

# EDEXCEL IAL MATHEMATICS - MECHANICS 1 (M1) COMPLETE STUDY GUIDE

## Unit M1: Mechanics 1

### Assessment Overview

- **Duration:** 1 hour 30 minutes
- **Marks:** 75 marks
- **Prerequisite:** Knowledge of P1 and P2, vectors in two dimensions
- **Calculator:** Permitted
- **Formulae Booklet:** Provided

### Key Formulae (Provided in Exam)

**Momentum:**  $p = mv$

**Impulse:**  $I = mv - mu$

### Constant Acceleration Equations:

$$v = u + at \quad s = ut + \frac{1}{2}at^2 \quad s = \frac{1}{2}(u + v)t \quad v^2 = u^2 + 2as \quad s = vt - \frac{1}{2}at^2$$

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## TOPIC 1: MATHEMATICAL MODELS IN MECHANICS

### 1.1 Key Modelling Assumptions

In mechanics, we simplify real-world situations using idealised models. Understanding these assumptions is crucial for solving problems correctly.

### 1.2 Standard Models

Term	Meaning
<b>Particle</b>	An object with mass but negligible size. Can be treated as a point mass.
<b>Lamina</b>	A flat object with negligible thickness.
<b>Rigid Body</b>	Does not deform under force.
<b>Light Rod/String</b>	Mass can be ignored.
<b>Uniform Rod</b>	Mass evenly distributed; centre of mass at midpoint.

Term	Meaning
<b>Inextensible String</b>	Does not stretch under tension.
<b>Smooth Surface</b>	No friction between surfaces.
<b>Rough Surface</b>	Friction must be considered.
<b>Light Pulley</b>	Mass can be ignored; pulley is frictionless.
<b>Bead</b>	Particle that slides on a wire/string.
<b>Peg</b>	Fixed support point.

### 1.3 Force Assumptions

- **Tension (T):** Force in a stretched string or rope, pulling towards the centre of the string.
- **Thrust/Push (P):** Compressive force pushing away from object.
- **Normal Reaction (R/N):** Perpendicular force from a surface.
- **Weight (W/mg):** Force of gravity acting downwards,  $W = mg$ .
- **Friction (F):** Force opposing motion or potential motion.

### 1.4 Key Principles

1. **Light String:** Tension is the same throughout.
2. **Inextensible String:** Particles attached to ends have equal acceleration.
3. **Smooth Pulley:** Tension is the same on both sides.
4. **Forces are vectors:** Can be resolved into components.

## TOPIC 2: VECTORS IN MECHANICS

### 2.1 Vector Basics

**Scalar:** Has magnitude only (mass, time, speed)

**Vector:** Has magnitude AND direction (velocity, acceleration, force)

### 2.2 Vector Representation

**Column Form:**  $\vec{a} = \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$

**Unit Vectors:**  $\vec{i} = \begin{pmatrix} 1 \\ 0 \end{pmatrix}, \vec{j} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}$

$$\vec{a} = a_1\vec{i} + a_2\vec{j}$$

### 2.3 Magnitude and Direction

**Magnitude:**  $|\vec{a}| = \sqrt{a_1^2 + a_2^2}$

**Direction:** Angle  $\theta$  measured from positive x-axis:  $\tan \theta = \frac{a_2}{a_1}$

## 2.4 Vector Operations

**Addition:**  $\vec{a} + \vec{b} = \begin{pmatrix} a_1 + b_1 \\ a_2 + b_2 \end{pmatrix}$

**Scalar Multiplication:**  $k\vec{a} = \begin{pmatrix} ka_1 \\ ka_2 \end{pmatrix}$

**Parallel Vectors:** Two vectors are parallel if  $\vec{a} = k\vec{b}$  for some scalar  $k$ .

## 2.5 Vector Algebra

**Position Vector:**  $\vec{r} = x\vec{i} + y\vec{j}$  describes position relative to origin O.

**Displacement Vector:**  $\overrightarrow{AB} = \overrightarrow{OB} - \overrightarrow{OA}$

**Example:** If  $\overrightarrow{OA} = 3\vec{i} + 2\vec{j}$  and  $\overrightarrow{OB} = 7\vec{i} - \vec{j}$ , find  $\overrightarrow{AB}$ .

**Solution:**  $\overrightarrow{AB} = (7 - 3)\vec{i} + (-1 - 2)\vec{j} = 4\vec{i} - 3\vec{j}$

## 2.6 Relative Position and Velocity

**Relative Position:**  $\vec{r}_{B \text{ relative to } A} = \overrightarrow{OB} - \overrightarrow{OA}$

**Relative Velocity:**  $\vec{v}_{B \text{ relative to } A} = \vec{v}_B - \vec{v}_A$

**Example:** A particle A has velocity  $\vec{v}_A = 3\vec{i} + 4\vec{j}$  and particle B has velocity  $\vec{v}_B = 5\vec{i} + 2\vec{j}$ . Find the velocity of B relative to A.

**Solution:**  $\vec{v}_{B/A} = \vec{v}_B - \vec{v}_A = (5 - 3)\vec{i} + (2 - 4)\vec{j} = 2\vec{i} - 2\vec{j}$

## 2.7 Vector Applications in Mechanics

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

**Acceleration:**  $\vec{a} = \frac{d\vec{v}}{dt}$

**Example:** A particle's position is given by  $\vec{r} = (3t^2 + 1)\vec{i} + (4t - 2)\vec{j}$ . Find velocity and acceleration.

**Solution:**  $\vec{v} = \frac{d\vec{r}}{dt} = 6t\vec{i} + 4\vec{j}$   $\vec{a} = \frac{d\vec{v}}{dt} = 6\vec{i}$

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## TOPIC 3: KINEMATICS OF A PARTICLE IN A STRAIGHT LINE

### 3.1 Constant Acceleration Equations

For motion in a straight line with constant acceleration  $a$ :

Equation	Formula
Velocity-Time	$v = u + at$
Displacement (1)	$s = ut + \frac{1}{2}at^2$
Displacement (2)	$s = \frac{1}{2}(u + v)t$
Velocity-Displacement	$v^2 = u^2 + 2as$
Displacement (3)	$s = vt - \frac{1}{2}at^2$

Where:

- $u$  = initial velocity
- $v$  = final velocity
- $s$  = displacement
- $a$  = acceleration
- $t$  = time

**SI Units:**

- $s$ : metres (m)
- $u, v$ : metres per second ( $\text{ms}^{-1}$ )
- $a$ : metres per second squared ( $\text{ms}^{-2}$ )
- $t$ : seconds (s)

### 3.2 Vertical Motion Under Gravity

- Acceleration due to gravity:  $g = 9.8\text{ms}^{-2}$  (downwards)
- Can treat as constant acceleration problems
- Choose a positive direction (usually up)

**Example:** A ball is thrown vertically upwards with speed  $14 \text{ ms}^{-1}$ . Find: a) Greatest height b) Time to return to starting point

**Solution:**

a) At greatest height,  $v = 0$  Taking upwards as positive ( $a = -9.8$ ):  $v^2 = u^2 + 2as$   
 $0 = 14^2 + 2(-9.8)s$   
 $s = \frac{196}{19.6} = 10 \text{ m}$

b) For return to start,  $s = 0$ :  $s = ut + \frac{1}{2}at^2$   $0 = 14t - 4.9t^2$   $t(14 - 4.9t) = 0$   $t = 0$  or  $t = \frac{14}{4.9} = 2.86 \text{ s}$

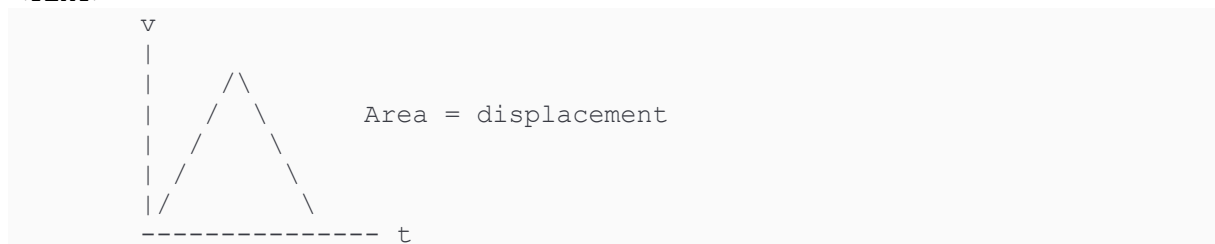
Total time = 2.86 s

### 3.3 Velocity-Time Graphs

#### Key Properties:

- **Gradient** = acceleration
- **Area under graph** = displacement

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**Example:** A car accelerates from rest at  $3 \text{ ms}^{-2}$  for 10 s, travels at constant speed, then decelerates at  $2 \text{ ms}^{-2}$  until it stops. Total distance = 1130 m. Find time at constant speed.

#### Solution:

Phase 1 (acceleration):  $s_1 = \frac{1}{2}(0 + 30) \times 10 = 150 \text{ m}$   $v_{\text{max}} = 0 + 3(10) = 30 \text{ ms}^{-1}$

Phase 3 (deceleration):  $s_3 = \frac{1}{2}(30 + 0) \times \frac{30}{2} = 225 \text{ m}$

Phase 2 (constant speed):  $s_2 = 1130 - 150 - 225 = 755 \text{ m}$   $t_2 = \frac{755}{30} = 25.2 \text{ s}$

### 3.4 Problem-Solving Strategy

1. **Draw a diagram** showing the motion
2. **Choose positive direction** (stick to it!)
3. **List known quantities:**  $u, v, s, a, t$
4. **Select appropriate formula**
5. **Solve and check**

## TOPIC 4: DYNAMICS OF A PARTICLE

### 4.1 Newton's Laws of Motion

**First Law:** A particle remains at rest or continues in a straight line at constant speed unless acted upon by a resultant force.

**Second Law:**  $F = ma$

Where  $F$  is the resultant force in Newtons (N),  $m$  is mass in kg, and  $a$  is acceleration in  $\text{ms}^{-2}$ .

**Third Law:** For every action, there is an equal and opposite reaction.

## 4.2 Force Diagrams

Always draw a **clear diagram** showing:

- All forces acting on the particle
- Direction of acceleration (if known)
- Choose a positive direction

**Example:** A box of mass 30 kg is pulled along a smooth horizontal floor by a force of 95 N. Find acceleration.

**Solution:**

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R
↑
|   95 N →
□-----→ Friction = 0 (smooth)
↓
W = mg

```

Resolving horizontally:  $F = ma$   
 $95 = 30a$   
 $a = 3.17 \text{ ms}^{-2}$

## 4.3 Connected Particles

When particles are connected by strings:

1. **Same magnitude of acceleration** (string inextensible)
2. **Same tension** (light, smooth pulley if applicable)

**Example:** A lift of mass 600 kg carries a man of mass 70 kg. Tension in cable is 7000 N. Find acceleration and normal reaction.

**Solution:**

Combined system (lift + man):  $R_{up} - 670g = 670a$   
 $7000 - 670(9.8) = 670a$   
 $a = 0.648 \text{ ms}^{-2}$

Man alone:  $N - 70g = 70a$   
 $N = 70(9.8 + 0.648) = 731 \text{ N}$

## 4.4 Particles on Inclined Planes

### Key Resolution:

- Parallel to plane:  $mg \sin \theta$
- Perpendicular to plane:  $mg \cos \theta$

**Example:** A particle of mass 5 kg rests on a rough plane inclined at  $30^\circ$  to the horizontal.  $\mu = 0.4$ . Will it slide?

### Solution:

Resolving perpendicular to plane:  $R = mg \cos 30^\circ = 5 \times 9.8 \times 0.866 = 42.4 \text{ N}$

Maximum friction:  $F_{\max} = \mu R = 0.4 \times 42.4 = 16.97 \text{ N}$

Force down plane (without friction):  $F_{\text{gravity}} = mg \sin 30^\circ = 5 \times 9.8 \times 0.5 = 24.5 \text{ N}$

Since  $F_{\text{gravity}} > F_{\max}$ , the particle will slide.

## 4.5 Friction

### Types of Friction:

- **Static Friction** ( $F \leq \mu R$ ): Prevents motion
- **Limiting Equilibrium:**  $F = \mu R$  (about to move)
- **Dynamic/Moving:**  $F = \mu R$

**Direction:** Opposes motion or tendency to move.

**Example:** A block of mass 8 kg rests on a rough horizontal surface. A force of 30 N is applied at  $20^\circ$  above horizontal.  $\mu = 0.3$ . Find acceleration.

### Solution:

Resolve vertically:  $R + 30 \sin 20^\circ = 8g$   
 $R + 10.26 = 78.4$   
 $R = 68.14 \text{ N}$

Maximum friction:  $F_{\max} = 0.3 \times 68.14 = 20.44 \text{ N}$

Resolve horizontally:  $30 \cos 20^\circ - F = 8a$   
 $28.19 - 20.44 = 8a$   
 $a = 0.97 \text{ ms}^{-2}$

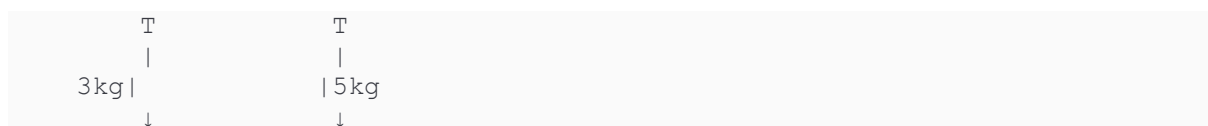
## 4.6 Pulleys

**Light, Smooth Pulley:** Tension same on both sides.

**Example:** Masses of 3 kg and 5 kg are attached to ends of a light string over a smooth pulley. Find acceleration.

### Solution:

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For 3 kg (upward = positive):  $T - 3g = 3a(1)$

For 5 kg (downward = positive):  $5g - T = 5a(2)$

Adding (1) and (2):  $2g = 8a \Rightarrow a = 2.45 \text{ ms}^{-2}$

Substituting:  $T = 3(9.8 + 2.45) = 36.75 \text{ N}$

## 4.7 Impulse and Momentum

**Momentum:**  $p = mv(\text{kg ms}^{-1})$

**Impulse:**  $I = Ft = mv - mu(\text{Ns})$

**Impulse-Momentum Principle:**  $I = \Delta(mv) = mv - mu$

**Example:** A ball of mass 2 kg moving at  $4 \text{ ms}^{-1}$  is hit by a bat, reversing its direction at  $8 \text{ ms}^{-1}$ . Find impulse.

**Solution:**

Taking original direction as positive:  $I = m(v - u) = 2(-8 - 4) = -24 \text{ Ns}$

Impulse magnitude = 24 Ns (opposite to original direction)

## 4.8 Conservation of Linear Momentum

**Principle:** In the absence of external forces, total momentum is conserved.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

**Example:** A railway truck A (mass 1500 kg) moving at  $3 \text{ ms}^{-1}$  collides with truck B (mass 1000 kg) moving at  $5 \text{ ms}^{-1}$  in the opposite direction. They couple together. Find common velocity.

**Solution:**

Taking right as positive:  $1500(3) + 1000(-5) = (1500 + 1000)v \Rightarrow 4500 - 5000 = 2500v \Rightarrow v = -0.2 \text{ ms}^{-1}$

They move at  $0.2 \text{ ms}^{-1}$  to the left.

## 4.9 Impulse in Strings

When particles connected by a string separate:



- Internal impulse (string tension) acts on each particle
- Equal and opposite impulses
- Can use conservation of momentum

**Example:** Two particles P (2 kg) and Q (5 kg) connected by string, moving at  $3 \text{ ms}^{-1}$  and  $4 \text{ ms}^{-1}$  respectively away from each other. String becomes taut. Find common velocity.

**Solution:**

Before string taut: system has no external forces in horizontal direction.

Taking right as positive:  $2(-3) + 5(4) = 7v - 6 + 20 = 7v \Rightarrow v = 2 \text{ ms}^{-1}$

## TOPIC 5: STATICS OF A PARTICLE

### 5.1 Equilibrium

A particle is in equilibrium if the resultant force is zero:  $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \dots = 0$

This means:

- Resolve horizontally:  $\sum F_x = 0$
- Resolve vertically:  $\sum F_y = 0$

### 5.2 Resultant Forces

#### Method 1: Resolution

Break each force into horizontal and vertical components.

**Example:** Find the resultant of forces 9 N and 8 N at  $60^\circ$  to each other.

**Solution:**

Using cosine rule:  $R^2 = 9^2 + 8^2 - 2(9)(8)\cos 120^\circ$   
 $R^2 = 81 + 64 + 72 = 217$   
 $R = 14.73 \text{ N}$

Using sine rule for angle:  $\frac{\sin \theta}{8} = \frac{\sin 120^\circ}{14.73}$   
 $\theta = 27.4^\circ$

Direction =  $27.4^\circ$  from 9 N force

### 5.3 Equilibrium Problems

**Strategy:**

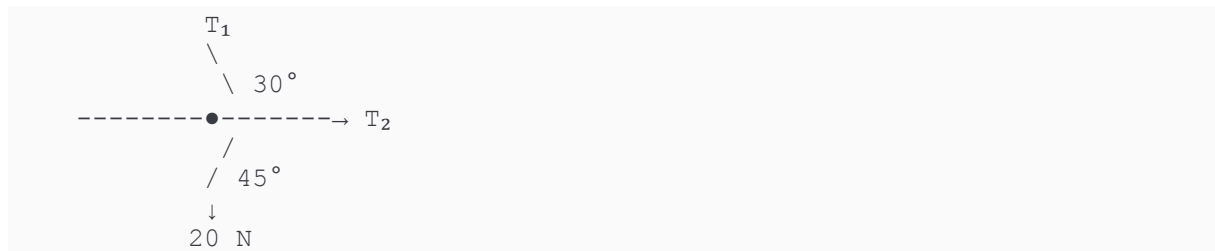
1. Draw a clear force diagram

2. Resolve all forces horizontally and vertically
3. Set each sum equal to zero
4. Solve the equations

**Example:** A particle of weight 20 N is suspended by two strings making angles  $30^\circ$  and  $45^\circ$  with the horizontal. Find tensions.

**Solution:**

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Resolve vertically:  $T_1 \sin 30^\circ + T_2 \sin 45^\circ = 20$   
 $0.5T_1 + 0.707T_2 = 20 \quad (1)$

Resolve horizontally (taking right as positive):  $T_2 \cos 45^\circ - T_1 \cos 30^\circ = 0$   
 $0.707T_2 = 0.866T_1$   
 $T_2 = 1.225T_1 \quad (2)$

Substituting (2) into (1):  $0.5T_1 + 0.707(1.225T_1) = 20$   
 $0.5T_1 + 0.866T_1 = 20$   
 $1.371T_1 = 20$   
 $T_1 = 14.6 \text{ N}$

$$T_2 = 1.225 \times 14.6 = 17.9 \text{ N}$$

## 5.4 Limiting Equilibrium

When a particle is about to move:  $F = \mu R$

**Example:** A particle of mass 5 kg rests on a rough horizontal plane. Coefficient of friction  $\mu = 0.4$ . Find the minimum force parallel to the plane needed to move it.

**Solution:**

Normal reaction:  $R = mg = 5 \times 9.8 = 49 \text{ N}$

Maximum friction:  $F_{\max} = \mu R = 0.4 \times 49 = 19.6 \text{ N}$

Minimum force needed = 19.6 N

## 5.5 Particles on Inclined Planes

**Example:** A particle of mass 3 kg rests in equilibrium on a rough plane inclined at  $25^\circ$  to the horizontal.  $\mu = 0.5$ . Find the force P parallel to the plane needed to: a) Just prevent it sliding down b) Just start it moving up

**Solution:**

Resolve perpendicular to plane:  $R = mg \cos 25^\circ = 3 \times 9.8 \times 0.906 = 26.6 \text{ N}$

Maximum friction:  $F_{\max} = \mu R = 0.5 \times 26.6 = 13.3 \text{ N}$

a) Prevent sliding down (friction acts up):  $P + F_{\max} = mg \sin 25^\circ$   
 $P = mg \sin 25^\circ - F_{\max} = 12.4 - 13.3 = -0.9 \text{ N}$

Negative means no force needed (gravity alone won't cause sliding), so  $P = 0$

b) Start moving up (friction acts down):  $P = mg \sin 25^\circ + F_{\max} = 12.4 + 13.3 = 25.7 \text{ N}$

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## TOPIC 6: MOMENTS

### 6.1 Definition

**Moment of a Force:**  $\text{Moment} = F \times d$

Where  $F$  is the force and  $d$  is the perpendicular distance from the pivot to the line of action.

**Unit:** Newton-metres (Nm)

**Direction:** Clockwise or anticlockwise.

### 6.2 Moment as Vector Product

If force makes angle  $\theta$  with line to pivot:  $M = Fd \sin \theta$

### 6.3 Finding Moments

**Example:** A force  $\vec{F} = 7\vec{i} + 4\vec{j}$  N acts at point (5, 3). Find moment about point (2, 1).

**Solution:**

Vector from (2,1) to (5,3):  $\vec{d} = 3\vec{i} + 2\vec{j}$

Taking moments clockwise (taking  $\vec{i}$  as x-axis,  $\vec{j}$  as y-axis):

**Method 1 - Perpendicular distances:**  $M = 7(2) - 4(3) = 14 - 12 = 2 \text{ Nm clockwise}$

**Method 2 - Using components:** Moment from  $\vec{i}$  component:  $7 \times (\text{perpendicular distance in y-direction}) = 7 \times 2 = 14 \text{ clockwise}$   
Moment from  $\vec{j}$  component:  $4 \times (\text{perpendicular distance in x-direction}) = 4 \times 3 = 12 \text{ anticlockwise}$   
Net moment =  $14 - 12 = 2 \text{ Nm clockwise}$

### 6.4 Equilibrium of Rigid Bodies

For equilibrium of a rigid body:

1. **Resultant force = 0:**  $\sum F_x = 0$ ,  $\sum F_y = 0$
2. **Resultant moment = 0:**  $\sum M = 0$  (about any point)

## 6.5 Problems Involving Beams and Rods

**Example:** A uniform beam of length 4 m and weight 20 N rests on two supports at A and B, 0.5 m from each end. A load of 15 N is placed 1 m from A. Find reactions at A and B.

**Solution:**

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Beam weight = 20 N acts at centre

Taking moments about A:  $R_B(4) - 20(2) - 15(1) = 0$   
 $4R_B = 40 + 15 = 55$   
 $R_B = 13.75$  N

Resolving vertically:  $R_A + R_B = 20 + 15 = 35$   
 $R_A = 35 - 13.75 = 21.25$  N

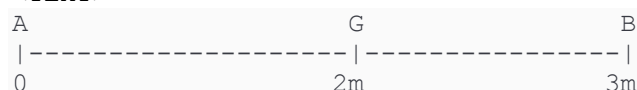
## 6.6 Non-Uniform Rods

A non-uniform rod has centre of mass not at midpoint.

**Example:** A non-uniform rod AB of length 6 m and weight 40 N has centre of mass 2 m from A. It rests on a pivot at its midpoint. A weight of 25 N is placed 1 m from B. Find where an additional weight W must be placed from A to balance the rod.

**Solution:**

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Pivot at M (3m from A)

Taking moments about M:

Clockwise:  $W \times (3 - x)$  (if weight to left of M)

Anticlockwise:  $25 \times 1.5 + 40 \times 1$

For equilibrium:

$$W(3 - x) = 25(1.5) + 40(1)$$

$$W(3 - x) = 37.5 + 40 = 77.5$$

If  $W = 30$  N:

$$30(3 - x) = 77.5$$

$$3 - x = 2.58$$

$$x = 0.42 \text{ m from M towards A}$$

$$\text{So distance from A} = 3 - 0.42 = 2.58 \text{ m}$$

## 6.7 Tilting Problems

A rod begins to tilt when the normal reaction at one end becomes zero.

**Example:** A uniform rod of length 4 m and weight 30 N rests horizontally on a peg at its midpoint. A weight of 20 N is placed at one end. How far from the end can a person of weight 70 N walk before the rod begins to tilt?

**Solution:**

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Peg at midpoint M
Person walks from end P
Taking moments about M:
Clockwise:  $\$70 \times x$  (person's moment)
Anticlockwise:  $\$30 \times 0$  (weight through M) +  $\$20 \times 2 = 40$ 
At point of tilting:
 $\$70x = 40$ 
 $\$x = 0.571$  m from M
Distance from end P =  $\$2 + 0.571 = 2.571$  m
```

## 6.8 Ladders and Leaning Problems

### Key Principles:

- Friction can act at ground (up to  $\mu R$ )
- Ladder in equilibrium if forces can be balanced

**Example:** A uniform ladder of length 5 m and weight 100 N rests against a smooth vertical wall. The foot of the ladder is 3 m from the wall. Find the reaction forces at the wall and ground.

**Solution:**

```
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Wall (smooth)
|
| \
|  \ Ladder ( $\theta$ )
|   \
|    \
|     \
Ground (rough)
```

$$\cos \theta = \frac{3}{5}, \sin \theta = \frac{4}{5}$$

**At wall (smooth):** Only vertical reaction  $R_W$

**At ground:** Horizontal friction  $F$ , vertical reaction  $R_G$

Resolve horizontally:  $F = R_W(1)$

Resolve vertically:  $R_G = 100(2)$

Take moments about ground:  $R_W(4) = 100(2.5)R_W = \frac{250}{4} = 62.5 \text{ N}$

Therefore  $F = 62.5\text{N}$

Check limiting equilibrium at ground:  $F = \mu R_G$  If  $\mu = 0.4$ :  $\mu R_G = 0.4 \times 100 = 40\text{N}$

Since  $F = 62.5 > 40$ , the ladder would slip with  $\mu = 0.4$ .

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## COMMON PROBLEM-SOLVING STRATEGIES

### 1. Drawing Clear Diagrams

**Always include:**

- All forces with arrows
- Direction of motion/acceleration
- Coordinate system
- Named points

### 2. Choosing Directions

- Choose positive direction at start
- Be consistent throughout
- For equilibrium, two directions are independent

### 3. Equations to Use

**Dynamics:**

- $F = ma$  (Newton's Second Law)
- $v = u + at$ ,  $s = ut + \frac{1}{2}at^2$ , etc.
- $I = mv - mu$

**Equilibrium:**

- $\sum F_x = 0$
- $\sum F_y = 0$
- $\sum M = 0$  (about any point)

### 4. Units

Always use SI units:

- Mass: kg
- Force: N
- Distance: m
- Time: s
- Acceleration:  $\text{ms}^{-2}$

## 5. Checking Answers

- Does the answer make physical sense?
  - Are forces reasonable?
  - Is equilibrium satisfied?
- 

## EXAM TIPS FOR M1

### Common Mistakes to Avoid

1. **Forgetting to draw a diagram** - Always start with a diagram
2. **Wrong direction for gravity** - Downwards, always
3. **Resolving perpendicular incorrectly** - Use  $mg\cos\theta$  perpendicular to slope
4. **Units** - Convert all to SI before calculating
5. **Sign conventions** - Be consistent
6. **Moments** - Use perpendicular distance, not horizontal distance

### Answer Presentation

1. **Draw a clear diagram** with all forces
2. **State assumptions** (smooth, light, etc.)
3. **Choose positive direction** and state it
4. **Show equations** before substituting numbers
5. **Give final answer** with units

### Time Management

- ~2 minutes per mark
  - Start with what you can do
  - Don't spend too long on one question
  - Read questions carefully - they often contain clues
- 

## PRACTICE PROBLEMS

### Kinematics

1. A car accelerates from  $20\text{ ms}^{-1}$  to  $30\text{ ms}^{-1}$  in 5 seconds. Find: a) Acceleration b) Distance travelled in this time
2. A stone is dropped from rest into a well. The splash is heard 3 seconds later. How deep is the well? (Take  $g = 10\text{ ms}^{-2}$ , speed of sound =  $340\text{ ms}^{-1}$ )

### Forces and Motion

- A particle of mass 6 kg is acted upon by forces  $(3\vec{i}+2\vec{j})\text{N}$  and  $(-\vec{i}+5\vec{j})\text{N}$ . Find the acceleration.
- Two particles of masses 2 kg and 3 kg are connected by a light string over a smooth pulley. Find the acceleration and tension.

## Equilibrium

- A particle is in equilibrium under forces  $(3\vec{i}-2\vec{j})\text{N}$ ,  $(k\vec{i}+4\vec{j})\text{N}$ , and  $(-7\vec{i}+m\vec{j})\text{N}$ . Find  $k$  and  $m$ .
- A sign of weight 50 N hangs from a horizontal rod of length 2 m, supported by a string making  $30^\circ$  with the rod. Find tension in the string.

## Friction

- A block of mass 10 kg rests on a rough horizontal plane.  $\mu = 0.3$ . Find: a) The maximum horizontal force before it moves b) If a force of 40 N is applied, find acceleration

## Momentum

- A ball of mass 0.5 kg moving at  $8\text{ ms}^{-1}$  hits a wall and rebounds at  $6\text{ ms}^{-1}$ . Find: a) Change in momentum b) Impulse on the ball

## Moments

- A non-uniform beam AB of length 6 m weighs 80 N. Its centre of mass is 2 m from A. It rests on supports at A and at a point 1 m from B. Find the reactions at the supports when a load of 100 N is placed 1 m from A.

# ANSWERS TO PRACTICE PROBLEMS

## 1. Kinematics

a)  $a = \frac{30-20}{5} = 2\text{ms}^{-2}$

b)  $s = \frac{(20+30)}{2} \times 5 = 125\text{m}$

## 2. Stone Drop

Time to fall:  $t_1 s = \frac{1}{2} g t_1^2 \Rightarrow t_1 = \sqrt{\frac{2s}{10}}$

Time for sound:  $t_2 = \frac{s}{340}$



Total:  $t_1 + t_2 = 3\sqrt{\frac{s}{5}} + \frac{s}{340} = 3$

Solving:  $s \approx 41\text{m}$

### 3. Acceleration

Resultant force =  $(3 - 1)\vec{i} + (2 + 5)\vec{j} = 2\vec{i} + 7\vec{j}\text{N}$   $a = \frac{F}{m} = \frac{2\vec{i}+7\vec{j}}{6} = \frac{1}{3}\vec{i} + \frac{7}{6}\vec{j} \text{ ms}^{-2}$

### 4. Pulley System

Taking 3 kg moving down as positive:  $3g - T = 3a(1)T - 2g = 2a(2)$

Adding:  $g = 5a a = \frac{9.8}{5} = 1.96 \text{ ms}^{-2}$

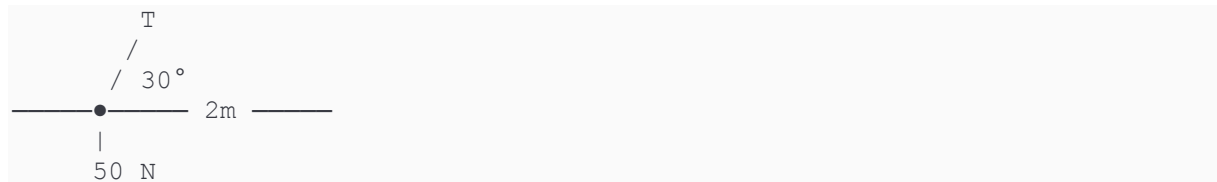
From (2):  $T = 2(9.8 + 1.96) = 23.5\text{N}$

### 5. Equilibrium

For equilibrium: Sum of forces = 0  $3 + k - 7 = 0 \Rightarrow k = 4 - 2 + 4 + m = 0 \Rightarrow m = -2$

### 6. Sign and String

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Resolving vertically:  $T \sin 30^\circ = 50 T = \frac{50}{0.5} = 100 \text{ N}$

### 7. Friction

a)  $R = mg = 98\text{N}$   $F_{max} = \mu R = 0.3 \times 98 = 29.4\text{N}$  Maximum horizontal force = 29.4 N

b) Since  $40 \text{ N} > 29.4 \text{ N}$ , block accelerates:  $40 - 29.4 = 10 a a = 1.06 \text{ ms}^{-2}$

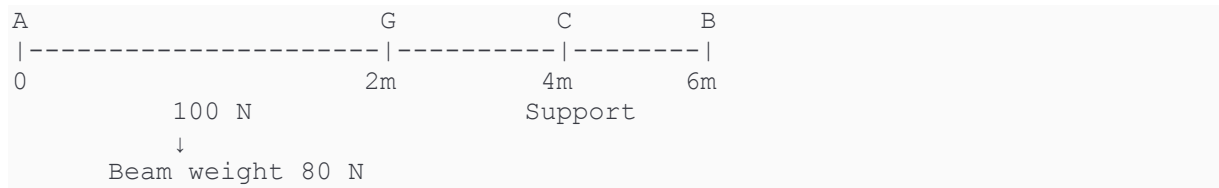
### 8. Momentum

Taking direction away from wall as positive:  $\Delta p = m(v - u) = 0.5(-6 - 8) = -7 \text{ kg ms}^{-1}$

Impulse = -7 Ns (opposite to original direction)

## 9. Moments

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Taking moments about A:  $R_C \times 6 = 100 \times 2 + 80 \times 4$   
 $R_C = 100 + 160 = 260$   
 $R_C = 52 \text{ N}$

Resolving vertically:  $R_A + R_C = 100 + 80 = 180$   
 $R_A = 180 - 52 = 128 \text{ N}$