Name	Date started	Target end date

GCE A LEVEL — FURTHER MECHANICS B QUESTION PACK

0981-01 (Legacy M2) & 0982-01 (Legacy M3) · New spec A2 Unit 6 Topic 2

REVISE
.wales

FURTHER MATHS — FM B · MOMENTUM & IMPULSE IN 2D

Momentum & Impulse in Two Dimensions — Vector Form

Every two-dimensional momentum / vector-impulse question from the legacy WJEC M2 and M3 papers (2005 – 2017) that maps onto the new-spec A2 Unit 6 Topic 2. Unit 3 of the new spec covers 1-D momentum and Newton's experimental law; this pack is the explicit 2-D extension where the vectors $\mathbf{i}, \mathbf{j}$ *matter.*

LEGACY 2008 SPECIFICATION

Estimated time for entire question pack: ~1 hours 54 minutes

Derived from the legacy M2/M3 paper's pace of ***~1.3 min/mark*** *(88 marks over 9 questions). The full Unit 6 exam is* ***1 hour 45 minutes for 80 marks*** *(25% of the A-level qualification, A2 optional paper alongside Unit 5 Further Statistics B).*

You are advised to ***not*** *attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every momentum & impulse in 2d question from the legacy WJEC M2/M3 papers (2008 modular spec) that maps onto new-spec A2 Unit 6 Topic 2 (2.6.2). Unit 6 (Further Mechanics B) is one of two **80-mark A2 optional papers** (the other being Unit 5 Further Statistics B), each worth 25% of the A-level qualification.

Questions are ordered roughly by topic / difficulty.

INSTRUCTIONS

Use black ink or black ball-point pen. Show all working — method marks are awarded for clear setup.

A calculator is allowed. The WJEC Formula Booklet for Mechanics may be referred to.

For Examiner's use only

Q	Source	Max	Mark
1	Jun 08 Q6	5	
2	Jun 09 Q6	11	
3	Jun 11 Q3	7	
4	Jun 15 Q4	10	
5	Jun 17 Q1	11	
6	Jun 06 Q5	12	
7	Jun 07 Q4	14	
8	Jun 09 Q4	12	
9	Jun 17 Q2	6	
	Total	88	

Momentum & Impulse in Two Dimensions — Vector Form — what the new spec asks

WJEC GCE A Level Further Mathematics (from 2017) · Unit 6: Further Mechanics B · Topic 2.6.2.

Momentum and impulse in 2D 2.6.2

- Vector momentum: $\mathbf{p} = m\mathbf{v}$.
- Vector impulse: $\mathbf{J} = \Delta\mathbf{p} = m(\mathbf{v}_2 - \mathbf{v}_1) = \int \mathbf{F}(t)\,dt$.
- Conservation of momentum holds component-by-component: $\sum m_i \mathbf{v}_i = \text{const}$.
- When a force acts along one direction only, the perpendicular component of momentum is unchanged.

Working in components 2.6.2

- Resolve impulses and velocities into orthogonal components.
- Set up scalar conservation equations along $\mathbf{i}$ and $\mathbf{j}$ independently.
- For a particle on a smooth surface, the impulse from a string acts along the string; the perpendicular velocity is unchanged.
- Speed before/after is $|\mathbf{v}| = \sqrt{v_x^2 + v_y^2}$.

Oblique impulses 2.6.2

- When an impulse acts at an angle to a particle's initial motion, decompose along and perpendicular to the impulse direction.
- The component of velocity along the impulse changes by $|\mathbf{J}|/m$.
- The perpendicular component is unchanged.
- Common setting: slack string between two particles — impulse propagates only along the string once taut.

Energy considerations 2.6.2

- Even with momentum conserved, kinetic energy is usually *not* conserved during an impulsive jerk or collision.
- Energy lost $= \frac{1}{2}\sum m_i v_i^2(\text{before}) - \frac{1}{2}\sum m_i v_i^2(\text{after})$.
- For a perfectly elastic collision in 2D, KE is conserved; for inelastic, KE decreases.
- Expect "find the loss of kinetic energy" as a final part.

Momentum & Impulse in 2D in one page

Quick-reference notes — revisit before each section. Don't use during questions.

Vector momentum

For mass m at velocity $\vec{v}$:

$$\vec{p} = m\vec{v}$$

Components: $p_x = mv_x, p_y = mv_y$.

Magnitude: $|\vec{p}| = m\sqrt{v_x^2 + v_y^2}$.

Vector impulse

Impulse delivered during $[t_1, t_2]$:

$$\vec{J} = \int_{t_1}^{t_2} \vec{F}\,dt = m(\vec{v}_2 - \vec{v}_1)$$

Units: Ns. For a sudden jerk, $\vec{J}$ is given directly.

Conservation in 2D

If no external impulse acts, total vector momentum is conserved:

$$\sum m_i \vec{v}_i \text{ before} = \sum m_i \vec{v}_i \text{ after}$$

Holds component-by-component along x and y independently.

Working with components

Resolve into orthogonal components when more than one direction matters.

Set up scalar conservation along the line of impact and perpendicular.

For a smooth oblique impact: perpendicular component is unchanged; impact-line component changes.

Slack-string jerk

Two particles joined by an initially slack string of length ℓ.

While slack: particles move independently.

When taut: an impulsive tension acts along the string.

Only the along-string component changes; perpendicular components are preserved.

From force to impulse

If $\vec{F}(t) = F_x(t)\,\vec{i} + F_y(t)\,\vec{j}$ over $[t_1, t_2]$:

$$\vec{J} = (\int F_x\,dt)\vec{i} + (\int F_y\,dt)\vec{j}$$

Integrate each scalar component independently.

Energy after a jerk

KE is generally *not* conserved during an impulsive jerk.

$$\Delta\text{KE} = \tfrac{1}{2}\sum m_i v_i^2 \text{ after} - \tfrac{1}{2}\sum m_i v_i^2 \text{ before}$$

Elastic impact: KE conserved. Inelastic: KE decreases.

Common pitfalls

- Treating 2-D as 1-D — always resolve.
- Adding speeds rather than vector velocities.
- Assuming perpendicular component changes — it does not.
- Confusing momentum (vector) with energy (scalar) conservation.

Strategy

1. Identify the line of impulse and the perpendicular direction.
2. Resolve velocities into these components.
3. Apply conservation along impulse line; preserve perpendicular.
4. Recombine via Pythagoras for the new speed.

Questions begin overleaf.

SECTION T2

Momentum & Impulse in 2D

Questions 1–9 · 88 marks

6. A constant force $\mathbf{F} = \mathbf{i} - 4\mathbf{j} + \mathbf{k}$ acts on a bead as it moves along a straight smooth wire from point A to point B. Point A has position vector $2\mathbf{i} + \mathbf{j} + \mathbf{k}$ and point B has position vector $3\mathbf{i} - \mathbf{j} + 2\mathbf{k}$. Find

(a) the vector **AB**, [2]

(b) the work done by the force **F**. [3]

6. A particle, of mass 2 kg, moves in a horizontal plane such that its position vector **r** m at time t s is given by

$$\mathbf{r} = (1 - 4t^2)\,\mathbf{i} + (3t^2 - 5t)\mathbf{j}.$$

(a) Find, in terms of t, an expression for the momentum of the particle at time t s. [3]

(b) Show that the acceleration of the particle is constant and find its magnitude. [4]

(c) Find the time when the velocity of the particle is perpendicular to its acceleration. [4]

3. A particle P, of mass 2 kg, is moving under the action of a force $\mathbf{F}$ N so that its velocity $\mathbf{v}$ ms^{-1} at time t s is given by

$$\mathbf{v} = 2\mathbf{i} + 6t\mathbf{j} + 4t^3\mathbf{k}.$$

(a) Find an expression for $\mathbf{F}$ at time t s. [3]

(b) Determine the value of $\mathbf{F}.\mathbf{v}$ when $t = 1$ and state the units of your answer. [4]

4. A particle of mass 0·5 kg is moving under the action of a single force $\mathbf{F}$ N, where $\mathbf{F} = (4t - 3)\mathbf{i} + (3t^2 - 5t)\mathbf{j}$.

(a) The velocity of the particle at time t s is $\mathbf{v}$ ms^{-1}. When $t = 0$, $\mathbf{v} = 8\mathbf{i} - 7\mathbf{j}$. Find an expression for $\mathbf{v}$ in terms of t. [5]

(b) When $t = 3$, the particle receives an impulse of $2\mathbf{i} - 9\mathbf{j}$ Ns. Find the speed of the particle immediately after the impulse. [5]

1. The position vector of a particle P at time t seconds is given by

$$\mathbf{r} = t\sin t\,\mathbf{i} + t\cos t\,\mathbf{j}.$$

(a) (i) Find the velocity vector of P and an expression for the speed of P at time t seconds in its simplest form.

(ii) Given that the mass of P is 3 kg, write down the momentum vector of P at time t seconds. [6]

(b) At time $t = \frac{\pi}{6}$, the vector $b\mathbf{i} + \sqrt{3}\mathbf{j}$ is perpendicular to $\mathbf{r}$. Find the value of b. [5]

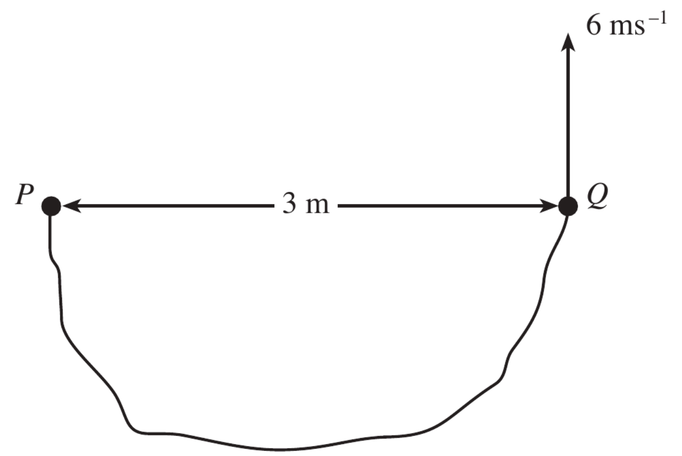
5. Particle A, of mass 2 kg, and particle B, of mass 3kg, are connected by a light inextensible string of length l m. Initially, both particles are lying at rest on a smooth horizontal surface a distance l m apart, with the string just slack. Particle B is given a blow of impulse 40 Ns in a direction away from A at an angle α to the line joining the initial positions of A and B.

Immediately after the blow, the speed of particle A is 4 ms^{-1}.

(a) Determine the value of α. [6]

(b) Calculate the magnitude and direction of the velocity of B immediately after the blow. [6]

4. Two particles P and Q, of mass 7 kg and 9 kg respectively, are attached one to each end of a light inextensible string of length 5 m. Initially, the particles are at rest on a smooth horizontal surface a distance 3 m apart, as shown in the diagram. Particle Q is then projected horizontally with velocity $6\,\text{ms}^{-1}$ in a direction at 90° to the line joining the initial positions of P and Q.



Calculate the speed of P and the speed of Q immediately after the string becomes taut. Determine the impulsive tension in the string during the jerk, and find the angle between the velocity of P and the velocity of Q immediately after the jerk. [14]

4. Two spheres P and Q, of mass 5 kg and 3 kg respectively, rest on a smooth table. They are connected by a light inextensible string which is initially slack. An impulse of magnitude 1·2 Ns is applied to Q in the direction PQ.

(a) Determine the speed with which Q begins to move. [2]

(b) Find the speed with which P moves after the string tightens, and determine the impulsive tension in the string. [6]

(c) Calculate the loss in energy when the string tightens. [4]

2. Two particles P and Q, of mass 3 kg and 7 kg respectively, are attached one to each end of a light inextensible string. Initially, the string is slack and the particles are at rest on a smooth horizontal surface. The particle Q is then projected across the surface with speed $8\,\text{ms}^{-1}$ away from P along the straight line passing through the initial positions of P and Q. Find the speed with which the particles begin to move immediately after the jerk and determine the impulsive tension in the string during the jerk. [6]

END OF MOMENTUM & IMPULSE IN 2D PACK

Source: WJEC M2/M3 (2008 modular spec) · 2005–2017

Curated for WJEC FM 2017 spec A2 Unit 6 — Topic 2 (2.6.2)