STUDY FORMULA BOOKLET

# Edexcel IAL Maths Unit M2 (WME02): mechanics 2

The booklet gives only the centre of mass of a triangle, arc and sector, and the cosine rule. Learn first power P = Fv, kinetic and potential energy, the work-energy equation, impulse, the restitution law, moments and the projectile formulae.

GIVEN printed in the formula booklet LEARN IT not in the booklet: learn it

Built by CuratedPrep from 18 past question papers for Unit M2 in our question bank, January 2021 to January 2026. Given means it is in the Mathematical Formulae and Statistical Tables booklet (Issue 2, 2021) handed out in every unit exam. Learn it means a past question needed it and the exam did not print it.

## Constants

### Acceleration due to gravity

Not on the sheet: printed on the front of the paper. Use 9.8, not 9.81 or 10: the schemes penalise it once per question. Used in: Jan 2021 Q7(a), speed of a particle from energy.

$$g = 9.8 \text{ m s}^{-2}$$

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## Kinematics with calculus and projectiles

The specification says M2 assumes P1 to P4 and M1, so the constant acceleration formulae and the rules of calculus are assumed.

### Velocity and acceleration from displacement

Differentiate each of the i and j components separately, and for motion on a line the same applies to x, v and a. Used in: Jan 2026 Q4(b), acceleration perpendicular to 2i - j; Oct 2025 Q3(a), acceleration at t = 4.

$$\mathbf{v} = \frac{d\mathbf{r}}{dt}, \qquad \mathbf{a} = \frac{d\mathbf{v}}{dt}$$

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### Velocity and displacement by integration

Add a constant of integration (a constant vector for i and j), then use the value you are given, such as the position at t = 1, to find it. Used in: Jan 2026 Q4(c), distance OP at t = 4; Oct 2025 (A) Q6(a), v from a = 2t - 3.

$$\mathbf{v} = \int \mathbf{a}\, dt, \qquad \mathbf{r} = \int \mathbf{v}\, dt$$

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### Power rule for differentiating and integrating

Powers go down by 1 when you differentiate and up by 1 when you integrate. Used in: Jun 2023 Q2(a), position from a velocity; Oct 2025 (A) Q3(a), velocity from a position vector; Jan 2021 Q5(b), acceleration at A.

$$\frac{d}{dt}(t^n) = nt^{n-1}, \qquad \int t^n\, dt = \frac{t^{n+1}}{n+1}$$

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### Derivatives and integrals of sin and cos

Use radians. Used in: Jan 2022 Q3(a), force from a velocity 6 sin 3t i + (1 + 2 cos t) j; Jan 2022 Q3(b), position when P first moves parallel to i.

$$\frac{d}{dt}\sin kt = k\cos kt, \quad \frac{d}{dt}\cos kt = -k\sin kt, \quad \int \sin kt\, dt = -\frac{1}{k}\cos kt, \quad \int \cos kt\, dt = \frac{1}{k}\sin kt$$

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### Constant acceleration

Use them for each component of a projectile, with a = -g vertically and a = 0 horizontally. Used in: Jan 2026 Q5(c), time the stone moves faster than 25 m $s^{-1}$; Jan 2021 Q7(c), time a particle moves faster than 10 m $s^{-1}$; Jun 2023 Q7(c), time of flight of a ball.

$$v = u + at, \quad s = ut + \tfrac{1}{2}at^2, \quad v^2 = u^2 + 2as$$

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### Position of a projectile

u is the speed of projection and alpha the angle above the horizontal; y is measured from the point of projection. Used in: Oct 2025 (A) Q7(b), the angle alpha from a time of 1.5 s; Jan 2026 Q5(c), stone fired from a cliff.

$$x = ut\cos\alpha, \qquad y = ut\sin\alpha - \tfrac{1}{2}gt^2$$

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### Velocity of a projectile

The angle θ is below the horizontal when v_y is negative: say which side of the horizontal it is. Used in: Jan 2026 Q5(b), direction after 5 s; Oct 2025 (A) Q7(c), the angle beta at B; Jun 2023 Q7(b), direction just before the ball hits the ground.

$$v_x = u\cos\alpha, \quad v_y = u\sin\alpha - gt, \quad \text{speed} = \sqrt{v_x^2 + v_y^2}, \quad \tan\theta = \frac{v_y}{v_x}$$

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### Path of a projectile

Not on the sheet: the question printed it. The question asks you to show this and then expects you to use it: set y and x to the point you need and solve the quadratic in tan alpha. Used in: Jan 2022 Q7(b), angles that clear a pole; Jan 2023 Q8(c), the angle θ; Jan 2022 Q7(a), where it is printed.

$$y = x\tan\alpha - \frac{gx^2}{2u^2}\left(1 + \tan^2\alpha\right)$$

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### Range on level ground

Not on the sheet. Printed in the question for you to show, then used again in the next part. Used in: Oct 2024 Q5(b), distance CB with 20 m $s^{-1}$ at 60 degrees; Oct 2024 Q5(a), where it is printed (our bank files this paper under two dates).

$$XY = \frac{u^2\sin 2\theta}{g}$$

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## Centres of mass

### Centre of mass of particles

Take moments about the x-axis for the y coordinate and about the y-axis for the x coordinate. Used in: Oct 2025 (A) Q2, k and c for three particles; Oct 2022 Q1, three particles with the centre of mass on a line.

$$\bar{x} = \frac{\sum m_i x_i}{\sum m_i}, \qquad \bar{y} = \frac{\sum m_i y_i}{\sum m_i}$$

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### Composite lamina

Split the lamina into rectangles, triangles and sectors, use their areas as masses, and take moments about one axis through the lamina, or a parallel one. Used in: Jan 2026 Q2(a), rectangle joined to a triangle; Jun 2023 Q3(a), a folded triangular lamina.

$$\left(\sum m_i\right)\bar{x} = \sum m_i x_i, \qquad m_i \propto \text{area}$$

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### Lamina with a part removed

Give the removed part a negative mass: the whole lamina has mass M, the part removed has mass m_2 and distance x_2. Used in: Jan 2025 Q6, triangle removed from a rectangle; Jun 2021 Q3, a triangle and a circle removed from a square.

$$M\bar{x} = m_1 x_1 - m_2 x_2$$

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| **Framework of uniform wire**<br>Count each rod or wire as a particle at its midpoint with mass proportional to its length. Used in: Jan 2021 Q4, a framework shaped like the number 4; Jan 2022 Q6, wire with a semicircular arc; Jun 2025 Q3, two semicircular arcs and two straight pieces. | $m_i \propto \text{length}, \quad \text{centre of mass of a straight piece at its midpoint}$ | LEARN IT |
| **Triangular lamina**<br>Printed in the booklet. A triangle's centre of mass is 2/3 of the way down the median from a vertex, so 1/3 of the height from the base. Used in: Jun 2022 Q7, a triangle in a template; Jan 2021 Q2, a triangular lamina suspended from A. | $\frac{2}{3}$ along the median from the vertex | GIVEN |
| **Circular arc, radius r, angle at centre 2α**<br>Printed in the booklet. A semicircular arc is the case alpha = pi/2, which gives 2r/pi from the centre. Used in: Jun 2025 Q3, the question gives the 2r/pi value; Jan 2022 Q6, a semicircular arc in a framework. | $\frac{r \sin \alpha}{\alpha}$ from the centre | GIVEN |
| **Sector of a circle, radius r, angle at centre 2α**<br>Printed in the booklet. A semicircular lamina is the case alpha = pi/2, which gives 4r/(3 pi) from the centre. Used in: Oct 2025 Q4, the question gives the 4r/(3 pi) value; Jun 2025 (A) Q2, a semicircle removed from a square; Oct 2021 Q7, a sector joined to a rectangle. | $\frac{2r \sin \alpha}{3\alpha}$ from the centre | GIVEN |
| **Lamina suspended from a point**<br>A freely suspended lamina hangs with its centre of mass vertically below the suspension point, and θ is the angle a given line makes with the vertical. Used in: Jun 2023 Q3(b), folded lamina suspended from P; Jan 2021 Q4, framework suspended from B. | $\tan\theta = \frac{\text{horizontal distance of G from the point}}{\text{vertical distance of G below it}}$ | LEARN IT |

## Work, energy and power

The specification lists kinetic energy = 1/2 mv$^2$ and potential energy = mgh as formulae you must know: the booklet does not print them.

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| **Kinetic and potential energy**<br>h is the height above the level you choose, and the change in PE is mg times the change in height. Used in: Jan 2026 Q7(b), blocks A and B on a pulley system; Jun 2023 Q6(c), distance a trailer moves up a slope. | $\text{KE} = \frac{1}{2}mv^2, \qquad \text{PE} = mgh$ | LEARN IT |
| **Work done by a force**<br>F is the force along the line of motion and d the distance. Work done against friction is F times the distance, with F = μ R. Used in: Jan 2023 Q5(a), work done against friction up a ramp; Oct 2025 Q7(a), work done against friction from A to B; Jan 2025 Q1, total work done in pushing a package up a slope. | $\text{work done} = Fd$ | LEARN IT |

### Work-energy principle

Write one equation for the motion, with all three kinds of term, and use only the mass of the part that is moving. Used in: Jun 2023 Q6(c), trailer after the towbar breaks; Jan 2026 Q7(b), speed of B as it hits the ground.

$$\text{WD by driving force} = \Delta\text{KE} + \Delta\text{PE} + \text{WD against resistances}$$

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### Conservation of mechanical energy

Use it when only gravity acts, so a projectile's speed depends only on its height. Used in: Oct 2025 (A) Q7(a), vertical distance AB from two speeds; Jun 2023 Q7(a), speed of a ball just before it hits the ground; Jan 2021 Q7(a), speed of P at B.

$$\tfrac{1}{2}mu^2 + mgh_1 = \tfrac{1}{2}mv^2 + mgh_2$$

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### Power

F is the driving force of the engine, found from P and the speed at that instant. Used in: Jan 2026 Q1(a), van on a slope at 20 000 W; Jun 2023 Q6(a), the speed of a van at 24 kW.

$$P = Fv$$

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### Equation of motion for a vehicle

R is the resistance from non-gravitational forces; swap the sign of the weight term for motion down the slope. Treat a car and trailer as one system when the towbar is intact. Used in: Jan 2026 Q1(b), van moving down the road; Jun 2023 Q6(b), van and trailer up a slope; Jan 2021 Q3, car up an incline.

$$F - R - mg\sin\theta = ma \quad \text{(up the slope)}$$

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### Kinetic energy gained or lost

Use it with an impulse or a collision when the question gives the energy change. Used in: Jun 2023 Q4(d), kinetic energy lost in a collision; Jan 2023 Q2, kinetic energy gained by P.

$$\Delta\text{KE} = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mu^2$$

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## Impulse, momentum and collisions

### Impulse as a vector

Subtract the initial from the final velocity, component by component, and use Pythagoras for the size of the impulse or the speed. Used in: Jan 2026 (A) Q1(a), magnitude of an impulse on a 2 kg particle; Oct 2025 (A) Q1, speed after an impulse; Jan 2022 Q1(a), speed after an impulse of -4i + 6j.

$$\mathbf{I} = m\mathbf{v} - m\mathbf{u}$$

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### Cosine rule on an impulse triangle

Printed in the booklet. On the triangle of initial momentum, impulse and final momentum use $a^2 = b^2 + c^2 - 2bc\cos A$, or resolve parallel and perpendicular to the original motion instead. Used in: Oct 2023 Q3, impulse at 60 degrees to the motion; Oct 2022 Q3, values of λ for an impulse λ(i + j); Jan 2025 Q5(a), finding λ from an impulse of size 4 N s.

$$a^2 = b^2 + c^2 - 2bc\cos A$$

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### Angle between two vectors

Use it for the angle between an impulse and the velocity, or between the velocity before and after. Used in: Jan 2026 (A) Q1(b), angle between impulse and motion; Jun 2023 Q1(b), angle between I and the motion; Jan 2022 Q1(b), angle between the velocities.

$$\cos\theta = \frac{\mathbf{a}\cdot\mathbf{b}}{|\mathbf{a}||\mathbf{b}|} \quad \text{or a right-angled triangle with } \tan\theta$$

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### Conservation of momentum

Choose a positive direction and pair each mass with its own velocity. Used in: Jan 2026 Q6(a), speed of Q after P hits it; Oct 2025 (A) Q8(a), speeds of A and B.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

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### Newton's law of restitution

Write it the right way round: for particles moving the same way, (speed of the one ahead) - (speed of the one behind) after, over the difference before. Used in: Jan 2026 Q6(a), the speed of Q; Oct 2025 (A) Q8(a), speeds of A and B; Jun 2023 Q4(c), the value of e.

$$e = \frac{\text{speed of separation}}{\text{speed of approach}}$$

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### Range of the coefficient of restitution

Use it to decide whether a particle's direction is reversed or unchanged, giving a set of values of e. Used in: Jan 2026 Q6(b), P and Q move the same way; Oct 2025 (A) Q8(b), the set of possible values of e.

$$0 \le e \le 1$$

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### Collision with a fixed wall

The speed changes by a factor e and the direction reverses, so a particle hitting at speed u receives an impulse μ(1 + e). Used in: Jan 2026 Q6(c), finding e from the impulse at the wall; Jan 2021 Q8(b), B rebounding from a wall.

$$\text{speed after} = e \times \text{speed before}$$

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## Statics of rigid bodies

### Moment of a force

d is the perpendicular distance from the pivot; take moments about the hinge or the foot of the rod, so that unknown forces drop out. For a force at an angle use its component perpendicular to the rod. Used in: Jan 2026 Q3(a), tension in a string holding a rod; Oct 2025 (A) Q5(a), tension in the string at B; Jun 2022 Q5(a), cable perpendicular to a rod.

$$M = F \times d$$

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### Equilibrium of a rigid body

Resolve in two directions as well as taking moments. Used in: Oct 2025 (A) Q5(b), forces on a rod against a wall; Jun 2023 Q5(b), vertical and horizontal forces on a beam; Jan 2021 Q6(a), forces on a ladder.

$$\sum F_x = 0, \qquad \sum F_y = 0, \qquad \sum M = 0$$

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### Friction in limiting equilibrium

On the point of slipping, friction is at its maximum, with R the normal reaction at that contact; at each rough contact there is a different R and F. Used in: Oct 2025 (A) Q5(b), the coefficient of friction at the wall; Jun 2023 Q5(b), the coefficient at the ground.

$$F = \mu R$$

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### Resultant of reactions

X and Y are the horizontal and vertical parts of the force from a hinge or from the ground; θ is the angle of the force to the horizontal. Used in: Jan 2021 Q6(a), force from the ground on a ladder; Jan 2022 Q5(c), resultant at A; Oct 2025 (A) Q5(c), direction of the force from the wall.

$$R = \sqrt{X^2 + Y^2}, \qquad \tan\theta = \frac{Y}{X}$$

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|---|---|---|
| **Pythagoras' theorem**<br>Use it for the lengths in the geometry of a rod resting on a hemisphere or a peg, and for the speed from two components. Used in: Oct 2025 Q5(a), AC = 24a from AO = 25a and radius 7a; Jan 2022 Q5(a), AO = 13a; Oct 2025 (A) Q1, speed from two components. | $a^2 + b^2 = c^2$ | LEARN IT |

## Also learn these

**Direction given as a vector**
A particle moving in the direction of (i + j) has equal i and j components of velocity; form the equation from the ratio of the components. Used in: Jan 2021 Q5(a); Jun 2023 Q2(b).

**Instantaneous rest**
Instantaneous rest means v = 0, so put each component, or the velocity on a line, equal to 0 and solve for t. Used in: Jan 2026 Q4(a); Oct 2025 (A) Q6(b); Jun 2025 (A) Q1(a).

**Total distance with a reversal**
When velocity changes sign, find the times it is zero and integrate over each interval separately, then add the sizes. Used in: Oct 2025 (A) Q6(b); Jun 2025 Q1(c); Oct 2021 Q3(b).

**Constant speed means no acceleration**
At constant or maximum speed the resultant force is zero, so the driving force balances the resistance and any weight component. Used in: Jan 2021 Q3; Jun 2021 Q1.

**Reactions at smooth and rough contacts**
A smooth wall gives a horizontal reaction and no friction; a smooth peg or hemisphere gives a reaction perpendicular to the rod; a rough contact has both a normal reaction and friction. Used in: Jan 2021 Q6; Jan 2022 Q5.

**A hinge force has two parts**
A freely hinged rod can have a horizontal and a vertical force at the hinge, so take moments about the hinge to avoid them. Used in: Jan 2025 Q7; Jan 2023 Q6; Jun 2021 Q5.

**Using symmetry for the centre of mass**
On an axis of symmetry the centre of mass lies on the axis, so only one coordinate is needed. Used in: Oct 2025 (A) Q4; Jan 2025 Q6.

**Direction of motion after a collision**
To say whether a particle's direction is reversed or unchanged, write the velocity after the collision in terms of e and use 0 <= e <= 1. Used in: Jan 2026 Q6(b); Oct 2025 (A) Q8(b).

**Equal and opposite impulses**
The impulse on one particle in a collision is equal in size and opposite in direction to the impulse on the other, so use I = change in momentum for either particle. Used in: Jan 2021 Q8(a); Oct 2021 Q6(a); Jun 2023 Q4(a).

**Successive collisions**
After a collision with a wall or a third particle, work out new speeds step by step and check whether another collision happens. Used in: Jan 2021 Q8(b); Jun 2025 (A) Q7.

**Modelling a rod**
State why a model assumption is used: a rod has no thickness or bending, so its weight acts at one point and the ends are points of contact. Used in: Jan 2021 Q6(c), the ladder modelled as a rod.

**Show that questions**
Show at least one line of working between your equation and the given answer. Used in: Jan 2026 Q2(a); Jan 2026 Q6(a).

## Using the booklet in the exam

- The booklet's M2 page gives the centre of mass of a triangular lamina, a circular arc and a sector. Everything else is Learn it: kinetic energy, potential energy, power, impulse, restitution, moments and the projectile formulae.
- In projectile questions treat the horizontal and vertical motions separately: a = 0 horizontally and a = -g vertically, and the same time t for both. Use conservation of energy when the question asks for a speed at a given height.
- For an arc, sector or semicircle, write the formula as r sin(alpha)/alpha or 2r sin(alpha)/(3 alpha) with alpha = pi/2, or use the value the question prints, and check that the question gives alpha in radians.
- For restitution, write the momentum equation and the law of restitution with the same directions and the same labels for the velocities, then solve the two equations together.
- Use g = 9.8 and give answers to 2 or 3 significant figures. The schemes penalise g = 9.81 or 10 and over-accurate answers once per question.
- For calculus questions that say solutions relying on calculator technology are not acceptable, show your differentiation or integration and the equation you solve.

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