0 m/s². Calculate the friction force required to accelerate the package with the belt. **[4 marks]**

(g) Determine whether the package will slip on the belt during this acceleration. **[3 marks]**

(h) If the package does slip, calculate its acceleration relative to the belt. **[2 marks]**

Section C: Friction Problems [45 marks]

Question 6 [18 marks] A wooden crate of mass 25 kg rests on a horizontal wooden floor. The coefficient of static friction is 0.5 and the coefficient of kinetic friction is 0.4.

(a) Calculate the normal reaction force between the crate and floor. **[2 marks]**

(b) Find the maximum static friction force available. **[2 marks]**

(c) What horizontal force is required to just start the crate moving? **[2 marks]**

(d) Once the crate is moving at constant velocity, calculate the horizontal force needed to maintain this motion. **[3 marks]**

(e) If a horizontal force of 140 N is applied to the crate, determine whether it will move. **[3 marks]**

(f) For the force in part (e), calculate the acceleration of the crate. **[3 marks]**

(g) Find the velocity of the crate after it has moved 4.0 m from rest under this force. **[3 marks]**

Question 7 [27 marks] A box of mass 15 kg is placed on an inclined plane. The angle of inclination can be adjusted.

(a) If the coefficient of static friction between the box and plane is 0.7, calculate the maximum angle of inclination before the box starts to slide. **[4 marks]**

(b) At this critical angle, what is the magnitude of the static friction force? **[3 marks]**

(c) The angle is now increased to 40°. If the coefficient of kinetic friction is 0.5, calculate the acceleration of the box down the plane. **[6 marks]**

(d) Starting from rest, find the time taken for the box to slide 6.0 m down the plane at this angle. **[4 marks]**

(e) Calculate the velocity of the box after sliding this distance. **[3 marks]**

(f) Find the work done against friction as the box slides 6.0 m down the plane. **[4 marks]**

(g) Calculate the kinetic energy gained by the box and verify that energy is conserved. **[3 marks]**

Section D: Connected Particles [35 marks]

Question 8 [20 marks] Two particles A and B, with masses 4.0 kg and 6.0 kg respectively, are connected by a light inextensible string passing over a smooth fixed pulley. Particle A rests on a rough horizontal table with coefficient of kinetic friction 0.3, while particle B hangs freely.

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

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

(c) Find the maximum static friction force that can act on particle A. **[3 marks]**

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

(e) Calculate the acceleration of the system when it moves. **[5 marks]**

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

Question 9 [15 marks] Particle C (mass 3.0 kg) is connected by a light inextensible string to particle D (mass 5.0 kg). Particle C rests on a smooth inclined plane at 30° to the horizontal, while particle D hangs vertically over a smooth pulley at the top of the inclined plane.

(a) Draw force diagrams for both particles. **[3 marks]**

(b) Write down the equation of motion for particle C parallel to the inclined plane. **[3 marks]**

(c) Write down the equation of motion for particle D in the vertical direction. **[2 marks]**

(d) Calculate the acceleration of the system. **[4 marks]**

(e) Find the tension in the string connecting the particles. **[3 marks]**

Section E: Motion Under Variable Forces [25 marks]

Question 10 [15 marks] A particle of mass 2.0 kg moves in a straight line under the action of a variable force F = (6 + 4t) N, where t is time in seconds.

(a) Calculate the acceleration of the particle when t = 3.0 s. **[3 marks]**

(b) If the particle starts from rest, find expressions for:

(i) The velocity as a function of time. **[4 marks]**

(ii) The displacement as a function of time. **[3 marks]**

(c) Calculate the velocity and displacement of the particle when t = 4.0 s. **[3 marks]**

(d) Find the average acceleration during the first 4.0 seconds. **[2 marks]**

Question 11 [10 marks] A particle experiences a retarding force proportional to its velocity, given by F = -kv, where k = 0.8 Ns/m and v is the velocity in m/s.

(a) If the particle has mass 0.5 kg and initial velocity 10 m/s, write the equation of motion. **[3 marks]**

(b) Solve this equation to find velocity as a function of time. **[4 marks]**

(c) Calculate the time taken for the velocity to reduce to 2.0 m/s. **[3 marks]**

Section F: Projectile Motion Basics [30 marks]

Question 12 [18 marks] A ball is projected horizontally from the top of a cliff 45 m high with an initial velocity of 20 m/s.

(a) Calculate the time taken for the ball to reach the ground. **[4 marks]**

(b) Find the horizontal distance traveled by the ball. **[3 marks]**

(c) Calculate the vertical component of velocity just before impact. **[3 marks]**

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

(e) Calculate the maximum height above the launch point reached by the ball. **[2 marks]**

(f) Sketch the trajectory of the ball, marking key values. **[2 marks]**

Question 13 [12 marks] A projectile is launched at an angle of 35° above the horizontal with an initial speed of 25 m/s from ground level.

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

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

(c) Calculate the time of flight. **[3 marks]**

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

Physics Data and Formulae

Forces and Equilibrium:

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

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

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

Friction:

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

Kinetic friction: $f_k = \mu_k N$

Normal reaction on horizontal surface: $N = mg$

Normal reaction on inclined plane: $N = mg\cos\theta$

Inclined Planes:

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

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

Newton's Laws:

First Law: A particle remains at rest or in uniform motion unless acted upon by a resultant force

Second Law: $F = ma$ or $\sum F = ma$

Third Law: Action and reaction forces are equal and opposite

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

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

$v_y = u_y - gt$

Energy:

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

Gravitational potential energy: $PE = mgh$

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

Constants:

Acceleration due to gravity: $g = 9.81$ m/s^2

Trigonometric values:

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

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

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

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

$\sin 45 = 0.707$, $\cos 45 = 0.707$, $\tan 45 = 1.000$

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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