# Teacher Delivery Guide Mechanics: Momentum and Impulse

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| **Specification** | **Ref.** | **Learning outcomes** | **Notes** | **Notation** | **Exclusions** |
| **Y421 MECHANICS MAJOR: MOMENTUM and IMPULSE (a)****Y431 MECHANICS MINOR: MOMENTUM and IMPULSE****Y411 MECHANICS a: MOMENTUM and IMPULSE** |
| Momentum and impulse treated as vectors | Mi1 | Be able to calculate the impulse of a force as a vector and in component form. | Impulse = force × time over which it acts. |  | The use of calculus for variable forces. |
| i2 | Understand and use the concept of linear momentum and appreciate that it is a vector quantity. |  |  |  |
| i3 | Understand and use the impulse-momentum equation. | The total impulse of all the external forces acting on a body is equal to the change in momentum of the body. Use of relative velocity in one dimension is required. |  |  |
| Conservation of linear momentum | i4 | Understand and use the principle that a system subject to no external force has constant total linear momentum and that this result may be applied in any direction. | The impulse of a finite external force (e.g. friction) acting over a very short period of time (e.g. in a collision) may be regarded as negligible.Application to collisions, coalescence and a body dividing into one or more parts. |  |  |
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***DISCLAIMER***

This resource was designed using the most up to date information from the specification at the time it was published. Specifications are updated over time, which means there may be contradictions between the resource and the specification, therefore please use the information on the latest specification at all times.If you do notice a discrepancy please contact us on the following email address: resources.feedback@ocr.org.uk

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| **Specification** | **Ref.** | **Learning outcomes** | **Notes** | **Notation** | **Exclusions** |
| Direct impact | i5 | Understand the term direct impact and the assumptions made when modelling direct impact collisions1. | E.g. a collision between an ice hockey puck and a straight rink barrier: puck moving perpendicular to barrier.E.g. a collision between two spheres moving along their line of centres. E.g. a collision between two railway trucks on a straight track. |  | Any situation with rotating objects. |
| **1Assumptions when modelling direct impact collisions** |
| This note explains the implicit assumptions made in examination questions when modelling direct impact collisions. Learners may be asked about these assumptions. An *object* means a real-world object. It may be modelled as a *particle* or a *body*.* If the non-fixed objects involved in collisions may be modelled as particles, then all the motion and any impulses due to the collisions act in the same straight line.
* If the non-fixed objects involved in collisions may be modelled as bodies then these bodies will be uniform bodies with spherical or circular symmetry.
* The impulse of any collision between such bodies acts on the line joining their centres, and the motion takes place along this line.

These assumptions ensure that the collision happens at a point and that no angular momentum is created, hence none of the objects starts to rotate. * The impulse of any collision between such a body, or a particle, and a plane (e.g. a wall or floor) acts in a direction perpendicular to the plane.

For a direct impact the motion of the object is also in the direction perpendicular to the plane.* Objects do not rotate before or after the collision. Rotating objects are beyond this specification.
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| **Specification** | **Ref.** | **Learning outcomes** | **Notes** | **Notation** | **Exclusions** |
| Direct impact (cont) | Mi6 | Be able to apply the principle of conservation of linear momentum to direct impacts within a system of bodies. |  |  |  |
|  | i7 | Know the meanings of Newton's Experimental Law and of coefficient of restitution when applied to a direct impact. | Newton's Experimental Law is:the speed of separation is  the speed of approach where  is known as the coefficient of restitution. | Coefficient of restitution is. |  |
|  | i8 | Understand the significance of .  | The bodies coalesce. The collision is inelastic.  |  |  |
|  | i9 | Be able to apply Newton's Experimental Law in modelling direct impacts. | E.g. between a particle and a wall.E.g. between two discs. |  |  |
| i10 | Be able to model situations involving direct impact using both conservation of linear momentum and Newton's Experimental Law. |  |  |  |
|  | i11 | Understand the significance of *.* | The collision is perfectly elastic. Kinetic energy is conserved.  |  |  |
|  | i12 | Understand that when  kinetic energy is not conserved during impacts and be able to find the loss of kinetic energy. |  |  |  |

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| **Specification** | **Ref.** | **Learning outcomes** | **Notes** | **Notation** | **Exclusions** |
| **Y421 MECHANICS MAJOR: MOMENTUM and IMPULSE (b)****Y415 MECHANICS b: MOMENTUM and IMPULSE** |
| Oblique impact | Mi13 | Understand the term oblique impact and the assumptions made when modelling oblique impact collisions1. | E.g. a collision between a sphere and a surface when the sphere is moving in a direction which is not perpendicular to the surface.E.g. a collision between two discs not moving along their lines of centres.  |  | Any situation with rotating objects. |
| i14 | Know the meanings of Newton's Experimental Law and of coefficient of restitution when applied to an oblique impact. | The coefficient of restitution is the ratio of the components of the velocities of separation and approach, in the direction of the line of impulse. |  |  |
|  | i15 | Be able to model situations involving oblique impact between an object and a smooth plane by considering the components of its motion parallel and perpendicular to the line of impulse. |  |  |  |
|  | i16 | Be able to model situations involving oblique impact between two bodies by considering the components of their motion in directions parallel and perpendicular to the line of impulse. |  |  |  |
|  | i17 | Be able to calculate the loss of kinetic energy in an oblique impact. |  |  |  |

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| **Assumptions when modelling oblique impact collisions** |
| This note explains the implicit assumptions made in examination questions when modelling oblique impact collisions. Learners may be asked about these assumptions. When two objects collide obliquely they cannot be modelled as particles; with two particles there is no preferred direction to act as the line of impulse. If an object collides with a plane (e.g. a wall or a floor) then it may be modelled as a particle or as a body, as appropriate.* If the non-fixed objects involved in collisions may be modelled as bodies then these bodies will be uniform bodies with spherical or circular symmetry.
* The impulse of any collision between such bodies acts on the line joining their centres.

These assumptions ensure that the collision happens at a point and that no angular momentum is created, hence none of the objects starts to rotate. An oblique impact collision occurs when the line of relative motion of the bodies is not the same as the line joining their centres at the point of collision.* The impulse of any collision between such a body, or a particle, and a plane (e.g. a wall or floor) acts in a direction perpendicular to the plane.

An oblique impact collision in this situation means that the motion of the object is not in the direction perpendicular to the plane.* The contact between the surfaces in any collision is smooth.

This is an extra assumption for oblique collisions. It ensures that the linear momentum of each object is conserved in the direction perpendicular to the line of impulse.* Objects do not rotate before or after the collision. Rotating objects are beyond this specification.
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# Thinking Conceptually

### General approaches

There are opportunities in this subject content area for some nice practical investigations, using simple apparatus (see also the ‘Leeds Mechanics Kit’ referenced in the ‘Resources’ section). These can provide strong motivation for developing the theoretical ideas. One first needs to establish the definition of linear momentum; then extend this to studying the conservation of linear momentum, and the impulse-equation equation. Learners then extend these ideas to include Newton’s Experimental Law and collisions in two dimensions.

### Common difficulties learners may have

Practical activities can present problems of measurement and inaccuracy in timings. There may be discrepancies between actual and expected results which need to be discussed with learners

In momentum calculations, learners often make sign errors signs when considering motion: it is important to emphasise that the equations are vectorial in nature and involve velocities rather than speeds. In particular, velocity arrows in diagrams often define implicitly the direction of velocities, which need to be consistent with the equations.

It is important to clarify the difference between force and impulse / momentum, for example by considering impulse as the area under a force-time graph.

It is also worth pointing out the qualitative difference between the impulse-momentum principle and Newton’s Law of restitution, which is an empirical law.

### Common misconceptions learners may have

Misconceptions often arise from failing to distinguish between impulse/momentum, which are vector quantities, and work/energy, which are scalars. Momentum is conserved in collisions, whereas energy is not. The practical work advocated in the last section can be used to highlight the differences.

In some problems, it may not be possible to determine the direction of motion of objects after collisions, as this may depend upon their momentum prior to collision, or the value of the coefficient of restitution. In these circumstances, it is important to choose a direction for the velocities to be added to diagrams, and formulate equations consistent with these choices. If calculations subsequently prove they are negative, then this means the direction of motion can then be adjusted accordingly.

It is also worth discussing circumstances in which momentum is not conserved due to an external force, such as in the collision of a particle with a wall.

### Conceptual links to other areas of the specification

The impulse-momentum equation arises from integrating Newton’s second law with respect to time:

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This explains why the impulse of a force is the (signed) area under the force-time graph, and contrasts with the concept of work, which is the integrating Newton’s second law with respect to displacement. It is instructive to solve the same problem using both theoretical approaches, in order to highlight this conceptual link.

# Thinking Contextually

If time and classroom circumstances allow experimental, or software based simulation, approaches to help reinforce the connections between contexts and the theory.

Contexts encountered frequently in exam questions include:

* collisions between spheres/particles
* impacts with barriers
* hitting balls with bats / racquets
* bouncing balls.

Collision problems such as these use the impulse-momentum equation rather than Newton’s second law because the contact force between the balls acts over a small time interval, and the results in a sudden change in velocity. It is useful to think of the contact forces delivering a ‘package’ of impulse over a short period of time:

*t*

*F*

*J*

Newton’s experimental law links easily with our experience of how different materials behave under collision, from the close to perfectly elastic behaviour of rubber balls, to the inelastic behaviour of materials which ‘soak up’ the energy of collisions.

Apparatus, such as the Leeds Mechanics Kit, may be a useful resource for centres wanting to deliver this strand through a practical approach.

# Resources

| **Title** | **Organisation** | **Description** | **Ref** |
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| [8.1 A first look at momentum](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 8.1, page 97, provides a range of contextual questions to introduce momentum. | i1, i 2 and i3 |
| [Linear Momentum and Principle of Conservation of Momentum](https://www.sciencetopia.net/physics/linear-momentum-principles) | Sciencetopia | Notes on principle starting from Newton’s third law. Includes reference to dimensional analysis. | i1, i 2, i3 and i4 |
| [Principle of the Conservation of Momentum](https://www.s-cool.co.uk/a-level/physics/momentum-and-impulse/revise-it/principle-of-the-conservation-of-momentum) | S-cool | Notes with common errors highlighted. | i1, i 2, i3 and i4 |
| [8.2 The impulse-momentum equation](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 8.2, page 99 deals with momentum changes and the impulse-momentum equation which is used in the impulse topic, 6.03f and 6.03g. | i3 |
| [8.4 Newton’s cradle](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 8.4, based around Newton’s cradle establishes the principle of conservation of linear momentum either practically or theoretically. | i1, i2, i3, i4, i5, i6, i7, i8, i9, i10, i11 and i12 |
| [8.5 The principle of the conservation of momentum](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 8.5 page 105 explores further the modelling of collisions.Again there is a link into the next topic. | i1, i2, i3, i4 and i5 |
| [8.7 Problems in 2 dimensions](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 8.7, page 109,considers the oblique impact of 2 spheres. | i13, i14, i15 and i16 |
| [9.1 Limits of conservation of momentum](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 9.1, page 114, is a theoretical activity which leads into activity 9.2. | i13, i14, i15, i16 and i17 |
| [9.2 Validating Newton’s Law of restitution](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 9.2, page 115 – a practical activity;  | i13, i14, i15, i16 and i17 |
| [9.3 using Newton’s law of restitution in 1 dimension](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 9.3 on page 117 introduces the work necessary for activity 9.4. | i13, i14, i15, i16 and i17 |
| [9.4 bouncing against the ground and walls](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 9.4, page 119, which considers oblique impact. | i13, i14, i15, i16 and i17 |
| [9.5 Bouncing along](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 9.5 is a practical activity seeking validation that Newton’s Law applies for oblique impact and could be followed by activity 9.6. | i13, i14, i15, i16 and i17 |
| [9.6 Collisions in 2 dimensions](https://www.stem.org.uk/rxvq2) | Nuffield | Activity 9.6 which is a theoretical activity considering collisions in 2 dimensions. | i13, i14, i15, i16 and i17 |
| [Rebound](https://www.stem.org.uk/rxtgk) | Mechanics in Action | Rebound page 163, task sheet 52, investigates the rebound of a snooker ball off a cushion. | i10 |
| [1.5 The long golf drive](https://www.stem.org.uk/rxyt3) | The Spode Group | The long golf drive, page 22, is a theoretical activity concerned with the conservation of momentum. | i10 |
| [The superball as a deadly weapon](https://www.stem.org.uk/rxtgk) | Mechanics in Action | The superball as a deadly weapon, page 164, task sheet 53, is a challenging problem to solve with the theory for impact. | i13, i14, i15, i16 and i17 |
| [2.5 Whose fault?](https://www.stem.org.uk/rxyt3) | The Spode Group | Whose fault? , page 49, Is a theoretical activity which is set in the context of a road accident, involving collisions and momentum. | i13, i14, i15, i16 and i17 |
| [Mechanical Mindgames](https://nrich.maths.org/7110) | Nrich | Interesting set of problems to ponder, building upon the content of impulse and momentum section for more able students. | i5 and i16 |

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