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IGCSE PHYSICS 0625 · TOPICAL PAST PAPERS

Momentum — Paper 2

Worked Solutions (Theory / Structured)

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Momentum — Paper 2 · Worked Solutions

These are **Megalecture worked solutions** for the topical structured-question compilation on **Momentum (IGCSE Physics 0625, Paper 2)**. Every part below was solved from first principles by the Megalecture team — no official mark scheme has been copied. Calculations use the key relations $p = mv$, the principle of **conservation of momentum**, $\text{impulse} = F\,t = \Delta p$ and $F = \Delta p\ /\ t$, with *g* = 10 N/kg where needed. Final answers are shown in **bold with units**. Each card names the exam reference so you can match it to your paper.

1 Hammer driving a nail — 0625/42/F/M/16 Q2

> Hammer head: **m** = 0.15 kg, speed on impact **v** = 8.0 m/s, contact time **t** = 0.0015 s; the head stops after the blow.

(a) Change in momentum of the hammer head.

The head goes from 8.0 m/s to rest, so Δp = m(v − u) = 0.15 × (0 − 8.0) = −1.2 kg m/s.

Change in momentum = **1.2 kg m/s** (a decrease, i.e. 1.2 kg m/s in magnitude).

(b) Impulse given to the nail.

By Newton's third law the impulse the hammer gives the nail equals the momentum the hammer loses.

Impulse = **1.2 N s** (in the direction the nail is driven).

(c) Average force between hammer and nail.

F = Δp / t = 1.2 / 0.0015.

Average force = **800 N**.

2 Car crumple zone — 0625 Paper 4, part (c)

> A car of mass **m** = 1500 kg collides with a wall; all the energy of the collision is absorbed by the crumple zone. Energy absorbed = 4.3×10^5 J.

Only part (c) of this question appears in the compilation; the earlier parts are not shown.

(c)(i) Show that the speed before the collision is 24 m/s.

All the kinetic energy is absorbed, so $\frac{1}{2}mv^2 = 4.3 \times 10^5$ J.

$v^2 = (2 \times 4.3 \times 10^5) / 1500 = 8.6 \times 10^5 / 1500 = 573\ (\text{m/s})^2$.

$v = \sqrt{573} = 23.9$ m/s.

v ≈ **24 m/s** (shown).

(c)(ii) If the car travels faster than 24 m/s when it hits the wall.

The kinetic energy would be greater than 4.3×10^5 J, so the crumple zone cannot absorb all of it. The extra energy is transferred to the rest of the car (and occupants), so the passenger compartment would also be damaged / the people would be hurt. **Damage extends beyond the crumple zone.**

3 Crash-test dummy — 0625/41/2016 Q2

Dummy mass **m** = 70 kg; the car approaches a solid barrier at 20 m/s and stops suddenly.

(a)(i) Momentum of the dummy just before the crash.

$p = mv = 70 \times 20$.

Momentum = **1400 kg m/s**.

(a)(ii) Impulse needed to bring the dummy to rest.

Impulse = change in momentum = 1400 − 0.

Impulse = **1400 N s** (opposite to the original motion).

(b) Deceleration of the passenger compartment (rest in 0.20 s).

$a = (v - u)/t = (0 - 20)/0.20 = -100$ m/s^2.

Deceleration = **100 m/s^2**.

(c) Average resultant force on the dummy (deceleration 80 m/s^2, mass 70 kg).

$F = ma = 70 \times 80$.

Force = **5600 N**.

(d) Why a smaller dummy deceleration benefits passenger safety.

A smaller deceleration means a smaller resultant force acts on the body ($F = ma$). The smaller force reduces the risk of injury, and the dummy is brought to rest over a longer time, spreading the change in momentum out so the body is decelerated more gently. **Lower force → less injury.**

4 Two railway trucks — 0625/42/2016 Q2

> Truck A: $\mathbf{m}_A$ = 6000 kg moving at 5.0 m/s; Truck B: $\mathbf{m}_B$ = 5000 kg, stationary. They collide and bounce apart.

(a) Momentum of truck A.

$p = mv = 6000 \times 5.0$.

Momentum = **30 000 kg m/s**.

(b)(i) Impulse applied to truck B (B has 27 000 kg m/s after).

B starts at rest, so impulse = Δp_B = 27 000 − 0.

Impulse = **27 000 N s**.

(b)(ii) Average force on truck B (contact 0.60 s).

$F = \Delta p / t$ = 27 000 / 0.60.

Force = **45 000 N**.

(b)(iii) Final speed of truck A.

Conservation of momentum: total before = 30 000 kg m/s = $p_{A,after} + p_{B,after}$.

$p_{A,after}$ = 30 000 − 27 000 = 3000 kg m/s.

$v_A = p / m$ = 3000 / 6000.

Final speed of A = **0.5 m/s** (still in its original direction).

5 Two colliding cars — 0625/43/2016 Q2

Car A: $\mathbf{m}_A$ = 2000 kg at 18 m/s; Car B: $\mathbf{m}_B$ = 1200 kg, stationary. After: A continues with momentum 21 000 kg m/s.

(a) Momentum of car A before.

$p = mv = 2000 \times 18$.

Momentum = **36 000 kg m/s**.

(b)(i) Momentum of car B immediately after.

Conservation: total = 36 000 = 21 000 + p_B, so p_B = 36 000 − 21 000.

Momentum of B = **15 000 kg m/s**.

(b)(ii) Average impulse on car B.

Impulse = Δp_B = 15 000 − 0.

Impulse = **15 000 N s**.

(b)(iii) Average resultant force on car B (contact 0.20 s).

$F = \Delta p / t$ = 15 000 / 0.20.

Force = **75 000 N**.

(c) Benefit of increasing the time of contact.

The change in momentum is fixed, so a longer contact time gives a smaller average force ($F = \Delta p / t$). The smaller force on the people in the car reduces the risk of injury. **Longer time → smaller force → safer.**

6 Footballer kicking a ball — 0625/41/M/J/17 Q2

> Boot in contact for **t** = 0.050 s, average force **F** = 180 N, ball leaves at **v** = 20 m/s (vertically up); ball starts at rest.

(a)(i) Impulse of the force on the ball.

Impulse = F t = 180 × 0.050.

Impulse = **9.0 N s**.

(a)(ii) Mass of the ball.

Impulse = Δp = mv, so m = impulse / v = 9.0 / 20.

Mass = **0.45 kg**.

(a)(iii) Height the ball rises (ignore air resistance).

At the top, all kinetic energy becomes gravitational PE: $\frac{1}{2}mv^2 = mgh$, so $h = v^2 / (2g)$.

$h = 20^2 / (2 \times 10) = 400 / 20$.

Height = **20 m**.

(b) Energy stored in the squashed ball.

Elastic (strain) potential energy.

7 Two blocks that move off together — 0625/42/M/J/17 Q3

> Block A: $\mathbf{m}_A$ = 2.4 kg moving at 3.0 m/s; Block B: $\mathbf{m}_B$ = 1.2 kg, at rest. After the collision A and B move off together with common velocity **v**.

(b)(i) Momentum of A before the collision.

p = mv = 2.4 × 3.0.

Momentum = **7.2 kg m/s**.

(b)(ii) The common velocity v.

Conservation: $m_A u = (m_A + m_B)v$, so v = 7.2 / (2.4 + 1.2) = 7.2 / 3.6.

v = **2.0 m/s**.

(b)(iii) Impulse experienced by block B during the collision.

Impulse on B = $\Delta p_B = m_B v$ = 1.2 × 2.0.

Impulse = **2.4 N s**.

(c) Why the kinetic energy after is less than before.

This is an inelastic collision: some kinetic energy is transferred to other forms — heat (and sound) — as the blocks deform and rub on impact. **KE is not conserved in an inelastic collision (momentum still is).**

8 Metal block collision — 0625/43/M/J/17 Q2

Block A: $\mathbf{m}_A$ = 3.2 kg at 4.0 m/s; Block B: $\mathbf{m}_B$ = 1.6 kg, at rest. After: A moves at 1.5 m/s, B moves at v.

(a) Word equation for momentum.

momentum = mass × velocity.

(b)(i) Momentum of A before.

$p = mv = 3.2 \times 4.0$.

Momentum = **12.8 kg m/s**.

(b)(ii) Velocity v of B after.

Conservation: total = 12.8 kg m/s. After, A has 3.2 × 1.5 = 4.8 kg m/s.

$p_B = 12.8 - 4.8 = 8.0$ kg m/s, so $v = 8.0 / 1.6$.

v = **5.0 m/s**.

(c) Average force on B (contact 0.050 s).

$F = \Delta p / t = 8.0 / 0.050$.

Force = **160 N**.

(d) Why total KE after is less than KE of A before.

The collision is inelastic: some kinetic energy is converted to internal (thermal) energy and sound as the blocks deform on impact. **Energy transferred to heat/sound.**

9 Accelerating rocket — 0625/41/M/J/19 Q1

> A rocket starts at rest; from **t** = 0 its acceleration rises and then stays constant (Fig. 1.1). Later it is far from Earth where gravity is insignificant.

(a) Define acceleration.

Acceleration is the rate of change of velocity (change in velocity per unit time).

(b) Sketch of speed against time.

Speed starts at 0 and continuously increases (the gradient = acceleration). While acceleration rises, the speed–time curve gets steeper (curves upward); once acceleration is constant, the speed–time graph becomes a straight line with constant positive gradient. **An upward-curving line that straightens into a steady upward slope.**

(c)(i) Principle of conservation of momentum.

For a system with no external resultant force, the total momentum before an interaction equals the total momentum after it (total momentum is conserved).

(c)(ii) How conservation of momentum applies to the rocket and its exhaust gases.

The hot exhaust gases are pushed backwards, gaining momentum in that direction. To keep the total momentum of the system unchanged, the rocket gains an equal amount of momentum in the opposite (forward) direction. **Backward momentum of gas = forward momentum gained by rocket.**

10 Model fire-engine water jet — 0625/42/M/J/19 Q2

> 0.80 kg of water is emitted every 6.0 s at a velocity of 0.72 m/s relative to the model (which is initially at rest).

(a) Change in momentum of the water ejected in 6.0 s.

$\Delta p = mv = 0.80 \times 0.72$.

Change in momentum = **0.576 kg m/s** (≈ 0.58 kg m/s).

(b) Magnitude of the force on the model due to the jet.

$F = \Delta p / t = 0.576 / 6.0$.

Force = **0.096 N** (≈ 0.096 N).

(c) Statement and explanation about the model's acceleration when the brakes are off.

Statement: the model accelerates (moves off / speeds up in the opposite direction to the water jet).
Explanation: the water is given momentum one way, so by conservation of momentum the model gains equal momentum the other way; the jet exerts a forward resultant force on the model (Newton's third law), and since there is now a resultant force it accelerates.

(d) What happens when the tank is nearly empty (compared with part (c), tank full).

Statement: the model accelerates more (greater acceleration).
Explanation: the force from the jet stays about the same, but the model now has far less mass (little water left). From $a = F / m$, a smaller mass with the same force gives a larger acceleration.

11 Fairground bumper cars — 0625/42/O/N/16 Q2

> Moving car (with passenger): **m** = 200 kg at 2.5 m/s. It hits a stationary empty car of mass 50 kg. After, the empty car moves forward at 4.0 m/s.

(a)(i) Expression for kinetic energy.

KE = ½mv².

(a)(ii) Is KE a scalar or a vector?

Scalar — it has magnitude (a size in joules) only, with no associated direction.

(b)(i) Momentum of the car with passengers at 2.5 m/s.

p = mv = 200 × 2.5.

Momentum = **500 kg m/s**.

(b)(ii) Speed and direction of the car with passengers just after.

Empty car after: p = 50 × 4.0 = 200 kg m/s.

Conservation: 500 = 200 + p_{moving}, so p_{moving} = 300 kg m/s; v = 300 / 200.

Speed = **1.5 m/s**, direction = **the same (original forward) direction**.

(b)(iii) Energy transfers as the cars collide and separate (KE conserved overall).

As the cars push together, the springs compress and kinetic energy is stored as **elastic (strain) potential energy** in the springs; as the cars separate the springs expand and this elastic PE is transferred back to **kinetic energy** of the cars. (Because total KE after = total KE before, this collision is elastic.)

12 Spacecraft that splits in two — 0625/43/O/N/16 Q3

> Spacecraft: **m** = 35 kg at velocity 1200 m/s, no external forces. Its fuel then explodes and it splits into two sections (one speeds up, one slows down).

(a)(i) How a vector differs from a scalar.

A vector has both magnitude and direction; a scalar has magnitude only.

(a)(ii) Is momentum a vector or a scalar?

Vector — momentum = mass × velocity, and velocity has a direction, so momentum acts in a definite direction.

(b)(i) Momentum of the spacecraft.

$p = mv = 35 \times 1200$.

Momentum = **42 000 kg m/s**.

(b)(ii) Kinetic energy of the spacecraft.

$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 35 \times 1200^2 = \frac{1}{2} \times 35 \times 1.44 \times 10^6$.

Kinetic energy = **2.52×10^7 J** (25 200 000 J).

(c)(i) What happens to the total momentum after the explosion.

There is no external resultant force, so the total momentum is unchanged. **Total momentum stays the same (conserved) = 42 000 kg m/s.**

(c)(ii) What happens to the total kinetic energy.

The total kinetic energy **increases**. The chemical (potential) energy released by the exploding fuel is transferred into extra kinetic energy of the two sections, so the KE after the explosion is greater than before.

13 Girl throwing a heavy ball — 0625/41/O/N/18 Q3

> Ball mass **m** = 4.0 kg; the girl exerts a force for **t** = 0.60 s; the ball's speed rises from 0 to 12 m/s before it leaves her hand.

(a) Principle of conservation of energy.

Energy cannot be created or destroyed, only transferred from one form to another; the total energy of a closed system stays constant.

(b)(i) Energy changes from the push until the ball stops on the ground.

Chemical (potential) energy in the girl's muscles → kinetic energy of the ball; as the ball rises, kinetic energy → gravitational potential energy; as it falls, GPE → kinetic energy; on hitting the ground the kinetic energy → heat (thermal) and sound. **Chemical → KE ↔ GPE → heat + sound.**

(b)(ii)1. Momentum of the ball on leaving the hand.

$p = mv = 4.0 \times 12$.

Momentum = **48 kg m/s**.

(b)(ii)2. Average resultant force on the ball.

$F = \Delta p / t = 48 / 0.60$.

Force = **80 N**.

14 Tennis ball — 0625/42/O/N/18 Q3

> Ball starts at rest. Racquet contact time **t** = 6.0 ms = 6.0×10^{-3} s, average force **F** = 400 N, ball mass **m** = 0.056 kg.

(a) Change of momentum in terms of m, u, v.

Change of momentum = mv − mu = m(v − u).

(b)(i) Impulse on the ball.

Impulse = F t = $400 \times 6.0 \times 10^{-3}$.

Impulse = **2.4 N s**.

(b)(ii) Speed with which the ball leaves the racquet.

Impulse = Δp = mv (starts from rest), so v = impulse / m = 2.4 / 0.056.

Speed = **43 m/s** (42.9 m/s).

(b)(iii)1. Energy transfer as the ball changes shape during contact.

Kinetic energy / work done by the racquet is stored as **elastic (strain) potential energy** in the squashed ball.

(b)(iii)2. Energy transfer as the ball leaves the racquet.

The stored **elastic potential energy is transferred back to kinetic energy** of the ball as it springs back to shape and flies off.

15 Golf ball — 0625/43/O/N/18 Q2

> Ball mass **m** = 0.046 kg; club contact time **t** = 5.0×10^{-4} s; ball leaves at **v** = 65 m/s (from rest).

(a) Name the quantity given by each product (Fig. 2.1).

mass × acceleration = **force**; force × time = **impulse** (= change in momentum).

(b)(i)1. Momentum of the ball as it leaves the club.

p = mv = 0.046 × 65.

Momentum = **2.99 kg m/s** (≈ 3.0 kg m/s).

(b)(i)2. Average resultant force while in contact.

F = Δp / t = 2.99 / (5.0×10^{-4}).

Average force = **5980 N** (≈ 6.0×10^{3} N).

(b)(ii) Energy stored in the compressed ball.

Elastic (strain) potential energy.

16 Air-rifle pellet — 0625/41/O/N/19 Q3

> When fired the rifle gives the pellet an impulse of 0.019 N s. Pellet mass **m** = 1.1×10^{-4} kg (starts from rest).

(a) Define impulse.

Impulse = force × the time for which it acts (equal to the change in momentum it produces).

(b)(i) Speed with which the pellet leaves the rifle.

Impulse = $\Delta p = mv$ (from rest), so v = impulse / m = $0.019 / (1.1 \times 10^{-4})$.

Speed = **173 m/s** (172.7 m/s).

(b)(ii) Kinetic energy of the pellet as it leaves.

$KE = \frac{1}{2}mv^2 = \frac{1}{2} \times 1.1 \times 10^{-4} \times 172.7^2$.

Kinetic energy = **1.6 J** (1.64 J).

(c) How the molecular structure of the molten metal differs from the solid.

In the solid the atoms are held in fixed positions in a regular pattern (lattice) by strong forces, vibrating about those positions. In the liquid the atoms are still close together but the forces are weaker, so they are **no longer in fixed positions / no regular pattern — they can move past one another (the structure is disordered and the atoms are mobile).**

Note from Megalecture. These are original Megalecture worked solutions prepared for revision use; no official Cambridge mark scheme has been reproduced. Values are given to a sensible number of significant figures using g = 10 N/kg. Where a question asked you to "show that" a value, the working confirms it (e.g. the crumple-zone speed comes out as 23.9 m/s ≈ 24 m/s). One item (Q2) appears in the compilation as part (c) only, so the missing earlier context is noted rather than guessed.