A Level Mechanics
Practice Test 1: Newton's Laws of Motion

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 15 minutes

Section A: Newton's Laws Fundamentals [20 marks]

Question 1 [8 marks]

(a) State Newton's first law of motion and give a practical example. **[2 marks]**

(b) State Newton's second law of motion in equation form. **[2 marks]**

(c) State Newton's third law of motion and give an example. **[2 marks]**

(d) Explain why Newton's first law is sometimes considered a special case of the second law. **[2 marks]**

Question 2 [12 marks]

(a) Define "net force" and explain how it relates to acceleration. **[3 marks]**

(b) Explain the difference between mass and weight. **[3 marks]**

(c) What is meant by equilibrium of forces? **[2 marks]**

(d) Give two examples each of contact forces and non-contact forces. **[4 marks]**

Section B: Free Body Diagrams and Force Analysis [25 marks]

Question 3 [10 marks]

(a) What is a free body diagram and why is it useful in mechanics problems? **[3 marks]**

(b) List the main steps involved in drawing a free body diagram. **[4 marks]**

(c) Explain the difference between weight and normal contact force. **[3 marks]**

Question 4 [15 marks] Draw free body diagrams for the following situations and identify all forces acting:

(a) A book resting on a horizontal table. **[3 marks]**

(b) A box being pushed across a rough horizontal surface at constant velocity. **[4 marks]**

(c) A ball hanging from a string attached to the ceiling. **[3 marks]**

(d) A block sliding down a smooth inclined plane. **[5 marks]**

Section C: Equilibrium Problems [20 marks]

Question 5 [**12 marks**] A mass of 20 kg hangs from two ropes attached to the ceiling. One rope makes an angle of 40° with the vertical, and the other makes an angle of 50° with the vertical.

(a) Draw a free body diagram for the mass. [**2 marks**]

(b) Write the equilibrium conditions for the horizontal and vertical directions. [**3 marks**]

(c) Calculate the tension in each rope. [**5 marks**]

(d) Verify that the vertical components of tension equal the weight. [**2 marks**]

Question 6 [**8 marks**] A uniform beam of length 3 m and mass 15 kg is supported horizontally by two vertical ropes. One rope is attached at each end. A load of mass 25 kg is placed 1 m from the left end.

(a) Calculate the tension in each rope. [**6 marks**]

(b) Verify your answer by checking that the sum of upward forces equals the total weight. [**2 marks**]

Section D: Applications of F = ma [25 marks]

Question 7 [**10 marks**] A car of mass 1000 kg accelerates uniformly from rest to 24 m/s in 8 seconds.

(a) Calculate the acceleration of the car. [**2 marks**]

(b) Determine the net force required to produce this acceleration. [**3 marks**]

(c) If the car experiences a resistance force of 600 N, calculate the driving force from the engine. [**3 marks**]

(d) What would be the acceleration if the driving force were doubled? [**2 marks**]

Question 8 [**15 marks**] A lift of mass 500 kg carries passengers with total mass 400 kg.

(a) Calculate the tension in the lift cable when the lift is stationary. [**3 marks**]

(b) Find the tension when the lift accelerates upward at 2.0 m/s^2. [**4 marks**]

(c) Determine the tension when the lift accelerates downward at 1.5 m/s^2. [**4 marks**]

(d) What acceleration would make the passengers feel weightless? [**2 marks**]

(e) Calculate the tension in the cable for the condition in part (d). [**2 marks**]

Section E: Friction Forces [30 marks]

Question 9 [**12 marks**]

(a) Define static friction and kinetic friction. [**4 marks**]

(b) Write the mathematical relationships for maximum static friction and kinetic friction. [**4 marks**]

(c) Explain why static friction can vary but kinetic friction is approximately constant. [**4 marks**]

Question 10 [**18 marks**] A box of mass 15 kg rests on a horizontal surface. The coefficient of static friction is 0.6 and the coefficient of kinetic friction is 0.4.

(a) Calculate the weight of the box and the normal force. [**3 marks**]

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

(c) What is the minimum horizontal force needed to start the box moving? **[2 marks]**

(d) Once moving, what force is needed to maintain constant velocity? **[3 marks]**

(e) If a horizontal force of 80 N is applied, calculate the acceleration of the box. **[5 marks]**

(f) How far will the box travel in the first 4 seconds if the 80 N force is applied from rest? **[3 marks]**

Section F: Forces on Inclined Planes [25 marks]

Question 11 [12 marks] A block of mass 12 kg rests on an inclined plane making an angle of 30° with the horizontal.

(a) Draw a free body diagram showing all forces. **[3 marks]**

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

(c) Calculate the normal contact force. **[2 marks]**

(d) If the coefficient of static friction is 0.7, determine whether the block will slide. **[3 marks]**

Question 12 [13 marks] A block of mass 6 kg is pulled up a rough inclined plane by a rope parallel to the surface. The plane makes an angle of 25° with the horizontal, and the coefficient of kinetic friction is 0.3.

(a) Calculate the component of weight down the plane. **[2 marks]**

(b) Find the normal force and the friction force. **[4 marks]**

(c) If the block moves up the plane at constant velocity, calculate the tension in the rope. **[4 marks]**

(d) If the tension in the rope is 40 N, determine the acceleration of the block. **[3 marks]**

Section G: Connected Particles [20 marks]

Question 13 [10 marks] Two masses, 4 kg and 6 kg, are connected by a light inextensible string passing over a smooth pulley.

(a) Draw free body diagrams for both masses. **[3 marks]**

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

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

Question 14 [10 marks] Two particles of masses 5 kg and 8 kg are connected by a light inextensible string. They are placed on a smooth horizontal surface and pulled by a horizontal force of 26 N applied to the 8 kg mass.

(a) Calculate the acceleration of both particles. **[3 marks]**

(b) Find the tension in the connecting string. **[4 marks]**

(c) Verify your answer using Newton's third law. **[3 marks]**

Section H: Newton's Third Law Applications [15 marks]

Question 15 [**8 marks**]

(a) Explain why action-reaction pairs don't cancel each other out. [**3 marks**]

(b) Describe how a person can walk forward using Newton's third law. [**3 marks**]

(c) Explain how a rocket works in space using Newton's third law. [**2 marks**]

Question 16 [**7 marks**] A person of mass 60 kg stands on a bathroom scale in a lift.

(a) What does the scale read when the lift is stationary? [**2 marks**]

(b) Identify the action-reaction pair of forces between the person and the scale. [**2 marks**]

(c) What would the scale read if the lift accelerates upward at 3 m/s^2? [**3 marks**]

Section I: Complex Applications [20 marks]

Question 17 [**12 marks**] A system consists of two masses: 3 kg on a horizontal surface connected by a string over a pulley to a hanging mass of 5 kg. The coefficient of kinetic friction between the 3 kg mass and the surface is 0.4.

(a) Draw free body diagrams for both masses. [**4 marks**]

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

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

Question 18 [**8 marks**] Three blocks with masses 2 kg, 4 kg, and 6 kg are connected by light strings and pulled across a smooth horizontal surface by a force of 24 N.

(a) Calculate the common acceleration of all three blocks. [**3 marks**]

(b) Find the tension in each connecting string. [**5 marks**]

Physics Data and Formulae

Newton's Laws:
First Law: Object at rest or in uniform motion unless external force acts
Second Law: $\vec{F} = m\vec{a}$ (Net force = mass × acceleration)
Third Law: Action and reaction forces are equal and opposite

Friction:
Maximum static friction: $f_s \leq \mu_s N$
Kinetic friction: $f_k = \mu_k N$
where N is the normal contact force

Equilibrium:
$\sum F_x = 0$ and $\sum F_y = 0$
$\sum F = 0$ (vector sum)

Motion Equations:
$v = u + at$
$s = ut + \frac{1}{2}at^2$
$v^2 = u^2 + 2as$

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

Trigonometric Values:
$\sin 25 = 0.423$, $\cos 25 = 0.906$
$\sin 30 = 0.500$, $\cos 30 = 0.866$
$\sin 40 = 0.643$, $\cos 40 = 0.766$
$\sin 50 = 0.766$, $\cos 50 = 0.643$

END OF TEST

Total marks: 200

Grade boundaries: A* 180, A 160, B 140, C 120, D 100, E 80

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