IGCSE Physics 0625 · Topical Past Papers

Worked Solutions · Theory / Structured

FORCES (DYNAMICS)

Paper 2

Worked Solutions

Authored Solutions

Megalecture · Original Worked Solutions

Each question is solved from first principles with full working shown. Force diagrams are described with calculated magnitudes. All calculations use Newton’s laws (F = ma), weight (W = mg), and energy considerations. All answers use SI units and appropriate significant figures based on the data provided. This is owner’s authorised material for IGCSE Physics 0625 study support.

Forces (Dynamics) — Paper 2

Overview: This document contains detailed worked solutions for all questions from the IGCSE Physics 0625 topical past papers on Forces and Dynamics (Paper 2). Questions cover Newton's three laws of motion, calculating acceleration using F = ma, determining braking distances and forces, analysing friction and air resistance, and solving problems involving weight, normal forces, and resultant forces. Each solution shows complete working with final answers highlighted in boxes.

Key Principles: Weight W = mg (where g = 10 N/kg or 9.81 N/kg as specified); Resultant force F = ma; Braking distance from graphs or $v^2 = u^2 + 2as$; Think about whether forces are balanced (equilibrium) or unbalanced (acceleration); Always identify all forces acting (weight, normal, friction, driving force, air resistance).

Worksheet 1 — Braking & Emergency Stops

1 Car Braking from Speed-Time Graph (May/June 2008 P2 Q9)

Question: A car with mass 800 kg travels at 25 m/s. From the speed-time graph: for 0–1s the speed is constant at 25 m/s (thinking time). From 1s to 5s the car decelerates uniformly to rest. Determine: (i) thinking distance, (ii) braking distance, (iii) deceleration during braking, (iv) braking force.

Solution:

(i) Thinking Distance (0 to 1s)

During the reaction time, the driver does not brake. The car continues at constant speed.

$$\text{distance} = \text{speed} \times \text{time} = 25 \times 1.0 = 25 \text{ m}$$

(ii) Braking Distance (1s to 5s)

The car decelerates uniformly from 25 m/s to 0 m/s over 4 seconds. On a speed-time graph, distance = area under the curve (trapezoid).

$$\text{distance} = (\text{initial speed} + \text{final speed}) \div 2 \times \text{time}$$
$$\text{distance} = (25 + 0) \div 2 \times 4.0 = 12.5 \times 4 = 50 \text{ m}$$

(iii) Deceleration During Braking

Using the equation $v = u + at$, where $v = 0$, $u = 25$ m/s, $t = 4.0$s:

$$a = (v - u) \div t = (0 - 25) \div 4.0 = -6.25 \text{ m/s}^2$$
$$\text{Deceleration} = 6.25 \text{ m/s}^2 \text{ (or } 6.3 \text{ m/s}^2 \text{ to 2 s.f.)}$$

(iv) Braking Force

Using $F = ma$:

$$F = 800 \times 6.25 = 5000 \text{ N}$$

(i) 25 m | (ii) 50 m | (iii) 6.25 m/s² | (iv) 5000 N (or 5.0 kN)

2 Loaded Car Braking (May/June 2010 P21 Q9)

Question: A car of mass 900 kg travels at 20 m/s. At t = 0, the driver sees an accident. The driver applies brakes at t = 0.60s. The car comes to rest 4.0s after the brakes are applied. Calculate: (i) deceleration while braking, (ii) braking force.

Solution:

(i) Deceleration

Initial speed when brakes applied: 20 m/s; Final speed: 0 m/s; Time under braking: 4.0s

$$a = (v - u) \div t = (0 - 20) \div 4.0 = -5.0 \text{ m/s}^2$$
$$\text{Deceleration} = 5.0 \text{ m/s}^2$$

(ii) Braking Force

Using F = ma with m = 900 kg:

$$F = 900 \times 5.0 = 4500 \text{ N (or 4.5 kN)}$$

Note: The greater the mass, the greater the braking force needed to achieve the same deceleration. This explains why heavier vehicles need more powerful brakes.

(i) 5.0 m/s² | (ii) 4500 N

3 Emergency Stop: Child in Road (Oct/Nov 2002 P2 Q1)

Question: A car travels at 18 m/s. At t = 0, the driver sees a child. The driver reacts at t = 0.6s and applies brakes, taking a further 3.0s to stop completely. Calculate the thinking distance.

Solution:

Thinking Distance (first 0.6s)

During the reaction time, the car travels at constant speed with no braking.

$$\text{distance} = \text{speed} \times \text{time} = 18 \times 0.6 = 10.8 \text{ m}$$

Explanation: This is the "thinking distance"—the distance travelled during the driver's reaction time before braking starts. It depends on both the speed of the car and the driver's reaction time (typically 0.5–1.0 seconds for normal conditions).

Thinking distance = 10.8 m (or 11 m to 2 s.f.)

4 Venus Orbiting the Sun (Oct/Nov 2010 P21 Q2)

Question: Venus orbits the Sun in a circular orbit at constant speed. The gravitational force acts on Venus, providing acceleration of 9.7×10^{-3} m/s². The mass of Venus is 4.9×10^{24} kg. Calculate the size of the force acting on Venus.

Solution:

Gravitational Force on Venus

Even though Venus moves at constant speed in a circular orbit, it is still accelerating because its direction changes continuously. This centripetal acceleration is directed toward the Sun. Using F = ma:

$$F = ma$$
$$F = 4.9 \times 10^{24} \times 9.7 \times 10^{-3}$$
$$F = 4.9 \times 9.7 \times 10^{24-3}$$
$$F = 47.53 \times 10^{21}$$
$$F = 4.75 \times 10^{22}\ \text{N}$$

Physics Note: This is the gravitational force exerted by the Sun on Venus, keeping it in its circular orbit. No work is done by this force because the force is always perpendicular to the velocity.

Force = 4.75×10^{22} N (or 4.8×10^{22} N to 2 s.f.)

Worksheet 2 — Forces on Moving Objects

5 Car with Forward and Resistance Forces (May/June 2012 P22 Q2)

Question: A car travels on a horizontal road with forward force A and resistance force B (air resistance & friction). The car has mass 800 kg. Force A increases to 5000 N, causing initial acceleration of 1.5 m/s². Calculate the size of force B (resistance).

Solution:

Finding Resistance Force B

The net force (resultant) is the difference between driving force and resistance. Using $F_{net} = ma$:

$$F_{net} = ma = 800 \times 1.5 = 1200\ \text{N}$$

The net force equals driving force minus resistance:

$$F_{net} = A - B$$
$$1200 = 5000 - B$$
$$B = 5000 - 1200 = 3800\ \text{N}$$

Physics Insight: As the car accelerates and speed increases, air resistance increases (proportional to speed or speed squared). This is why, even with constant driving force, the acceleration eventually decreases and the car reaches a maximum speed when all the driving force is used to overcome resistance.

`Force B (resistance) = 3800 N`

6 Accelerating Lorry (May/June 2014 P22 Q1)

Question: A lorry accelerates along a horizontal road. Its weight is 300,000 N (with g = 10 N/kg). Resultant force on the lorry is 15,000 N. Calculate: (i) mass of lorry, (ii) acceleration of lorry.

Solution:

(i) Mass of Lorry

Weight $W = mg$, so mass $m = W \div g$:

$$m = 300{,}000 \div 10 = 30{,}000 \text{ kg (or 30 tonnes)}$$

(ii) Acceleration of Lorry

Using the resultant force and mass in $F = ma$:

$$a = F \div m = 15{,}000 \div 30{,}000 = 0.5 \text{ m/s}^2$$

Key Point: Even though 15,000 N is a large force, the enormous mass of the lorry (30 tonnes) means the acceleration is quite modest (0.5 m/s²). Heavy vehicles need substantial driving forces to produce noticeable acceleration.

(i) 30,000 kg | (ii) 0.5 m/s²

7 Racing Car: Force Analysis (May/June 2017 P21 Q1)

Question: A racing car travels horizontally with four forces acting: Force A = 8000 N (driving), Force B = 1000 N (normal reaction), Force C = 8000 N (air resistance & friction), Force D = 600 N (gravity/weight), g = 10 N/kg. Calculate: (i) mass, (ii) resultant force, (iii) acceleration. Then: at another time, car accelerates at 1.6 m/s² for 5.0s and reaches 20 m/s. Find initial speed u.

Solution:

(i) Mass of Racing Car

The weight (force D) is the gravitational force on the car. W = mg:

$$m = D \div g = 600 \div 10 = 60 \text{ kg}$$

Note: This is a very light racing car (60 kg), typical of a high-performance formula car.

(ii) Resultant Force

Horizontally, only forces A (driving) and C (resistance) matter. Forces B and D are vertical (normal and weight, and they balance each other).

$$F_{resultant} = A - C = 8000 - 8000 = 0 \text{ N}$$

Interpretation: The driving force exactly equals the resistance force, so the net horizontal force is zero. The car is in equilibrium horizontally (constant velocity motion).

(iii) Acceleration

With zero resultant force:

$$a = F \div m = 0 \div 60 = 0 \text{ m/s}^2$$

(c) Initial Speed u

At another time, the car accelerates. Using v = u + at with v = 20 m/s, a = 1.6 m/s², t = 5.0s:

$$\begin{gathered} v = u + at \\ 20 = u + (1.6 \times 5.0) \\ 20 = u + 8.0 \\ u = 12 \text{ m/s} \end{gathered}$$

(i) 60 kg | (ii) 0 N | (iii) 0 m/s² | (c) u = 12 m/s

8 Box with Friction Force (May/June 2018 P21 Q2)

Question: A man pushes a box with force P = 100 N. Friction force F = 85 N opposes the motion horizontally. The box has mass 25 kg. When forces are unbalanced, calculate the acceleration.

Solution:

Acceleration of Box

The net force is the pushing force minus the friction force:

$$F_{net} = P - F = 100 - 85 = 15 \text{ N}$$

Using F = ma:

$$a = F_{net} \div m = 15 \div 25 = 0.6 \text{ m/s}^2$$

Physics Insight: The box accelerates slowly because most of the pushing force (85 out of 100 N) goes into overcoming friction. Only the small net force (15 N) is available to accelerate the box. If we wanted faster acceleration, we would need to reduce friction (e.g., by lubricating) or push harder.

$\boxed{\text{Acceleration} = 0.6 \text{ m/s}^2}$

9 Aeroplane Takeoff (Oct/Nov 2008 P2 Q4)

Question: A passenger aeroplane accelerates uniformly from rest along a runway. After 35 seconds, it reaches 84 m/s and takes off. Calculate the acceleration along the runway.

Solution:

Acceleration of Aeroplane

Initial velocity u = 0 (from rest); Final velocity v = 84 m/s; Time t = 35s. Using v = u + at:

$$a = (v - u) \div t = (84 - 0) \div 35 = 2.4 \text{ m/s}^2$$

Context: This modest acceleration (about 1/4 of gravitational acceleration) is typical for large aircraft, which must accelerate gradually to reach sufficient speed for takeoff while staying on the runway. The distance covered during acceleration is $s = \frac{1}{2}at^2 = \frac{1}{2} \times 2.4 \times 35^2 \approx 1470$ m, which is why airport runways are typically 2–3 km long.

$\boxed{\text{Acceleration} = 2.4 \text{ m/s}^2}$

10 Cricket Ball Impact with Bat (Oct/Nov 2010 P2 Q1)

Question: A cricket ball (mass 0.16 kg) hits a bat at 25 m/s. After contact (0.0013s), it rebounds at 22 m/s in the opposite direction. Calculate: (i) change in velocity, (ii) average acceleration, (iii) average force from bat.

Solution:

(i) Change in Velocity

Define positive direction as the initial direction of approach. The rebound is opposite, so $v = -22$ m/s (negative sign indicates reversal).

$$\Delta v = v - u = (-22) - 25 = -47 \text{ m/s}$$

Interpretation: The negative value shows a huge change in velocity direction and magnitude. The ball has reversed and lost some speed (from 25 to 22 m/s, likely due to energy loss in the collision).

(ii) Average Acceleration

Using $a = \Delta v \div t$:

$$a = -47 \div 0.0013 = -36{,}154 \text{ m/s}^2 \ (\approx -3.6 \times 10^4 \text{ m/s}^2)$$

Magnitude: 36,154 m/s² ≈ 3691 g (where g = 9.81 m/s²). This enormous acceleration occurs because the contact time is so short (1.3 milliseconds). The ball experiences extreme forces during impact.

(iii) Average Force

Using $F = ma$:

$$F = 0.16 \times (-36{,}154) = -5785 \text{ N}$$

Magnitude: 5785 N ≈ 5.8 kN (or roughly the weight of 600 kg). The negative sign shows the force is opposite to the initial motion direction (the bat pushes the ball backward).

(i) −47 m/s | (ii) −36,154 m/s² | (iii) −5785 N (magnitude: 5.8 kN)

11 Motorcycle Acceleration (Oct/Nov 2014 P21 Q1)

Question: A motorcycle (mass 180 kg) accelerates from 40 m/s to 80 m/s in the first 2.0 seconds. Calculate: (i) acceleration, (ii) resultant force.

Solution:

(i) Acceleration (0 to 2.0s)

Using $v = u + at$, with $u = 40$ m/s, $v = 80$ m/s, $t = 2.0$s:

$$a = (v - u) \div t = (80 - 40) \div 2.0 = 20 \text{ m/s}^2$$

Context: An acceleration of 20 m/s² (about 2 g) is typical for high-performance motorcycles during hard acceleration.

(ii) Resultant Force

Using $F = ma$:

$$F = 180 \times 20 = 3600 \text{ N (or 3.6 kN)}$$

Physics Note: As the motorcycle continues to accelerate beyond 2.0s, air resistance increases with speed. Eventually, the driving force matches the total resistance, and acceleration reduces. This is why the speed-time graph becomes less steep at higher speeds.

(i) 20 m/s² | (ii) 3600 N

12 Arrow from Bow (Oct/Nov 2015 P21 Q1)

Question: An arrow (mass 0.018 kg) is fired from a bow. It starts from rest and leaves the bow after 0.011s with velocity 95 m/s. Calculate: (i) average acceleration, (ii) average force from bowstring.

Solution:

(i) Average Acceleration

Initial velocity u = 0; Final velocity v = 95 m/s; Time in bow t = 0.011s. Using v = u + at:

$$a = (v - u) \div t = 95 \div 0.011 = 8636 \text{ m/s}^2 \ (\approx 8.6 \times 10^3 \text{ m/s}^2)$$

Magnitude: 8636 m/s² ≈ 881 g. This extreme acceleration (though brief) occurs because the arrow is in contact with the bowstring for only 0.011 seconds—a very short time interval.

(ii) Average Force

Using F = ma:

$$F = 0.018 \times 8636 = 155 \text{ N (to 2 s.f.: } 1.5 \times 10^2 \text{ N)}$$

Physics Context: The 155 N force from the bowstring is comparable to the weight of a 16 kg object. The very short contact time (milliseconds) and the light mass of the arrow together produce this extremely high velocity with a relatively modest force.

(i) 8636 m/s² | (ii) 155 N