Name	Date started	Target end date

GCE AS / A LEVEL — FURTHER MECHANICS A QUESTION PACK

0981-01 (Legacy M2) & 0982-01 (Legacy M3) · New spec Unit 3 Topic 1

REVISE
.wales

FURTHER MATHS — MECH A · MOMENTUM & IMPULSE

Momentum, Impulse & Newton's Experimental Law

Every momentum / impulse / impulsive-jerk question from the legacy WJEC M2 + M3 papers (June 2005 – June 2017 + Specimen) that maps onto new-spec AS Unit 3 Topic 1.

LEGACY 2008 SPECIFICATION

Estimated time for entire question pack: ~3 hours 27 minutes

*Derived from the legacy M2/M3 paper's pace of **~1.5 min/mark** (138 marks over 13 questions).*

*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 question from the legacy WJEC M2/M3 papers (2008 modular spec) that maps onto new-spec AS Unit 3 Topic 1 (2.3.1).

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 may be referred to. Take $g = 9.8$ m s^{-2} unless told otherwise.

For Examiner's use only

Q	Source	Max	Mark
1	Jun 17 Q4	12	
2	Jun 16 Q4	9	
3	Jun 15 Q4	10	
4	Jun 06 Q5	12	
5	Jun 07 Q4	14	
6	Jun 08 Q6	9	
7	Jun 09 Q4	12	

Q	Source	Max	Mark
8	Jun 10 Q4	11	
9	Jun 11 Q5	10	
10	Jun 13 Q4	9	
11	Jun 15 Q5	11	
12	Jun 17 Q2	6	
13	Spec. Q5	13	
Total		138	

Momentum, Impulse & Newton's Experimental Law — what the new spec asks

WJEC GCE AS / A Level Further Mathematics (from 2017) · Unit 3: Further Mechanics A · Topic 2.3.1.

Momentum & impulse 2.3.1

- Linear momentum of a particle of mass m with velocity $\mathbf{v}$: $\mathbf{p} = m\mathbf{v}$.
- Impulse of a constant force $\mathbf{F}$ over time t: $\mathbf{J} = \mathbf{F}t$.
- Variable force: $\mathbf{J} = \int \mathbf{F}\,dt = \Delta\mathbf{p}$.
- Impulsive tension when a string suddenly becomes taut — treat as instantaneous.

Conservation of momentum 2.3.1

- For an isolated system of two particles colliding: $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$.
- Generalises to n particles: $\sum m_iu_i = \sum m_iv_i$.
- Applies to *1D* direct impacts and to *jerk problems* with light strings.
- Momentum is conserved even though KE is generally *not* conserved.

Newton's Experimental Law (NEL) 2.3.1

- Direct impact of two smooth bodies: $v_1' - v_2' = -e\,(u_1 - u_2)$.
- Coefficient of restitution e satisfies $0 \le e \le 1$.
- $e = 1$: perfectly elastic (KE conserved); $e = 0$: perfectly inelastic (particles coalesce).
- Impact with a fixed plane normal: outgoing normal speed $= e \times$incoming normal speed.

Working scientifically general

- Pick a positive direction **before** writing momentum equations — sign errors are the #1 marks lost.
- For 2D impulses on a single particle, split into components.
- KE loss in collision: $\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \frac{1}{2}(m_1v_1^2 + m_2v_2^2)$.
- For string jerks: the impulsive tension acts equally and oppositely on the two bodies.

Momentum & Impulse in one page

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

Momentum

Linear momentum of a particle:

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

Units: kg m s^{-1} (equivalent to N s).

For a system: total momentum is the vector sum of individual momenta.

Impulse

Impulse of a constant force $\mathbf{F}$ over time t:

$$\mathbf{J} = \mathbf{F}t$$

Variable force: $\mathbf{J} = \displaystyle\int_0^t \mathbf{F}\,dt$.

Impulse-momentum theorem: $\mathbf{J} = \Delta\mathbf{p} = m\mathbf{v} - m\mathbf{u}$.

Conservation of momentum

For an isolated system (no external impulses):

$$\sum m_i \mathbf{u}_i = \sum m_i \mathbf{v}_i$$

Apply *component-wise* in 2D / 3D.

Choose +ve direction before writing the equation.

Newton's Experimental Law

For direct impact between two smooth bodies:

$$v_1' - v_2' = -e(u_1 - u_2)$$

$0 \le e \le 1$ (coefficient of restitution).

$e = 1$: perfectly elastic (KE conserved).

$e = 0$: particles stick.

Impact with a plane

For a ball hitting a smooth fixed plane:

Normal component: $v_n' = -e\,u_n$.

Tangential component: unchanged ($v_t' = u_t$).

Speed after: $|v'| = \sqrt{e^2u_n^2 + u_t^2}$.

KE lost in a collision

$\Delta KE = \frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2 - \frac{1}{2}m_1v_1^2 - \frac{1}{2}m_2v_2^2$

For an inelastic ($e < 1$) collision, $\Delta KE > 0$.

For $e = 1$: $\Delta KE = 0$.

Express as a fraction of initial KE for "energy lost" parts.

Impulsive tension in a jerk

When a slack light string suddenly becomes taut, an *impulsive tension* $\mathbf{J}$ acts equally and oppositely on the two ends.

Along the string: $m_1(u_1 - v_1) = J = m_2(v_2 - u_2)$.

If B is projected at angle θ to line AB, only the component along AB contributes.

Common pitfalls

- Sign of velocity after collision — pick +ve once and stick with it.
- Forgetting to scale impulse to component along the string in 2D jerks.
- Using $e = 1$ when energy is asked to be lost — check the question.
- Treating impulsive tension as a normal tension (it acts instantaneously).

Strategy

1. Draw the before / after diagram with chosen positive direction.

2. Write momentum conservation along that direction.

3. If e is given, add NEL: $v_1' - v_2' = -e(u_1 - u_2)$.

4. Solve simultaneously. For 2D, split into components.

SECTION T1

Momentum & Impulse

Questions 1–13 · 138 marks

4. *A* and *B* are points a distance 18 m apart on horizontal ground. An object *P* is projected from *A* towards *B* with velocity $15\,\text{ms}^{-1}$ at an angle of 60° to the horizontal. Simultaneously, another object *Q* is projected from *B* towards *A* with velocity $v\,\text{ms}^{-1}$ at an angle of 30° to the horizontal. The objects collide.

(a) Find the value of v. [5]

(b) Show that the time from projection to collision is 0·6 seconds. [3]

(c) Determine the speed of the object *P* just before collision. [4]

4. By burning a charge, a cannon fires a cannon ball of mass 12 kg horizontally. As the cannon ball leaves the cannon, its speed is 600 ms^{-1}. The recoiling part of the cannon has a mass of 1600 kg.

(a) Determine the speed of the recoiling part immediately after the cannon ball leaves the cannon. [3]

(b) Find the energy created by the burning of the charge. State any assumption you have made in your solution. [4]

(c) Calculate the constant force needed to bring the recoiling part to rest in 1·2 m. [2]

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]

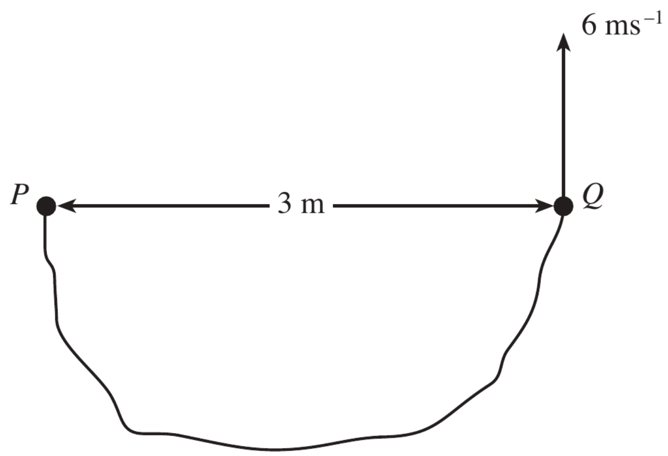
5. Particle A, of mass 2 kg, and particle B, of mass 3kg, are connected by a light inextensible string of length l m. Initially, both particles are lying at rest on a smooth horizontal surface a distance l m apart, with the string just slack. Particle B is given a blow of impulse 40 Ns in a direction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

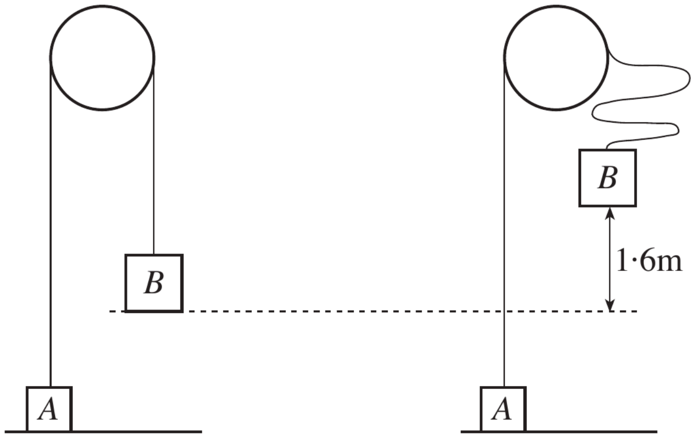
(b) Calculate the magnitude and direction of the velocity of B immediately after the blow. [6]

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]

6. A particle A, of mass 7 kg, rests on a horizontal table. It is attached to one end of a light inextensible string which passes over a smooth light pulley. The other end of the string is attached to another particle B, of mass 3 kg. Initially, the particles are held at rest with the string just taut. Particle B is raised vertically through a distance of 1·6 m and released from rest.



Find the speed with which particle A begins to rise, and the impulsive tension in the string. [9]

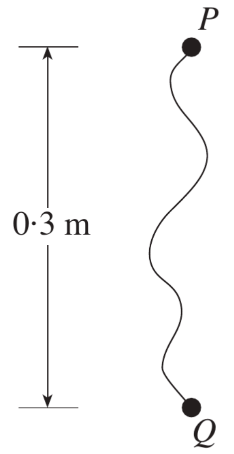
4. Two spheres *P* and *Q*, of mass 5 kg and 3 kg respectively, rest on a smooth table. They are connected by a light inextensible string which is initially slack. An impulse of magnitude 1·2 Ns is applied to *Q* in the direction *PQ*.

(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]

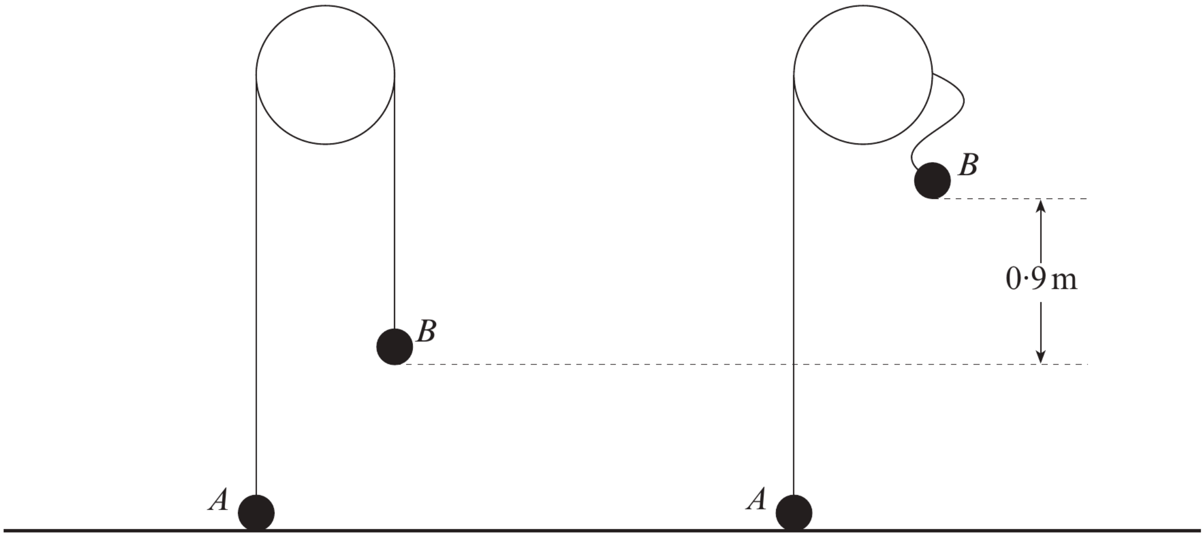
(c) Calculate the loss in energy when the string tightens. [4]

4. Two particles P and Q, of mass 3 kg and 5 kg respectively, are attached one to each end of a light inextensible string of length 0·6 m. Initially, the particles are at rest on a smooth horizontal surface a distance 0·3 m apart, as shown in the diagram.



The particle Q is projected across the surface with speed 8 ms^{-1} in a direction at 90° to the line joining the initial positions of P and Q. Determine the impulsive tension in the string during the jerk, stating your unit clearly. Find the speed with which each particle begins to move immediately after the jerk. [11]

5. The diagram shows two particles A and B, of masses 4 kg and 3 kg respectively, connected by a light inextensible string passing over a smooth light pulley fixed above a horizontal plane. Initially, the particle A is at rest on the plane and particle B hangs at a depth of 1·0 m below the pulley.



Particle B is then raised vertically a distance of 0·9 m and released from rest from that position.

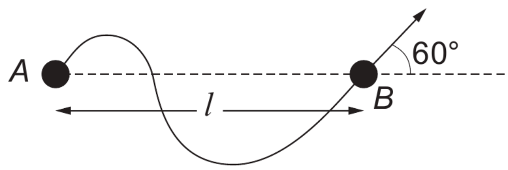
(a) Calculate the speed of B immediately before the string tightens. [3]

(b) Determine the speed with which A leaves the plane and the impulsive tension in the string immediately after the string tightens. [7]

TURN OVER

4. Two particles A and B, of masses 5 kg and 3 kg respectively, rest on a smooth horizontal surface. Particle A lies at the edge of the surface and particle B lies a distance of 0·2 m from the edge such that the line AB is perpendicular to the edge of the surface. The two particles are connected by a light inextensible string of length 1·8 m. Particle A is then allowed to drop from rest from the edge of the surface. Calculate the speed of B immediately after the string becomes taut and find the impulsive tension in the string. [9]

5. Two particles A and B, of mass 3 kg and 5 kg respectively, are attached one to each end of a light inextensible string of length $\sqrt{3}l$ m. Initially, the particles are at rest on a smooth horizontal surface a distance l m apart, as shown in the diagram. Particle B is then projected horizontally with speed 8 ms^{-1} at an angle of 60° to the line joining the initial positions of A and B produced.



Immediately after the string becomes taut,

(a) show that the particle A starts to move in a direction which makes an angle of 30° with the line joining the initial positions of A and B. [2]

(b) find the speed with which each particle begins to move and determine the magnitude of the impulsive tension in the string. [9]

TURN OVER

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 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]

5. A light inextensible string, of length 1 m, connects particles A and B, of masses 2 kg and 5 kg respectively. Initially, the particles are lying on a smooth horizontal surface 0·6 m apart. Particle B is projected with a velocity of 7 ms^{-1} in a direction perpendicular to the line joining the initial positions of A and B.

(a) Determine the speeds of A and B immediately after the string becomes taut, and find the impulsive tension in the string. [9]

(b) Calculate the energy lost by the system when the string becomes taut. [4]

END OF MOMENTUM & IMPULSE PACK

Source: WJEC M2/M3 (2008 modular spec) · 2005–2017
Curated for WJEC FM 2017 spec AS Unit 3 — Topic 1 (2.3.1)