GCSE ONLINE TUTORING

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OCR GCSE Physics B

Twenty First Century Science J259

CHAPTER P4

Explaining Motion

Higher Tier

Systematic lesson notebook

Teaching and worked examples, lesson practice, a chapter assessment, complete indicative answers and a knowledge organiser.

Read the explanation, try the practice independently, then use the answers to improve your reasoning and calculations.

Name _____ Class _____

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How to use this notebook

Follow the lesson sequence. Each assessed lesson includes an explanation, a worked example and practice. Keep your working and units visible. Check the numbered lesson answers after attempting the questions; equivalent correct scientific wording can receive credit.

Specification reference: Cambridge OCR J259, Version 5.0, July 2026. References identify the intended outcomes; this independent notebook does not replace the official specification.

Foundation and Higher

Higher contains shared outcomes and Higher-only requirements. Some additional questions simply increase demand within shared content; they do not imply that the entire lesson is Higher-only.

Separate Physics content belongs to J259 at both tiers unless the specification explicitly marks an outcome as Higher-only.

Working and marking

Use the maximum mark shown for each question. The answer sections are indicative classroom guidance, not official OCR mark schemes. Credit valid alternatives and avoid awarding the same idea twice. This assessment is diagnostic; no GCSE grade boundary is implied.

Numerical tariffs, example data and model situations are classroom examples, not current prices or real safety estimates.

Lesson map

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Use lesson numbers to locate the matching practice and answers. Pagination differs between editions because the assessed scope differs.

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Use lesson numbers to locate the matching practice and answers. Pagination differs between editions because the assessed scope differs.

Lesson 1 Interaction forces and Newton's third law

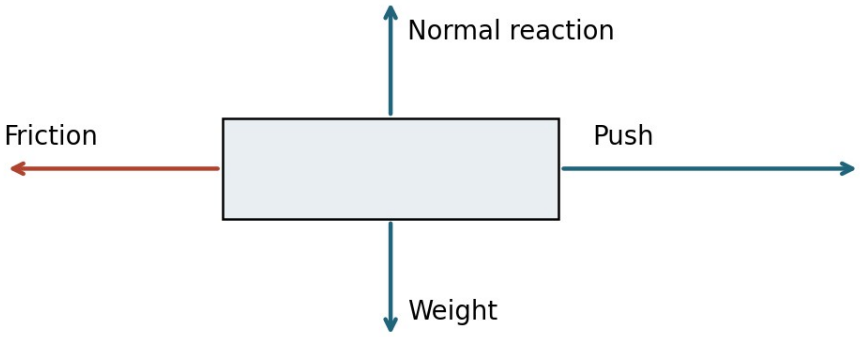
P4.1.1-4 | Higher

identify force interactions, apply Newton's third law and represent forces as vectors.

Forces arise from interactions between two objects. Newton's third law pairs are the same type of force, equal in size and opposite in direction, but act on different objects.

Contact interactions include friction and normal contact force. Non-contact interactions include gravity, electrostatics and magnetism.

Force arrows are vectors: arrow direction shows force direction and arrow length can represent magnitude.



Worked example

An ice skater pushes a wall with 40 N. The wall simultaneously pushes the skater with 40 N in the opposite direction. These forces do not cancel on the skater: one acts on the wall and one acts on the skater.

Lesson 1 practice

Interaction forces and Newton's third law

Answer independently. Show a clear method, substitutions and units for calculations.

1. State Newton's third law. [2]

2. Identify the interaction pair when a book rests on a table. [3]

3. Explain why action-reaction forces do not cancel on one object. [3]

4. Name one contact and one non-contact interaction. [2]

5. Draw force arrows for a pushed box with friction. [3]

Practice total 13 marks

Self check Write one correction you made and why it matters.

Lesson 2 Weight, mass and gravitational field strength

P4.1.5-7 | Higher

define and measure weight and calculate using W = mg.

Mass measures the amount of matter/inertia and is measured in kg. Weight is the gravitational force on an object and is measured in N.

Weight can be measured with a force/spring balance. Near Earth's surface g is about 9.8 N/kg, often estimated as 10 N/kg.

Use W = mg and keep mass in kilograms.

Worked example

A 2.0 kg object has weight 19.6 N where g = 9.8 N/kg. On a body with g = 1.6 N/kg its weight is 3.2 N, but its mass remains 2.0 kg.

Lesson 2 practice

Weight, mass and gravitational field strength

Answer independently. Show a clear method, substitutions and units for calculations.

1. Define weight. [2]

2. Calculate weight of a 6.0 kg object using g=9.8 N/kg. [2]

3. Explain difference between mass and weight. [3]

4. How is weight measured? [1]

5. A 490 N person stands on Earth. Calculate mass using g=9.8. [3]

Practice total 11 marks

Self check Write one correction you made and why it matters.

Lesson 3 Average speed, typical speeds and unit conversion

P4.2.1-4 | Higher

calculate average speed, recall typical speeds and convert between m/s and km/h.

Average speed = distance / time. It describes total distance over total time and does not necessarily equal the speed at every instant.

Typical speeds provide useful estimates: walking is a few m/s, cars are tens of m/s, sound in air is hundreds of m/s.

Convert m/s to km/h by multiplying by 3.6; convert km/h to m/s by dividing by 3.6.

Worked example

A cyclist travels 600 m in 40 s. Average speed = 600/40 = 15 m/s = 15 × 3.6 = 54 km/h. This does not establish the speed at every moment.

Lesson 3 practice

Average speed, typical speeds and unit conversion

Answer independently. Show a clear method, substitutions and units for calculations.

1. Calculate speed for 150 m in 20 s. [2]

2. Convert 72 km/h to m/s. [2]

3. Convert 12 m/s to km/h. [2]

4. Explain why average speed may differ from instantaneous speed. [2]

5. Give a reasonable estimate for walking speed. [1]

Practice total 9 marks

Self check Write one correction you made and why it matters.

Lesson 4 PAG3 investigating trolley speed

P4.2.3 | Higher

describe suitable apparatus and techniques to measure the speed of a trolley down a ramp.

Measure a known distance and the time taken, or use light gates/data logging for more precise timing.

Repeat readings, control ramp angle and release position, and avoid giving the trolley an extra push.

A suitable practical conclusion is supported by calculated speeds and an evaluation of timing uncertainty.

Worked example

A 0.050 m card blocks a light gate for 0.020 s. Speed ≈ 0.050/0.020 = 2.5 m/s. This is an average over the short card passage and approximates the speed at the gate.

Lesson 4 practice

PAG3: investigating trolley speed

Answer independently. Show a clear method, substitutions and units for calculations.

1. Describe apparatus to measure trolley speed down a ramp. [4]

2. State two control variables. [2]

3. Why should the release method be consistent? [2]

4. Explain one advantage of light gates over a stopwatch. [2]

5. Suggest one repeat/mean strategy. [2]

Practice total 12 marks

Self check Write one correction you made and why it matters.

Lesson 5 Scalars and vectors distance, displacement, speed and velocity

P4.2.5 | Higher

distinguish scalar quantities from vector quantities in motion.

Distance and speed are scalars: magnitude only. Displacement and velocity are vectors: magnitude and direction.

A runner can travel a non-zero distance but have zero displacement if they finish where they started.

Velocity changes if either speed or direction changes.

Worked example

A student walks 3 m east then 3 m west. Distance = 6 m, displacement = 0 m. Over 6 s, average speed = 1 m/s but average velocity = 0 m/s.

Lesson 5 practice

Scalars and vectors: distance, displacement, speed and velocity

Answer independently. Show a clear method, substitutions and units for calculations.

1. Classify distance, displacement, speed and velocity as scalar/vector. [4]

2. A runner completes one 400 m lap. State distance and displacement. [2]

3. Explain how velocity can change while speed is constant. [3]

4. Give one vector quantity with units. [1]

5. Explain why displacement needs direction. [2]

Practice total 12 marks

Self check Write one correction you made and why it matters.

Lesson 6 Acceleration and PAG3 acceleration methods

P4.2.6 | Higher

calculate acceleration and describe how to investigate it.

Acceleration = change in speed / time. Positive acceleration usually means increasing speed in the chosen direction; negative acceleration indicates decreasing velocity in that convention.

Light gates can measure speeds at different points; acceleration can then be calculated from the speed change and time interval.

State units as m/s^2.

Worked example

A trolley increases speed from 1.0 to 2.5 m/s in 0.75 s along a straight track. $a = (2.5 - 1.0)/0.75 = 2.0\ m/s^2$. Define the positive direction along the track before using signs.

Lesson 6 practice

Acceleration and PAG3 acceleration methods

Answer independently. Show a clear method, substitutions and units for calculations.

1. Calculate acceleration from 4 to 16 m/s in 6 s. [2]

2. State the unit of acceleration. [1]

3. Describe a light-gate method for acceleration. [4]

4. A car slows from 20 to 5 m/s in 3 s. Calculate acceleration. [3]

5. Explain what negative acceleration means in a chosen direction. [2]

Practice total 12 marks

Self check Write one correction you made and why it matters.

Lesson 7 Constant-acceleration modelling $v^2 - u^2 = 2as$

P4.2.7 | Higher

select and apply the constant-acceleration relationship.

Use $v^2 - u^2 = 2as$ when time is not given but initial speed, final speed, acceleration and distance are involved.

This equation assumes constant acceleration along a straight line.

Square speeds before subtracting and keep direction/sign conventions consistent.

Worked example

A trolley starts at 2.0 m/s and accelerates at 1.5 m/s² over 4.0 m. $v^2 = 2.0^2 + 2 \times 1.5 \times 4.0 = 16$, so $v = 4.0$ m/s. The positive root is appropriate for this stated continuing direction.

Lesson 7 practice

Constant-acceleration modelling: $v^2 - u^2 = 2as$

Answer independently. Show a clear method, substitutions and units for calculations.

1. A car starts at 5 m/s and accelerates at 2 m/s² over 24 m. Calculate final speed. [4]

2. State one condition for using $v^2-u^2=2as$. [1]

3. Rearrange the equation to make a the subject. [2]

4. Explain why speed values must be squared before subtraction. [2]

5. A ball slows from 10 to 4 m/s over 21 m. Calculate acceleration. [4]

Practice total 13 marks

Self check Write one correction you made and why it matters.

Lesson 8 Distance-time and speed/velocity-time graphs

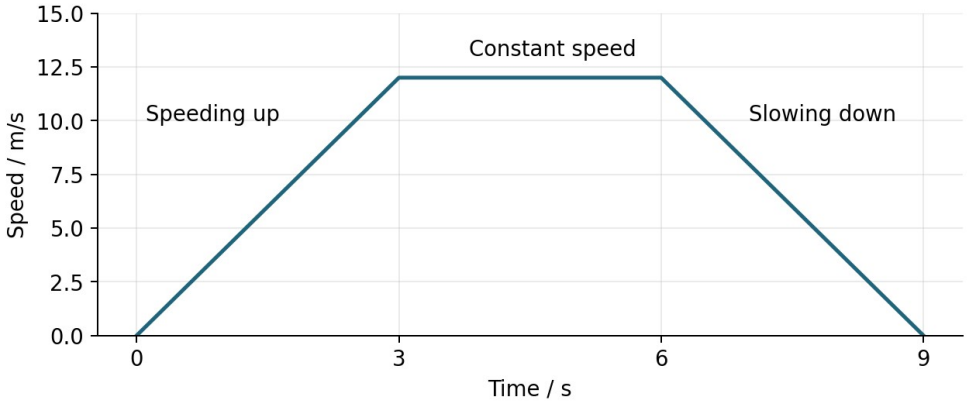
P4.2.8-9 | Higher

draw and interpret motion graphs and use slope to determine speed or acceleration.

The slope of a distance-time graph gives speed. A steeper line means a greater speed; a horizontal line means stationary.

The slope of a velocity/speed-time graph gives acceleration. A horizontal line means constant speed.

OCR examiner feedback has noted that 'accelerating' is not enough when the graph shows constant acceleration: describe the slope precisely.



Worked example

Distance increases from 10 m to 34 m between 2 s and 8 s on a straight graph section. Gradient = (34 − 10)/(8 − 2) = 4.0 m/s. A horizontal distance-time section would indicate zero speed.

Lesson 8 practice

Distance-time and speed/velocity-time graphs

Answer independently. Show a clear method, substitutions and units for calculations.

1. What does slope of a distance-time graph represent? [1]

2. Describe a horizontal section on a distance-time graph. [1]

3. What does slope of a speed-time graph represent? [1]

4. Explain difference between 'accelerating' and 'constant acceleration' on a straight sloping speed-time graph. [2]

5. Sketch a speed-time graph for accelerate, constant speed, decelerate. [3]

Practice total 8 marks

Self check Write one correction you made and why it matters.

Lesson 9 Area under velocity-time graphs and free fall

P4.2.10-11 | Higher

interpret velocity-time graph area and recall free-fall acceleration.

The area under a velocity-time graph represents displacement. OCR marks this P4.2.10 outcome as Higher-only.

Near Earth's surface the acceleration of a freely falling object is approximately 9.8 m/s² (often 10 m/s² for estimates), neglecting air resistance.

Everyday acceleration estimates should be physically reasonable and include correct units.

Worked example

A ball is released from rest. With air resistance neglected, after 0.50 s v = 9.8 × 0.50 = 4.9 m/s downwards. Its weight is still acting while it falls; free fall does not mean zero force.

Lesson 9 practice

Area under velocity-time graphs and free fall

Answer independently. Show a clear method, substitutions and units for calculations.

1. State approximate free-fall acceleration near Earth. [1]

2. Estimate speed gained after 2 s of free fall from rest, neglecting air resistance. [2]

3. State what area under a velocity-time graph represents. [1]

4. A car moves at 10 m/s for 5 s. Find area under graph. [2]

5. Explain why air resistance makes real free-fall acceleration change. [3]

6. A car accelerates uniformly from 4 to 16 m/s in 6 s. Use graph area to calculate displacement. [4]

Practice total 13 marks

Self check Write one correction you made and why it matters.

Lesson 10 Free-body diagrams, resultants and equilibrium

P4.3.1-2 | Higher

identify forces, draw free-body diagrams and explain balanced/resultant forces.

A free-body diagram shows the forces acting on one selected object, not forces that object exerts on other objects.

The resultant force is the vector sum of the forces. Balanced forces mean resultant force is zero.

Zero resultant force means no change in velocity: an object can be stationary or move at constant velocity.

Worked example

A car has 900 N forward driving force and 900 N total resistance. Resultant = 0 N, so it can continue at constant velocity. Removing the driving force would leave a backward resultant and change the velocity.

Lesson 10 practice

Free-body diagrams, resultants and equilibrium

Answer independently. Show a clear method, substitutions and units for calculations.

1. Draw forces on a stationary hanging mass. [2]

2. Explain what zero resultant force means for velocity. [2]

3. A 12 N push acts right and 5 N friction left. Find resultant. [1]

4. Explain why a moving object can have zero resultant force. [2]

5. State what a free-body diagram should include. [2]

Practice total 9 marks

Self check Write one correction you made and why it matters.

Lesson 11 Higher vector addition, momentum and impulse

P4.3.3-5 | Higher

use vector diagrams, momentum conservation and change-in-momentum calculations.

Higher tier uses scale drawings for parallel/perpendicular force vectors.

Momentum p = mv is a vector quantity. In a closed system total momentum is conserved in collisions.

Change in momentum = resultant force x time. Increasing impact time reduces average force for the same momentum change.

Worked example

A 2 kg trolley moving at 3 m/s sticks to a stationary 1 kg trolley. Initial momentum = 6 kg m/s. For the isolated pair, 3v = 6, so common final velocity = 2 m/s in the original direction.

Lesson 11 practice

Higher: vector addition, momentum and impulse

Answer independently. Show a clear method, substitutions and units for calculations.

1. A 3 kg object moves at 4 m/s. Calculate momentum. [2]

2. Two perpendicular forces 6 N and 8 N act. Calculate resultant magnitude. [3]

3. Explain conservation of momentum in a collision. [3]

4. A force of 500 N acts for 0.08 s. Calculate change in momentum. [2]

5. Explain how an airbag reduces average force. [3]

Practice total 13 marks

Self check Write one correction you made and why it matters.

Lesson 12 Newton's first law and circular motion

P4.3.6-7 | Higher

apply Newton's first law; Higher explains constant-speed circular motion as changing velocity.

If resultant force is zero, velocity remains constant. If a resultant force acts, velocity changes in magnitude and/or direction.

A force not along the direction of motion changes direction. Higher tier includes the case of a perpendicular force causing circular motion at constant speed.

Constant speed in a circle does not mean constant velocity because direction continuously changes.

Worked example

A puck slides in a straight line on an ideal frictionless horizontal surface. Weight and normal reaction balance and there is no horizontal force, so it continues at constant velocity. A force is needed to change its velocity, not to maintain it.

Lesson 12 practice

Newton's first law and circular motion

Answer independently. Show a clear method, substitutions and units for calculations.

1. State Newton's first law for zero resultant force. [2]

2. Explain why a car turning at constant speed is accelerating. [3]

3. What direction is the resultant force in uniform circular motion? [1]

4. Explain why constant speed does not imply constant velocity. [2]

5. Give one orbital example and identify the force. [2]

Practice total 10 marks

Self check Write one correction you made and why it matters.

Lesson 13 Separate Physics moments, levers and gears

P4.3.8-10 | Higher

describe rotation, calculate moments and explain levers/gears.

A moment is the turning effect of a force about a pivot.

Moment = force x perpendicular distance from pivot to line of action of force.

Levers and gears transmit rotational effects and can change force, distance moved or direction of rotation.

Worked example

A 20 N force acts perpendicular to a spanner at 0.25 m from its pivot. Moment = 20 × 0.25 = 5.0 N m. At 0.50 m, the same force would give 10 N m.

Lesson 13 practice

Separate Physics: moments, levers and gears

Answer independently. Show a clear method, substitutions and units for calculations.

1. Define moment. [2]

2. Calculate moment of 30 N acting 0.40 m from pivot. [2]

3. Explain why perpendicular distance matters. [2]

4. Describe one use of a lever. [2]

5. Explain qualitatively how gears transmit turning effects. [3]

Practice total 11 marks

Self check Write one correction you made and why it matters.

Lesson 14 Inertia, F = ma and linked force-motion equations

P4.3.11-13 | Higher

apply Newton's second law and connect force, mass, acceleration and (Higher) momentum.

Inertia is resistance to change in motion. OCR makes the formal definition of inertial mass as force/acceleration Higher-only.

For all tiers use F = ma: resultant force produces acceleration in its direction.

When combining equations, track units carefully and do not confuse force (N) with momentum (kg m/s).

Worked example

A resultant force of 18 N acts on a 6 kg object. $a = F/m = 18/6 = 3\ m/s^2$. If the same resultant acts on 12 kg, acceleration falls to 1.5 m/s^2.

Lesson 14 practice

Inertia, F = ma and linked force-motion equations

Answer independently. Show a clear method, substitutions and units for calculations.

1. Calculate force on 1200 kg car accelerating at 2.5 m/s². [2]

2. Calculate acceleration from 600 N on 200 kg. [2]

3. Explain how greater mass affects acceleration for same force. [2]

4. State the unit of force. [1]

5. Explain why momentum and force should not be confused. [2]

6. Explain inertial mass as F/a and calculate inertial mass for 240 N causing 3.0 m/s². [3]

Practice total 12 marks

Self check Write one correction you made and why it matters.

Lesson 15 Reaction time investigations

P4.3.14 | Higher

explain how reaction times can be measured and recall typical human response scales.

Reaction time can be measured with ruler-drop tests, electronic timers or computer tasks.

Repeat measurements and calculate a mean because reaction time varies naturally.

Control factors such as distraction, fatigue, caffeine and expectation if investigating their effects.

Worked example

A participant catches a falling ruler after 0.20 m. Under the free-fall model, $t = \sqrt{(2s/g)} = \sqrt{(0.40/9.8)} \approx 0.20$ s. Use consistent finger position and repeat; ruler distance is not itself a time.

Lesson 15 practice

Reaction time investigations

Answer independently. Show a clear method, substitutions and units for calculations.

1. Describe a ruler-drop reaction-time method. [4]

2. Why should trials be repeated? [2]

3. Give two factors that can affect reaction time. [2]

4. Explain how a teacher-approved reaction-time investigation comparing quiet and distracting conditions can be made fair. [3]

5. State a typical order of magnitude for human reaction time. [1]

Practice total 12 marks

Self check Write one correction you made and why it matters.

Lesson 16 Stopping distance, braking and large decelerations

P4.3.15-16 | Higher

explain factors affecting stopping distance and dangers of large deceleration.

Stopping distance = thinking distance + braking distance.

Thinking distance increases with speed and longer reaction time. Braking distance increases with speed and can increase with poor tyres, brakes, road conditions or greater load.

Large decelerations can cause injury because large forces act on occupants. OCR makes estimating those forces in typical public-road situations Higher-only.

Worked example

At 20 m/s with reaction time 0.70 s, thinking distance = vt = 14 m. Doubling reaction time to 1.4 s increases it to 28 m even if braking performance is unchanged.

Lesson 16 practice

Stopping distance, braking and large decelerations

Answer independently. Show a clear method, substitutions and units for calculations.

1. Define stopping distance. [1]

2. State three factors increasing thinking distance. [3]

3. State three factors increasing braking distance. [3]

4. Explain why higher speed increases stopping risk. [3]

5. Explain why large deceleration can injure occupants. [2]

6. Estimate force on a 70 kg passenger decelerating at 12 m/s². [2]

Practice total 14 marks

Self check Write one correction you made and why it matters.

Lesson 17 Separate Physics stopping estimates and crash-force calculations

P4.3.17-18 | Higher

use suitable data to estimate stopping distances, accelerations and forces in road situations.

Separate Physics requires numerical estimates of stopping distance over typical speeds.

Use changes in speed and time to estimate acceleration/deceleration, then F = ma for resultant force.

State assumptions clearly: constant deceleration, estimated reaction time and representative vehicle mass.

Worked example

A car slows uniformly from 18 m/s to rest in 3.0 s. a = (0 − 18)/3.0 = −6.0 m/s². For mass 1000 kg, average resultant force is −6000 N, opposite the motion.

Lesson 17 practice

Separate Physics: stopping estimates and crash-force calculations

Answer independently. Show a clear method, substitutions and units for calculations.

1. A car slows from 20 m/s to rest in 4 s. Calculate acceleration. [2]

2. A 1200 kg car has acceleration -5 m/s². Calculate resultant force magnitude. [2]

3. A driver reaction time is 0.8 s at 25 m/s. Estimate thinking distance. [2]

4. Explain one assumption in a stopping-distance estimate. [2]

5. Explain how crumple zones reduce injury using time/force ideas. [3]

Practice total 11 marks

Self check Write one correction you made and why it matters.

Lesson 18 Work done and mechanical energy transfer

P4.4.1-2 | Higher

describe energy transfers when forces move objects and calculate W = Fs.

When a force moves an object along its line of action, work is done and energy is transferred.

Work done = force x distance along the line of action. 1 N m = 1 J.

Lifting increases gravitational potential energy; accelerating increases kinetic energy; friction dissipates energy thermally.

Worked example

A force of 40 N moves a box 2.5 m along the force direction. W = Fs = 40 × 2.5 = 100 J. If the force is not parallel, using the whole force in this simple expression would overestimate the work.

Lesson 18 practice

Work done and mechanical energy transfer

Answer independently. Show a clear method, substitutions and units for calculations.

1. Calculate work done by 50 N over 3 m. [2]

2. State relation between N m and J. [1]

3. Explain energy transfer when lifting a box. [3]

4. A friction force of 200 N acts over 5 m. Calculate energy dissipated. [2]

5. Explain when W=Fs applies. [2]

Practice total 10 marks

Self check Write one correction you made and why it matters.

Lesson 19 Kinetic energy, GPE and multi-stage mechanical calculations

P4.4.3-6 | Higher

calculate KE, GPE and linked energy transfers.

Kinetic energy = 1/2 mv^2. Because speed is squared, doubling speed quadruples kinetic energy.

Gravitational potential energy = mgh.

Mechanical problems may combine work, KE and GPE. In idealised systems with negligible dissipation, energy transfers can be equated.

Worked example

A 2 kg ball is raised 3 m (g = 9.8 N/kg). $\Delta Ep = 2 \times 9.8 \times 3 = 58.8$ J. If it falls without losses, Ek gains 58.8 J; $\frac{1}{2} \times 2 \times v^2 = 58.8$ gives $v \approx 7.7$ m/s.

Lesson 19 practice

Kinetic energy, GPE and multi-stage mechanical calculations

Answer independently. Show a clear method, substitutions and units for calculations.

1. Calculate KE of 4 kg at 6 m/s. [3]

2. Calculate GPE gained by 3 kg lifted 5 m using g=9.8. [3]

3. Explain why doubling speed quadruples KE. [2]

4. An object loses 196 J GPE with no losses. State KE gain. [1]

5. A motor does 500 J work but KE rises 420 J. Explain difference. [2]

Practice total 11 marks

Self check Write one correction you made and why it matters.

Lesson 20 Energy-store changes and power

P4.4.7-9 | Higher

describe complete energy-store changes and calculate power.

Common situations include projectiles, motion up slopes, impacts, acceleration by constant force and vehicles slowing down.

Power is the rate of energy transfer or work done: P = E/t.

A more powerful machine transfers the same energy in less time, or more energy in the same time.

Worked example

Two motors each lift a load by 2400 J of gravitational potential energy. Motor A takes 8 s, so useful power = 300 W. Motor B takes 12 s, so useful power = 200 W. Both do the same useful work but at different rates.

Lesson 20 practice

Energy-store changes and power

Answer independently. Show a clear method, substitutions and units for calculations.

1. Describe energy changes for a ball thrown upward. [3]

2. Describe energy changes when a car brakes. [3]

3. Calculate power for 600 J transferred in 20 s. [2]

4. A 1.2 kW motor transfers 7200 J. Calculate time. [3]

5. Explain what higher power means for the same energy transfer. [2]

Practice total 13 marks

Self check Write one correction you made and why it matters.

End of chapter assessment

Higher | Total 58 marks across all assessment parts

Answer every question. Use additional paper for diagrams or longer explanations when needed.

1. Apply Newton's third law to a person standing on the floor. [3]

2. Calculate weight of a 72 kg person using g = 9.8 N/kg. [2]

3. Convert 90 km/h to m/s. [2]

4. Describe a PAG3 method to investigate trolley acceleration. [5]

5. A car accelerates from 4 to 16 m/s in 6 s. Calculate acceleration. [2]

End of chapter assessment continued

Higher | Total 58 marks across all assessment parts

Answer every question. Use additional paper for diagrams or longer explanations when needed.

6. A vehicle accelerates from 5 m/s to 17 m/s over 44 m. Calculate acceleration using $v^2-u^2=2as$. [4]

7. Interpret a velocity-time graph: explain slope and area. [4]

8. Use a scale vector diagram for two perpendicular forces of 6 N and 8 N; state resultant magnitude. [4]

9. A 1200 kg car at 18 m/s collides and stops in 0.15 s. Calculate momentum change and average force. [5]

10. Explain constant-speed circular motion in terms of force and velocity. [3]

End of chapter assessment continued

Higher | Total 58 marks across all assessment parts

Answer every question. Use additional paper for diagrams or longer explanations when needed.

11. Calculate moment of 45 N applied 0.35 m from a pivot. [2]

12. Explain inertial mass and calculate it for 300 N causing 2.5 m/s². [3]

13. Explain factors affecting stopping distance and estimate force on a 70 kg passenger decelerating at 10 m/s². [5]

14. A car slows from 25 m/s to rest in 5 s. Calculate deceleration and resultant force for a 1400 kg car. [4]

15. Calculate work done by 500 N over 12 m. [2]

End of chapter assessment continued

Higher | Total 58 marks across all assessment parts

Answer every question. Use additional paper for diagrams or longer explanations when needed.

16. Calculate KE of 1000 kg car at 20 m/s. [3]

17. Calculate GPE gained by 20 kg raised 8 m using g=9.8. [3]

18. A motor transfers 12 kJ in 15 s. Calculate power. [2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 1 Interaction forces and Newton's third law

1. When two objects interact, they exert equal-magnitude, opposite-direction forces on each other. The forces are of the same type and act on different objects. [maximum 2]

2. The table pushes upwards on the book; the book pushes downwards on the table. These equal, opposite contact forces act on different objects. The book's weight is not the partner of the table's upward contact force. [maximum 3]

3. Each force in the interaction pair acts on a different object. A resultant for one object adds only forces acting on that object; it does not add the force that object exerts on another. [maximum 3]

4. Contact: friction/contact push. Non-contact: gravity, magnetic or electrostatic interaction. [maximum 2]

5. On the box draw weight down and normal reaction up, a push in the chosen direction and friction opposite the motion. Label each arrow and show relative lengths if magnitudes are known. [maximum 3]

Lesson 2 Weight, mass and gravitational field strength

1. The gravitational force acting on an object; W = mg. [maximum 2]

2. W = mg = 6.0 × 9.8 = 58.8 N (about 59 N). [maximum 2]

3. Mass measures the amount of matter/inertia and is in kg. Weight is gravitational force in N. Mass is unchanged by location while weight changes with gravitational field strength. [maximum 3]

4. Using a calibrated force meter/newton meter. [maximum 1]

5. m = W/g = 490/9.8 = 50 kg. [maximum 3]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 3 Average speed, typical speeds and unit conversion

1. v = s/t = 150/20 = 7.5 m/s. [maximum 2]

2. 72/3.6 = 20 m/s. [maximum 2]

3. 12 × 3.6 = 43.2 km/h. [maximum 2]

4. Average speed is total distance divided by total time. Instantaneous speed describes one moment, so varying speed makes them differ. [maximum 2]

5. About 1.5 m/s; accept a reasonable walking estimate around 1–2 m/s. [maximum 1]

Lesson 4 PAG3 investigating trolley speed

1. Use a trolley on a stable ramp with a stop, a card of measured length and a light gate/data logger. Measure the time the card blocks the beam. Speed near the gate ≈ card length/blocking time; repeat from a marked release point. [maximum 4]

2. Any two suited to the investigation: trolley mass, release position, card length, gate position, ramp surface/slope when it is not varied. [maximum 2]

3. A push or different starting position changes the trolley's initial conditions and hence measured speed. A consistent release makes trials comparable. [maximum 2]

4. Automatic triggering reduces human reaction-time error and permits a short timed interval near the gate. [maximum 2]

5. Repeat each complete run at the same setting, investigate anomalies and calculate a mean of valid readings. Repeat for each changed setting. [maximum 2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 5 Scalars and vectors distance, displacement, speed and velocity

1. Distance and speed are scalars; displacement and velocity are vectors. [maximum 4]

2. Distance 400 m; displacement 0 m because the runner returns to the starting point. [maximum 2]

3. Velocity includes direction as well as speed. For example, moving at 2 m/s east and later at 2 m/s west gives equal speed but different velocity. [maximum 3]

4. Examples: force in N, velocity in m/s, displacement in m or acceleration in m/s². [maximum 1]

5. Displacement specifies the change from starting to finishing position, so both straight-line distance and direction are needed. [maximum 2]

Lesson 6 Acceleration and PAG3 acceleration methods

1. $a = (v - u)/t = (16 - 4)/6 = 2.0$ m/s². [maximum 2]

2. m/s². [maximum 1]

3. Measure speed at two light gates using a known card length and blocking times. Record the elapsed time between the centres of those measurements. Calculate $a = (v - u)/\Delta t$ and repeat consistent runs. [maximum 4]

4. $a = (5 - 20)/3 = -5.0$ m/s². [maximum 3]

5. Acceleration is in the direction chosen negative. It means slowing only when velocity is in the positive direction; a negative-moving object could instead be speeding up. [maximum 2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 7 Constant-acceleration modelling $v^2 - u^2 = 2as$

1. $v^2 = u^2 + 2as = 5^2 + 2 \times 2 \times 24 = 121$. $v = \sqrt{121} = 11$ m/s. Include rearrangement, substitution, square root and unit. [maximum 4]

2. Acceleration must be constant over the displacement. [maximum 1]

3. $a = (v^2 - u^2)/(2s)$. [maximum 2]

4. The relationship uses the difference of the squared speeds. $v^2 - u^2$ is generally not equal to $(v - u)^2$; squaring after subtraction would change the equation. [maximum 2]

5. $a = (4^2 - 10^2)/(2 \times 21) = -84/42 = -2.0$ m/s^2, taking the motion direction as positive. [maximum 4]

Lesson 8 Distance-time and speed/velocity-time graphs

1. Speed. [maximum 1]

2. The distance is unchanged, so the object is stationary. [maximum 1]

3. Rate of change of speed; for straight-line motion in a fixed direction this is acceleration. [maximum 1]

4. A non-zero slope shows speed changing. A straight sloping section has a constant slope, so the rate of change is constant, rather than merely non-zero. [maximum 2]

5. Draw labelled axes, time horizontally and speed vertically. Use an upward-sloping section, a horizontal section, then a downward-sloping section. Join them at matching speeds. [maximum 3]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 9 Area under velocity-time graphs and free fall

1. Approximately 9.8 m/s² downwards near Earth, neglecting air resistance. [maximum 1]

2. $v = u + at = 0 + 9.8 \times 2 = 19.6$ m/s downwards. [maximum 2]

3. Displacement (signed area); for a speed-time graph, area is distance travelled. [maximum 1]

4. Area = $10 \times 5 = 50$ m. [maximum 2]

5. As falling speed rises, air resistance increases. Resultant downward force and downward acceleration decrease; at terminal speed drag balances weight and acceleration is zero. [maximum 3]

6. Displacement = trapezium area = $\frac{1}{2}(4 + 16) \times 6 = 60$ m. [maximum 4]

Lesson 10 Free-body diagrams, resultants and equilibrium

1. Draw weight downwards and tension upwards, equal in length for equilibrium. Both forces act on the hanging mass. [maximum 2]

2. Velocity is constant: the object is either stationary or moving with unchanged speed and direction. [maximum 2]

3. $12 - 5 = 7$ N to the right. [maximum 1]

4. Zero resultant means no acceleration, not necessarily no motion. The forces can balance while velocity remains non-zero and constant. [maximum 2]

5. Include all external forces acting on the chosen object only, labelled with directions. Use relative arrow sizes if magnitudes are known. [maximum 2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 11 Higher vector addition, momentum and impulse

1. $p = mv = 3 \times 4 = 12$ kg m/s in the direction of motion. [maximum 2]

2. $F = \sqrt{(6^2 + 8^2)} = \sqrt{100} = 10$ N. A scale diagram gives the same magnitude. [maximum 3]

3. In an isolated system with no resultant external force, total momentum before equals total momentum after. Use signs/directions consistently and include both colliding objects. [maximum 3]

4. $\Delta p = F\Delta t = 500 \times 0.08 = 40$ kg m/s in the force direction. [maximum 2]

5. For the same momentum change, an airbag increases stopping time. $F_{average} = \Delta p/\Delta t$ is reduced, lowering injury risk; it also spreads contact force over a larger area. [maximum 3]

Lesson 12 Newton's first law and circular motion

1. With zero resultant force an object stays at rest or continues at constant velocity. [maximum 2]

2. Velocity includes direction. Turning continually changes direction even if speed is constant, so velocity changes and there is acceleration. [maximum 3]

3. Towards the centre of the circle. [maximum 1]

4. Speed is only magnitude; velocity also includes direction. Direction can change without the speed changing. [maximum 2]

5. A satellite orbiting Earth; gravity provides the inward force. [maximum 2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 13 Separate Physics moments, levers and gears

1. The turning effect of a force about a pivot; moment = force × perpendicular distance from pivot to force's line of action. [maximum 2]

2. M = 30 × 0.40 = 12 N m. [maximum 2]

3. Only the perpendicular distance from pivot to line of action sets the lever arm. A force whose line passes through the pivot produces no moment about it. [maximum 2]

4. Example: a long spanner gives a larger perpendicular lever arm, so the same force produces a greater moment when loosening a nut. [maximum 2]

5. Interlocking teeth transmit a force from one gear to another, creating moments. Meshing gears turn oppositely; a larger driven gear gives greater output torque but lower turning speed in an ideal system. [maximum 3]

Lesson 14 Inertia, F = ma and linked force-motion equations

1. F = ma = 1200 × 2.5 = 3000 N. [maximum 2]

2. a = F/m = 600/200 = 3.0 m/s^2. [maximum 2]

3. a = F/m: greater mass gives smaller acceleration for the same resultant force. [maximum 2]

4. The newton, N. [maximum 1]

5. Momentum is mv, measured in kg m/s. Force is the rate of change of momentum, measured in N; it is not itself a momentum store. [maximum 2]

6. Inertial mass measures resistance to acceleration and equals resultant F/a. m = 240/3.0 = 80 kg. [maximum 3]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 15 Reaction time investigations

1. Hold a ruler vertically with zero level with the participant's open finger/thumb reference point. Release without warning and without pushing. Catch it, record the fall distance, and use a suitable calibrated reaction-time scale/table (or $t = \sqrt{(2s/g)}$). Repeat consistent trials. [maximum 4]

2. Reaction times vary randomly between trials. Repeats show the variation and allow a more representative mean. [maximum 2]

3. Any two: tiredness, distraction, alcohol/drugs, alertness or practice. [maximum 2]

4. Use the same participant or comparable groups, consistent release/measurement method, and matched quiet/distraction conditions. Repeat trials, vary order to reduce practice effects and obtain consent. [maximum 3]

5. Of order tenths of a second, for example about 0.2 s. [maximum 1]

Lesson 16 Stopping distance, braking and large decelerations

1. Thinking distance + braking distance. [maximum 1]

2. Higher speed, longer reaction time from tiredness, and distraction (also accept alcohol/drugs). Each must be linked to longer travel before braking. [maximum 3]

3. Higher speed, reduced tyre/road grip such as wet or icy surfaces, and worn tyres/brakes. Any three appropriate factors. [maximum 3]

4. The vehicle travels farther during reaction time. It also has greater kinetic energy to dissipate during braking. The resulting longer stopping distance increases collision risk. [maximum 3]

5. A large deceleration means a large resultant force on occupants ($F = ma$). Forces can damage tissue or cause collision with the vehicle interior. [maximum 2]

6. $F = ma = 70 \times 12 = 840$ N in the deceleration direction. [maximum 2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 17 Separate Physics stopping estimates and crash-force calculations

1. $a = (0 - 20)/4 = -5.0\ m/s^2$. [maximum 2]

2. $|F| = m|a| = 1200 \times 5 = 6000\ N$. [maximum 2]

3. Distance = speed × reaction time = 25 × 0.8 = 20 m. [maximum 2]

4. Example: constant speed during thinking, constant braking force/deceleration, level road or fixed grip. Real changes in this assumption change the predicted distance. [maximum 2]

5. Crumple zones deform over a longer stopping distance and time. For the same change in speed, longer time reduces deceleration. F = ma therefore gives a smaller average force on the occupants (with restraints in use). [maximum 3]

Lesson 18 Work done and mechanical energy transfer

1. $W = Fs = 50 \times 3 = 150\ J$. [maximum 2]

2. 1 N m of work = 1 J. A moment is conventionally reported in N m rather than called joules. [maximum 1]

3. An upward force acts through an upward displacement. Mechanical work increases the gravitational potential energy of the box–Earth system; some energy may also be dissipated. [maximum 3]

4. $E = Fs = 200 \times 5 = 1000\ J$. [maximum 2]

5. This form applies when a constant force acts along the displacement (or F is the constant component in that direction). [maximum 2]

Lesson practice answers

Indicative answers. Credit equivalent correct wording, up to the maximum in the question.

Lesson 19 Kinetic energy, GPE and multi-stage mechanical calculations

1. $E_k = \frac{1}{2}mv^2 = 0.5 \times 4 \times 6^2 = 72$ J. [maximum 3]

2. $\Delta E_p = mg\Delta h = 3 \times 9.8 \times 5 = 147$ J. [maximum 3]

3. E_k is proportional to v^2 at constant mass. Replacing v with 2v multiplies the result by $2^2 = 4$. [maximum 2]

4. 196 J. [maximum 1]

5. 500 − 420 = 80 J goes to other stores, for example internal energy through friction/heating, rather than increasing kinetic energy. [maximum 2]

Lesson 20 Energy-store changes and power

1. As the ball rises, kinetic energy decreases and gravitational potential energy increases. Air resistance also increases internal energy of ball/air. At the top the vertical velocity is zero, but gravity still acts. [maximum 3]

2. Kinetic energy decreases. Braking/friction increases internal energy of brakes, tyres, road and surroundings; energy is conserved overall. [maximum 3]

3. $P = E/t = 600/20 = 30$ W. [maximum 2]

4. 1.2 kW = 1200 W. $t = E/P = 7200/1200 = 6.0$ s. [maximum 3]

5. The same energy is transferred in less time, because $P = E/t$. [maximum 2]

Assessment answers

Indicative marking guidance. Award distinct valid points and correct method, up to the stated maximum.

1. The person pushes down on the floor (1); the floor pushes up on the person with equal magnitude (1). These opposite contact forces act on different objects (1). The person's weight is a separate gravitational force. [maximum 3]

2. $W = mg = 72 \times 9.8 = 705.6$ N (about 706 N). [maximum 2]

3. 90/3.6 = 25 m/s. [maximum 2]

4. Use a trolley/card and two light gates on a stable ramp (1); measure card length and each beam-blocking time to obtain two speeds (1); measure elapsed time between centres of those speed measurements (1); $a = (v - u)/\Delta t$ (1); repeat from the same release point without pushing and maintain controls (1). [maximum 5]

5. $a = (16 - 4)/6 = 2.0$ m/s². [maximum 2]

6. $a = (v^2 - u^2)/(2s) = (17^2 - 5^2)/(2 \times 44) = 264/88 = 3.0$ m/s². Credit rearrangement, squared values, substitution and result. [maximum 4]

7. Velocity-time gradient = $\Delta v/\Delta t$, giving acceleration with unit m/s² (2). Signed area under the graph gives displacement, with unit m (2). [maximum 4]

Assessment answers continued

Indicative marking guidance. Award distinct valid points and correct method, up to the stated maximum.

8. Choose and label a force scale (1). Draw perpendicular 6 N and 8 N arrows head-to-tail (1), then the resultant from start to finish (1); measured/checked magnitude = 10 N (1). Its angle to the 8 N direction is about 37°. [maximum 4]

9. Take initial motion positive. $\Delta p = m(v - u) = 1200(0 - 18) = -21{,}600$ kg m/s (3). Faverage = $\Delta p/\Delta t = -21{,}600/0.15 = -144{,}000$ N (2), opposite initial motion. [maximum 5]

10. Speed remains constant but velocity direction changes (1). There is acceleration towards the centre (1), caused by a resultant inward force perpendicular to instantaneous velocity (1). [maximum 3]

11. $M = Fd = 45 \times 0.35 = 15.75$ N m. [maximum 2]

12. Inertial mass is resistance to acceleration and equals resultant force/acceleration (1). m = 300/2.5 (1) = 120 kg (1). [maximum 3]

13. Thinking distance increases with speed/reaction time (1). Braking distance increases with speed and reduced grip/brake condition (2). $|F| = ma = 70 \times 10 = 700$ N, opposite motion (2). [maximum 5]

14. $a = (0 - 25)/5 = -5.0$ m/s² (2). Deceleration magnitude is 5.0 m/s²; resultant force = $1400 \times (-5.0) = -7000$ N, opposite motion (2). [maximum 4]

Assessment answers continued

Indicative marking guidance. Award distinct valid points and correct method, up to the stated maximum.

15. $W = Fs = 500 \times 12 = 6000$ J. [maximum 2]

16. $Ek = \frac{1}{2}mv^2 = 0.5 \times 1000 \times 20^2 = 200{,}000$ J. [maximum 3]

17. $\Delta Ep = mg\Delta h = 20 \times 9.8 \times 8 = 1568$ J. [maximum 3]

18. 12 kJ = 12,000 J; $P = E/t = 12{,}000/15 = 800$ W. [maximum 2]

Knowledge organiser

Lesson 1 Interaction forces and Newton's third law

Forces arise from interactions between two objects. Newton's third law pairs are the same type of force, equal in size and opposite in direction, but act on different objects.

Lesson 2 Weight, mass and gravitational field strength

Mass measures the amount of matter/inertia and is measured in kg. Weight is the gravitational force on an object and is measured in N.

Lesson 3 Average speed, typical speeds and unit conversion

Average speed = distance / time. It describes total distance over total time and does not necessarily equal the speed at every instant.

Lesson 4 PAG3 investigating trolley speed

Measure a known distance and the time taken, or use light gates/data logging for more precise timing.

Lesson 5 Scalars and vectors distance, displacement, speed and velocity

Distance and speed are scalars: magnitude only. Displacement and velocity are vectors: magnitude and direction.

Lesson 6 Acceleration and PAG3 acceleration methods

Acceleration = change in speed / time. Positive acceleration usually means increasing speed in the chosen direction; negative acceleration indicates decreasing velocity in that convention.

Lesson 7 Constant-acceleration modelling $v^2 - u^2 = 2as$

Use $v^2 - u^2 = 2as$ when time is not given but initial speed, final speed, acceleration and distance are involved.

Lesson 8 Distance-time and speed/velocity-time graphs

The slope of a distance-time graph gives speed. A steeper line means a greater speed; a horizontal line means stationary.

Retrieval task Explain each idea without notes, then check it. For calculations, state the equation and SI units.

Knowledge organiser continued

Lesson 9 Area under velocity-time graphs and free fall

The area under a velocity-time graph represents displacement. OCR marks this P4.2.10 outcome as Higher-only.

Lesson 10 Free-body diagrams, resultants and equilibrium

A free-body diagram shows the forces acting on one selected object, not forces that object exerts on other objects.

Lesson 11 Higher vector addition, momentum and impulse

Higher tier uses scale drawings for parallel/perpendicular force vectors.

Lesson 12 Newton's first law and circular motion

If resultant force is zero, velocity remains constant. If a resultant force acts, velocity changes in magnitude and/or direction.

Lesson 13 Separate Physics moments, levers and gears

A moment is the turning effect of a force about a pivot.

Lesson 14 Inertia, F = ma and linked force-motion equations

Inertia is resistance to change in motion. OCR makes the formal definition of inertial mass as force/acceleration Higher-only.

Lesson 15 Reaction time investigations

Reaction time can be measured with ruler-drop tests, electronic timers or computer tasks.

Lesson 16 Stopping distance, braking and large decelerations

Stopping distance = thinking distance + braking distance.

Retrieval task Explain each idea without notes, then check it. For calculations, state the equation and SI units.

Knowledge organiser continued

Lesson 17 Separate Physics stopping estimates and crash-force calculations

Separate Physics requires numerical estimates of stopping distance over typical speeds.

Lesson 18 Work done and mechanical energy transfer

When a force moves an object along its line of action, work is done and energy is transferred.

Lesson 19 Kinetic energy, GPE and multi-stage mechanical calculations

Kinetic energy = 1/2 mv^2. Because speed is squared, doubling speed quadruples kinetic energy.

Lesson 20 Energy-store changes and power

Common situations include projectiles, motion up slopes, impacts, acceleration by constant force and vehicles slowing down.

Retrieval task Explain each idea without notes, then check it. For calculations, state the equation and SI units.

Publication notes and references

Independent resource

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Edition and sources

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