Mastering Essential GCSE Physics

Hints and notes for teachers

Contents

General

The best way of using this book

This book had its foundation in a set of worksheets written for GCSE students. The sheets would usually be one or two sides of A5 paper and would cover space for writing notes on a concept just taught (where precision in the definition was needed, this was in the form of a cloze text exercise), and simple questions allowing basic comprehension of the concept to be built. After a classroom introduction, most students would be able to complete the sheet with relatively little further help, and they would then move on to more advanced questions or tasks having mastered the main point. The answers would be reviewed in class before the majority had moved on to further work. While the majority were completing the sheet and sticking it in their exercise book, the teacher could work with students requiring more help, thus allowing for differentiation.

The requirements for a printed book are different, as all teachers will present and discuss a new concept in a different way, as befits their own students and outlook. Given that some students may wish to use the book even if their teacher does not, and some teachers will want students to study a section before it is dealt with in class (effectively the first part of a 'flipped lesson' approach), the notes in the book are complete. However, a teachers' version is available online for classroom projection, with some parts missing (those in general printed in red in the book), so that a teacher can hold a discussion with a class and formulate the ideas before the books are opened.

The questions generally increase in difficulty through each sheet. Thus, many students will be able to read the introduction, study the worked examples, and get started on the simpler questions; while the teacher gives a more structured introduction to the students in need of extra support. By the time those students are ready to tackle the first few questions (the easier ones) without the teacher, the more independent students will probably be requiring the teacher's input to help with harder questions. The sheets are also suitable for flipped lesson teaching, with the notes and easier questions suitable for homework before the lesson, before discussing the concept and tackling the harder ones in the lesson. In this case, the Isaac website with its answer-checking facility is vital in ensuring that students get immediate feedback during homework, and enabling the teacher to check that students have done the preparation work without having to use vital lesson time in checking.

Isaac questions can easily be used in spaced practice. Many sections of Mastering Essential GCSE Physics contain enough questions for teachers to set some initial practice questions (to be done in class or as a homework task), and for other questions to be allocated over the following weeks / months. There is much research suggesting the benefits of spaced practice (both in factual recall and in the learning of skills).

Please ensure that students are acquainted with the front and back inside covers. The front cover has a physics alphabet with all quantities and matching symbols are listed with their units. The back cover shows all equations – with page references to the places where those equations are explained or first used. These pages are useful during the revision phase.

Each page generally focuses on one formula or the application of one numeric skill (e.g. use of the formula $V = I R$).

Within each page, you will find about 70-80% of the questions are relatively routine practice to help students to master the process by repeated application. The remaining questions will usually include some subtlety or additional challenge. This might be unit conversion (including prefixes and conversions from minutes to seconds etc), or sometimes two or more steps of calculation are needed in these more challenging questions. In these notes for teachers:

- we have highlighted the more challenging questions;
- we list (in each section) the formulas that students must "recall and apply" or which they must "select and apply";
- we identify some of the additional challenge within the section;
- we offer some discussion regarding common mistakes and misconceptions;
- In smaller print, we offer comments/guidance on specific questions.

Teachers setting these questions as homework, should not expect that all students will manage the more challenging questions. Teachers are recommended to tell their students the same e.g. "You should find most of these questions routine, but there are deliberately some more challenging questions."

This book is intended to support teachers and students preparing for GCSE Physics Higher Tier (i.e. students who may aim for grades 9 – 4/5). In general, students are expected to be able to rearrange any GCSE Physics formula(s) they are using.

Some sections go beyond the level expected in GCSE specifications. We use a heart symbol ♡ online, and in this guidance, to indicate "Check whether this is in your specification. Some (or all) of the material on this page is beyond some of the English GCSE specifications."

Common reasons for this to appear include:

- One or more English GCSE specifications require a qualitative treatment, whilst the section includes quantitative questions (e.g. circular motion),
- a topic is not included in one or more English GCSE specifications (e.g. diffraction).

We hope that these notes help you to choose sections and questions appropriate for your students, and that your students may be encouraged to use in their physics work the skills they are being taught in their maths lessons.

Isaac does not make available any pdf of answers or solutions. We want your students to have to work to produce their answers and to learn from their mistakes.

SKILLS

Section 1 – Units

More challenging questions: 1.8 - 1.10 [Back to top]

Prefixes – all current GCSE specifications for England are consistent in expecting students to be familiar with prefixes: tera, giga, mega, kilo, centi, milli, micro and nano.

At GCSE, it is common to need to convert cm to m, g to kg, and to deal with prefixes related to A, W, J, etc.

Students may find conversions of areas and volumes more challenging. Two approaches can be used:

1. Find (or know) the conversion factor, and apply it.

   Example 1 cm^2 = 0.01 m x 0.01 m = 0.0001 m^2 OR 10^{-4} m^2.

   So 500 cm^2 = 500 x 0.0001 m^2 OR 500 x 10^{-4} m^2.

   OR (working the other way) 1 m = 100 cm, so 1 m^2 = 100 cm x 100 cm = 10 000 cm^2

2. Replace the prefix with the appropriate power of ten. Treat the prefix as part of the unit.

   Example 1 cm^2 = $(10^{-2})^2$ m^2

   500 cm^2 = 500 x $(10^{-2})^2$ m^2 = 500 x 10^{-4} m^2

The second method is good preparation for A Level (where e.g. kN / cm^2 might need to be converted into N / m^2).

1.1 Students will probably not have seen all of these equations before. To answer the questions, they do not need to understand the equations themselves, only what the symbols mean. The quantities represented by the symbols, with units, are listed on the inside cover of the book.

1.2 A useful exercise for students is to replace the prefix by a multiplication with the number it represents; however, with (h) and (j) the students should realise that the power on the unit also applies to the prefix.

1.3, 1.4 For (d), students may reach for their calculators, but they can be encouraged to deal with the powers of ten in their heads first.

1.5-10 These questions are more challenging for students, but as long as they apply the same techniques as for the previous questions, they should have no issues. Where areas are given in standard form with prefixes, students must be careful when writing down their numbers so that they do not accidentally apply the power on the unit to the power of ten of the standard form value. Judicious use of brackets should be encouraged.

Students will not be required in GCSE Physics exams (nor in GCSE Maths exams) to show knowledge or understanding of the term 'mantissa'. Nonetheless, ability to deal with Standard Form is required in the KS3 PoS for Mathematics, in GCSE Maths specifications at Foundation level, and it's required in GCSE Physics specifications.

The examples given at the start of questions 2.1, 2.2 and 2.4 should make answering the rest of those questions straightforward.

2.3 Students should be directed to the examples directly above the question in the book if they are struggling. If this is set as a homework and students are not working from the book, but rather exclusively using the website for the questions, they may not be aware that the guidance is there.

When entering numbers on their calculator, students should use the exponent button as directed in the book (often marked $x10^x$, or EXP); students who ignore this advice will often obtain incorrect answers on their calculator. For example, if a student divides a number by $6.5x10^{-5}$ by typing

6	.	5	x	1	0	x^y	-	5

then the answer displayed on the calculator will not be correct (unless they also include brackets around the whole of the symbols typed above). The calculator applies the 'divide by' to the 6.5 and then multiplies the result by 10^{-5}.

Section 3 – Rearranging Equations

More challenging questions: 3.6, 3.8, 3.9 Back to top

It is important that students master algebraic rearrangement. GCSE Maths specs expect ability to rearrange algebraic expressions for Basic Foundation tier. This ability is listed in the mathematical requirements of GCSE specifications for Physics (and Science, and Biology and Chemistry) and this skill is taught also in KS3 maths. Notice the book includes no formula triangles, but shows the skill from first principles – you can do anything, so long as you do the same to both sides. The language used by your maths colleagues will very likely include: performing the same operation to both sides. You may encounter students who have some procedural knowledge, but little conceptual knowledge or understanding. We believe procedural fluency is important, but without conceptual knowledge it is easy for a student to misremember a procedure and have no idea why it will not work. In short we discourage the use of "formula triangles" and other 'props' that only work in limited cases.

Some students may struggle when entering these equations into the website, so giving a short tutorial showing them what to do with some of the more basic questions may help here – or direct your students to the online guidance which includes a short video and practice questions: https://isaacphysics.org/solving_problems#symbolic

3.1 The students are unlikely to have met all of these equations, but they can still answer the questions.

3.2 Part (c) includes an addition, which often causes students some problems. They may need help understanding the order of operations on the quantity we wish to make the subject. i.e. a is multiplied by $2s$ and then added to u^2, so perform those operations in reverse.

3.3 Similarly to 3.2, students should understand that v is squared and then multiplied by $\frac{m}{2}$.

3.4 If $u = 0$, the whole ut term also equals zero. Adding zero to a value does not change the value, so the ut term can be neglected.

3.6 Students should spot the x on both sides of the equals sign. It may not be clear to them that they must multiply out the brackets first, and then gather the x terms on one side before factoring out the x again.

3.8 A common mistake is to forget that the equation includes r^2, not just r. This is an equation a GCSE student is very unlikely to have seen and is not included in GCSE specifications.

3.9 This is also an equation that students are unlikely to meet until they are studying for their A Levels, but it provides good practice of algebraic manipulation. Students should recognise that T is on the bottom of a fraction and is squared before being multiplied by r. When dividing through by r, students may not realise what happens to the r^2 term on the right hand side.

Section 4 – Vectors and Scalars

More challenging questions: 4.8, 4.9 *Back to top*

These questions include parallel and perpendicular vectors. To help build confidence, most of these questions are restricted to displacements and forces (though 4.6 involves velocities). Combination of perpendicular forces is limited to scale drawings (as per GCSE specifications).

4.1 Some students might get spooked by having vertical and horizontal forces, but as long as they handle the perpendicular forces separately, they should have no problems.

4.2 Students should be encouraged to draw a diagram, as in 4.1, even for simple cases like this.

4.3 Students can answer this question by drawing a scale diagram or using Pythagoras's theorem. Whether they chose to draw the diagram to scale or not, a diagram should be encouraged.

4.6 Students might not notice that the velocity of the car must be in the opposite direction to the velocity of the lorry at the instant the car has left the lorry. The minus sign here is very important. Drawing a diagram will help the students visualise the problem.

4.7-9 Scale diagrams are absolutely essential for these questions, and emphasis must be made on drawing the diagrams large enough to minimise the errors in measurement. If students are struggling to add vectors, refer them to the diagram on page 9, which shows the vector arrows drawn end-to-start.

Section 5 – Variables and Constants

Back to top

These two questions involve students understanding the experiment being described. Being able to identify variable types is an essential skill at GCSE and beyond. In each case, the students should think, "What is the experimenter directly choosing to change?" (this is the independent variable), "What do they hope to see affected by that change?" (this is the dependent variable), and "What could affect the results if not kept the same?" (these are the control variables).

Section 6 – Straight Line Graphs

More challenging questions: 6.4, 6.5

Back to top

Plotting of straight lines is taught in KS3 and GCSE maths, but the use of language in maths and science / physics can be confusing for students. For example, in science / physics we often use the word variable to refer to the quantities being measured in an experiment, whilst in maths lessons, the same word is more often used to refer to a 'term' in an algebraic expression e.g. 4 = 6 + x.

Questions 6.3 – 6.5 are more like typical questions from a GCSE Maths class than from a GCSE Physics class. Doing questions like this will help students to think more mathematically in physics. Furthermore, the ability to handle an equation in the form $y = mx + c$ is explicitly included in the mathematical requirements of the GCSE Physics specifications.

6.1 If the student writes $y = mx + c$ directly above or beneath the equation $I = \left(\frac{1}{R}\right) \times V$ it should help them to see how the latter equation is in the same form as the former; however, they may need to be reminded that they can add the number zero to the right hand side without changing the equation, making it easier to see the relationship between the two equations.

6.2 A common mistake here is to count squares rather than look at the values on the axes. Exam boards tend to include references to 'triangles' for gradient calculations in their mark schemes, and gradients are usually introduced in mathematics lessons with students counting squares along the x- and y-directions of the triangle. Students should be encouraged to extend lines to the axes horizontally and vertically to make it easier to read off the values. Another common mistake is to draw a small triangle floating in the middle of the straight line, rather than maximising the range of values taken from the x- and y-axes, which reduces the error in the gradient.

Section 7 – Proportionality

More challenging questions: 7.11, 7.12 [Back to top]

Proportionality and inverse proportionality are important ideas for GCSE Physics. Most of the standard Physics GCSE formulas (being of the form $a = b \times c$, or $d = \frac{e}{f}$) are much more meaningful to a student who understands these ideas.

7.1 Standard textbooks often do not include guidance on how to solve problems using factor changes, and the speed equation tends to be given as $v = \frac{s}{t}$. Suggesting that a student re-writes the equation as $s = vt$, hence $s \propto t$ with constant v can help them to understand how to quickly solve these equations. If the time doubles, so does the distance. If the time halves, so does the distance; they are directly proportional. The factor change in the variable on the left-hand side of the equation is equal to the factor change in the variable on the right-hand side of the equation.

7.2 As with the previous question, students should be encouraged to write an equation ($euros \propto sterling$) and work with factor changes.

7.3 Here, it can be easier for students to consider the equation in the form $earnings = constant \times time$, and for them to determine the value of the constant. They should be careful with units. It is best to work consistently throughout either in minutes or in hours.

7.4 This question can be tricky for students unless they realise that 25 staff working 35 hours per week is the same as 875 staff-hours / week, and write that *staff-hours* $\div$ $weeks \propto widgets$'. Students are unlikely to have had to form their own equations before, so they may need encouragement.

7.5 What fraction of total sales went to New Town? Scale that up.

7.6 How much time did the watch lose in one month? What fraction is that? Scale it down. It can be easier for students to work in seconds for this question, then convert back to days, hours, minutes, etc.

7.7-10 With these questions, the factor change in one variable is the inverse of the factor change in the other. Similar approaches can be used as in the previous questions, as long as the student remembers to take the reciprocal of the factor change. Most calculators have a dedicated reciprocal function (shown as either x^{-1} or 1/x).

7.12 Students should be encouraged to rearrange the equation so that the two variables in question are on opposite sides of the equals sign. Next, remove all of the constants to change the equation into a proportionality, which will reveal the relationship between the two variables. $x \propto y$ means directly proportional. $x \propto 1/y$ means inversely proportional. (d) – (f) are more challenging and will prompt the students to look carefully at the terms in the equation.

MECHANICS

Section 8 – Speed, Distance and Time

More challenging questions: 8.2 (parts), 8.8 – 8.10 [Back to top]

Recall and apply formulas:

$$s = v\,t \qquad distance\ travelled = (average)\ speed \times time$$

This section gives plenty of practice of speed, distance, time calculations, with plenty of standard unit conversions (minutes, hours, seconds; kilometres, metres).

8.1 Straightforward practice of $v = s/t$. Where standard form occurs in (e) onwards, students will need to use their calculators correctly (by using the $\boxed{\times 10^x}$ button, or by enclosing the denominator in brackets).

8.2 The extra complication here is the use of prefixes. Prefixes are listed on the inside of the front cover, so 20 µs = 20 × 10^{-6} s. Times in hours or minutes must first be converted to seconds.

8.7 You may wish to point out a method like this:

$$speed = dist/time = \frac{650\ \text{km}}{60\ \text{min}} = \frac{650 \times 1000\ \text{m}}{(60 \times 60\ \text{s})}$$

8.8,9 These require care with prefixes, and unit conversions.

8.10 The distance in metres is equal to one year (365 × 24 × 60 × 60 s), multiplied by the speed given. A division by 1000 then gives the distance in kilometres. Students often ask whether we need a normal year, a leap year, or an average (365 days, 366 days or 365.25 days respectively) – the answer is, that when we only need 2 significant figures in the answer, it doesn't matter. Online, Isaac asks explicitly for this answer to 2sf. The definition of the light-year is based on the Julian year, 365.25 days.

Section 9 – Displacement and Distance ♡

More challenging questions: 9.5, 9.6 [Back to top]

Note: all these questions lie beyond the scope of GCSE Physics exams (hence the heart symbol). Current specifications expect students to be able to calculate resultants of perpendicular vectors from scale diagrams (not from application of Pythagoras). The section notes explain how to use trigonometry and Pythagoras to solve the questions presented in this section. This is excellent preparation for A Level (as it uses GCSE Physics and GCSE Maths in combination).

Please note that other than 9.1, all questions require Pythagoras's Theorem, and most require trigonometry. The essential points are made in the first two questions. The other questions, however, give excellent opportunities for problem solving techniques to be honed by students. Encourage students to draw diagrams before calculating.

9.1 Remind students that the distance is the sum of the individual motions – here 500 m + 250 m + 500 m + 250 m. After all, if you have a journey and initially set off in the wrong direction, it DOES take you longer to get to your destination. The displacement however is just 1000 m (the 250 m north cancels with the 250 m south).

9.5 For part (a), the answer is one quarter of the circumference. A geometrical diagram will help the student to recognize the 90°/45°/45° triangle formed by: the centre of the circle; the start point; the end point.

9.6 For part (a) we can use $distance = speed \times time$. For (b) we compare this distance with the circumference of the circle. For (c) we take the fractional part only

$$\frac{distance}{circumference} = \frac{235.6\ m}{314.2\ m} = 0.750$$

so we know that the car has moved three quarters of the way round the roundabout. As in q9.5, a 90°/45°/45° triangle links the centre and the start and end points, and from this the overall displacement can be calculated.

Section 10 – Motion Graphs; Displacement-Time (s-t)

More challenging questions: 10.3 [Back to top]

Recall and apply formulas:

$$s = v\,t \qquad distance\ travelled = (average)\ speed \times time$$

$$acceleration = change\ in\ velocity \div time\ taken$$

{$a = \frac{\Delta v}{t}$ *OR* $a = \frac{(v - u)}{t}$ *according to exam board}*

It is worth checking all is well by doing 10.1 with the whole class before moving on. The steepness of the line gives the speed. A common misconception is that (a) is moving at a steady speed. It is not – it is stationary – the displacement does not change as time moves on.

10.2 The gradient of each section must be calculated. For example, in (c), the velocity will be $\frac{(25\ \text{cm} - 10\ \text{cm})}{5.0\ \text{s}} = \frac{15\ \text{cm}}{5.0\ \text{s}}$. Sections like (d) have negative gradients, thus negative velocities (i.e. backwards motion).

Note the prefixes in the units for displacement in 10.2 and 10.3.

Section 11 – Acceleration

More challenging questions: 11.4, 11.5, 11.8, 11.10 Back to top

Recall and apply formulas:

$$acceleration = change\ in\ velocity \div time\ taken$$

$$\{a = \frac{\Delta v}{t} \quad OR \quad a = \frac{(v-u)}{t} \text{ according to exam board}\}$$

Situations are limited to motion in a straight line (in line with GCSE Physics specifications). In some cases, the sign of an object's velocity changes during the period of acceleration.

Students should look for hidden information (e.g. 'dropped', 'from rest' both mean initial velocity = zero; 'stopped' at the end means final velocity = zero; 'dropped' for objects on Earth, also means the acceleration is known).

There may be some confusion after students have read examples 2 and 3 regarding deceleration. If so, take some time to explain

- Negative acceleration means 'final velocity is lower than starting velocity'.
- Deceleration means 'final speed is lower than starting speed'.
- Thus, if acceleration is negative, and velocity is positive, we have a deceleration.
- However, if acceleration is negative, and velocity is negative, we do not have a deceleration – the object is getting faster while reversing.

11.1 In this question, we hope that the students internalize the idea that the acceleration (in m/s^2) is the velocity change each second. Thus, in the first row, the numbers increase by 3.0 each time. In the second row, the numbers increase by 5.0 each time. Thus in (d) three 5.0 m/s increases have occurred since the start. For part (m), the object is losing 3.0 m/s in 2.0 s, so the calculated acceleration is negative.

11.4 In this question, encourage the students to regard 'upward' motion as positive. The starting velocity is +15 m/s, while the acceleration is -10 m/s^2. So after each second, the velocity is 10 m/s less. Therefore, after two seconds, it has lost 20 m/s of velocity, so the final velocity is calculated 15 m/s – 20 m/s. This final velocity is negative indicating that it is downwards.

11.5 In part (b), we can rephrase this as 'how long does it take to lose 45 m/s if you lose 10 m/s each second'.

11.8 The speed must be converted into m/s as the first stage (60 × 0.45 = 27 m/s).

11.10 The acceleration in mph/s is calculated thus: (70 mph – 50 mph) / 5.0 s. We then multiply by 0.45 to get the acceleration in m/s^2.

Section 12 – Motion Graphs; Velocity-Time (v-t)

More challenging questions: 12.4 Back to top

Recall and apply formulas:

$$s = v\,t \qquad distance\ travelled = (average)\ speed \times time$$

$$acceleration = change\ in\ velocity \div time\ taken$$

$$\{a = \frac{\Delta v}{t} \quad OR \quad a = \frac{(v-u)}{t}\ \textit{according to exam board}\}$$

Situations are limited to motion in a straight line (in line with GCSE specifications). In some cases, the sign of an object's velocity changes during the period of acceleration. Note that some graphs are speed-time graphs, allowing distance travelled to be calculated; others are velocity-time graphs, from which displacement can be calculated.

In velocity-time graphs, negative displacements follow from areas below the axis.

At GCSE, areas will be rectangles and triangles. A trapezium can be treated as a rectangle and triangle.

12.1 A good introduction, as students should have no difficulty working out the areas of the shapes. Note this is a speed-time graph, from which distance travelled can be calculated.

12.2 A displacement-time graph, builds on 12.1 – the only additional factor is that the displacements of C and D are negative, and should count negatively when the total displacement is calculated.

12.3 To answer (b) we need to know the distance moved between 10 s and 15 s. This shape is a trapezium. You can break it down into a rectangle (5.0 s × 10 m/s = 50 m) and a triangle (0.5 × 5.0 s × 10 m/s = 25 m) and add them. Alternatively, you can use the formula for the area of a trapezium: area = width × average of parallel sides = 5.0 × (10 + 20) / 2; this latter method is exactly equivalent to calculating displacement from average velocity x time.

12.4 The total displacement is the sum of the areas. The acceleration is the gradient of the line. In (f), only the acceleration of the first section is needed.

Section 13 – Resultant Force and Acceleration

More challenging questions: 13.1 (b) (vi), 13.9 (b), 13.10 Back to top

Recall and apply formulas:

$$F = m\,a$$

It is worth spending time looking at the definitions of 'resultant force' on p34 and the different approaches in Example 1 to ensure that each student has at least one method that they are comfortable with.

13.1 (a) should be reasonably straightforward. In (vi) the resultant is found by applying Pythagoras's Theorem (the question includes this suggestion).

(b) requires us to find an extra force which will balance the situation. Students should realise that their answers are 'opposites' of their answers in part (a) {same strength, opposite direction}.

13.2 Requires the student to take their answers to 13.1 (a) and divide by the mass.

13.4 This question uses g = 10 N/kg. In (a) students should use the mass in kg and work out 1.0 N / 0.10 kg. In (b) the mass is 0.30 kg and $W = mg$. This question can be used to help students understand that the acceleration of dropped objects is the same, regardless of mass (providing that there is no air resistance).

13.9 In part (a) we have a simple application of $F = ma$ = 3.0 kg × 4.0 m/s^2. In part (b) we still need a resultant force of 12N to give the required acceleration, but as there is 4 N of friction, the applied force will need to be greater. Some students may find it helpful to think of the applied force 'consisting of' 4N to balance the friction and 12 N to provide the acceleration.

13.10 This introduces the student to a concept they will cover later when they study momentum. At this stage, however, they can simply use the equation provided –

$$Force = mass\ of\ propellant\ burnt\ each\ second \times exhaust\ velocity.$$

(a) We need a lift force of at least 2 040 000kg × 10 N/kg = 20 400 000 N, so the mass required to be consumed each second will be 20 400 000 N / 3000 m/s.

(b) The force needed will be the weight of the rocket (20 400 000N) plus the force needed to accelerate it at 3g (mass × acceleration = 2 040 000 × 30).

Section 14 – Terminal Velocity

More challenging questions: 14.6, 14.7, 14.8 Back to top

Recall and apply formulas:

$$F = ma$$

$$W = mg$$

In this section, students determine whether or not there is a resultant force. When there is a resultant, there is practice determining the acceleration. Terminal velocity is used to describe the speed at which a drag force is equal to a steady driving force. The size of the drag force depends on the speed. The driving force is usually the weight of a falling object or it might be a constant driving force from an engine, rocket motor, bicycle, etc.

14.3 As the bottles are identical, they will have the same air resistance at any given speed. However, the heavy one will need more drag before it reaches terminal velocity, and therefore will have a higher terminal velocity.

14.6 Note that the question refers to an online graph – make sure that you project this if students are doing the question in class (it is at https://isaacphysics.org/questions/gcse_ch2_14_q6). Note that the units on the Drag Force axis are kN. In part (a), the drag (read from the graph) is 20 000 N, so the resultant is 60 000 N, so acceleration is given by F/m = 60 000 N / lorry mass. In (b) the terminal velocity is the speed (read from the graph) at which the resistive force will be 80 000 N. In (c) the drag is 80 000N, but the engine is only providing 40 000N. The resultant is therefore backwards, and the acceleration will be -40 000 N / lorry mass. In (d) students should take care reading the speed; there are 10 gridlines per 5 m/s. Online the answer is explicitly requested to 2 sig fig.

14.7 This is an exercise in proportionality (this is the topic of section 7 if students wish more information or practice). In (a) with drag being proportional to speed, to gain five times the drag (needed to counteract five times more driving force), the speed will need to multiply by five too. In (b) we need the force to multiply by five. But force is proportional to the square of speed (in symbols $F = kv^2$ where k is some constant). Thus $v = \sqrt{(F/k)}$, and if F has multiplied by 5, speed will be multiplied by √5.

14.7 In this questions students must apply knowledge in a less familiar situation, to make an algebraic expression.

Section 15 – Stopping With and Without Brakes

More challenging questions: 15.6 [Back to top](#)

Recall and apply formulas:

$$W = F\,s$$

$$acceleration = change\ in\ velocity \div time\ taken$$

$$\{a = \frac{\Delta v}{t} \quad OR \quad a = \frac{(v-u)}{t}\ \textit{according to exam board}\}$$

$$F = ma$$

$$W = mg$$

This section, like the last, gives more practice of $F = ma$. However, with many students only a few years from their driving licences, it is vital that the physics of stopping distances is explained well. Knowing the scientific consequences of speeding, or driving too close to the car in front, may well encourage better driving in the years to come. You are also welcome to use q34.2 to hammer the point home – travelling at 40 mph (as is all too tempting in a 30 mph area at times) almost doubles your kinetic energy, thereby having a devastating increase in the injury or damage you can cause.

15.1 Here, the student is simply asked to add the example answers: 8.9 m + 13.4 m to get the overall stopping distance.

15.2 Here, the student should repeat the logic of the examples with the new speed of 60 mph (which must be converted to m/s before calculations are attempted).

15.4 At 35 mph (15.6 m/s), the students should obtain a thinking distance of 10.4 m and a braking distance of 18.2 m, making an overall stopping distance of 28.6 m – several metres longer than the 22.3 m overall stopping distance at 30 mph (calculated in 15.1). I would hope that when this distance has been measured out (longer than some school minibuses) the consequences of even minor 'speeding' will become clear – this zone is the area in which an unwary pedestrian would be safe if you were keeping to the speed limit, but not safe if you went at 35 mph. That said, road safety campaigners produced a misleading poster to force the point home which showed this distance directly in front of the vehicle (and did not include the 22.3 m danger zone which is always in front of the vehicle when travelling at 30mph). You may wish to find a copy and discuss it.

15.5 This encourages students to see '$work\ done = force \times distance$' as an approach to braking distances if restated as '$kinetic\ energy\ [lost] = braking\ force \times braking\ distance$'. Thus braking distance equals $mv^2/(2F)$. You may wish to miss this question out if students haven't encountered kinetic energy yet. Alternatively, you can give them a whistle stop tour of sections 33 and 34 to cover these areas first.

15.6 Students must use the graph that appears online only (not in the printed version of the book). Students need to read information from the graph to find the terminal velocity for a given driving force, and to find the acceleration for a given driving force, at a certain speed.

15.7 Here the deceleration will be over 6g. Part (c) should show the student that increasing the collision time by a factor of 3 reduces the force by the same factor, and we now have a deceleration of less than 3g – much less likely to cause injury.

Section 16 – Moments, Turning and Balancing

More challenging questions: 16.7, 16.8 [Back to top]

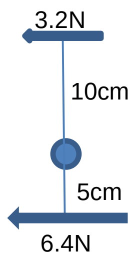
Recall and apply formulas:

$$M = F\,d$$

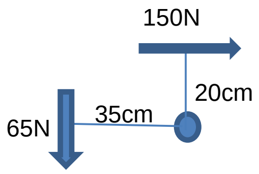
The content in this section, although mandated by GCSE specifications, includes difficult ideas which even Sixth Formers can struggle with. Please therefore take things steadily. Some students will be able to skim the early questions, and then proceed quickly to the harder ones. Others will need to spend longer on the examples and the early questions to gain familiarity. Remember that in the exam, they might only get questions at the level of 16.1.

16.6 These questions are unorthodox, but straightforward and should enable the student to gain an idea of moments balancing. It is very important that a diagram is drawn. To illustrate this, the first two are demonstrated here.

(a)



(b)



(a) The 3.2 N force gives an AC moment of 3.2 N × 0.10 m, while the other force gives a C moment of 6.4 N × 0.05 m.

(b) The 150 N force gives a C moment of 150 N × 0.20 m, while the other force gives an AC moment 65 N × 0.35 m. The clockwise moment is larger.

(f) We have two clockwise moments, and these must be added to give the total clockwise moment: 34 N × 3.5 m + 10 N × 0.80 m.

16.7 This contains more traditional balancing questions, which can be solved in the manner of Example 2. In (d), remember that the moments of weight C and weight A must be calculated separately and then added together to give the total clockwise moment. Similarly, in (e) the moments of weight A and weight C must be calculated separately and then added together to give the total anticlockwise moment. In both cases, the weight of C is not known, so call it C, and frame a suitable equation. For (d) this would be 20 N × 45 cm = C ×

30 cm + 10 N × 60 cm. Also note that the important distance is the distance to the axle – 60 cm for C in (d) and 80 cm for A in (e). Again, it is fine to work consistently in matching units of N cm and cm, or in N m and m.

16.8 This is a harder one, to give a bit of fun to the students who have found everything easy so far. A diagram will help – effectively there is a 0.5 N weight at the 20 cm mark, and a 0.5 N weight at the 50 cm mark (i.e. the centre of mass of the metre stick is at its centre – this is the place the weight acts from). As the forces are equal, the balance point must be half way between them – i.e. at the 35 cm mark. Students could then be challenged to work out where the balance point would be if the 'added' weight were 1.0 N not 0.5 N. They will probably guess that it should be twice as close to the 1.0 N weight – but proving it is harder! The easiest method is to take moments about the centre of the metre stick (the 50 cm mark), and remember that the support point must provide an upwards force equal to the total weight of ruler and mass (1.0 N for the situation in the question and 1.5 N in the amended version mentioned here). The 1.0 N weight is 30 cm from the centre (30 N cm moment), so the balancing force must have the same moment, so 30 N cm = 1.5 N × distance, so distance = 20cm, and the balancing point is 20 cm from the middle. In this analysis we did not need to include the weight of the ruler, as its force passes through our 'axle' and accordingly made no moment.

Section 17 – Pressure, Hydraulic Systems, Density and Depth

More challenging questions: 17.9 [Back to top]

Recall and apply formulas:

$$p = \frac{F}{A}$$

$$\rho = \frac{m}{V}$$

Select and apply formulas:

$$p = \rho g h$$

Note: Question 17.6 (density, mass, volume) did not appear in the first printing of the book.

The three formulas indicated above are covered in this section. Pressure calculations using $P = F/A$ often require unit conversions – lab measurements of area will often be recorded in cm^2 rather than m^2.

17.1 This question should be a straightforward application of $P = F/A$, however watch out when putting standard form numbers into a denominator – either use the $\times 10^x$ button and/or put the denominator in brackets. Parts (c), (d) and (h) require the use of numbers such as 10^6. For example, in part (c) 10^6 needs to be entered as

1	×10ˣ	6	and not as	1	0	×10ˣ	6

17.2 Students need to work in cm^2 and m^2. As there are 100 cm in 1 m, there are $(100 \text{ cm})^2 = 10\,000 \text{ cm}^2$ in 1 m^2.

17.3 After answering this question, you can have a discussion about the role of increasing surface areas to reduce pressures for the same force.

17.5 Remember that we have four jacks – so each will take 2.0 kN.

17.7 This question allows the student to see where the equation $p = \rho g h$ comes from – if your students only need practice in using the equation, you might want to miss this out. If they are doing it, note that (d) should be done using

$$pressure = \frac{force}{area} = \frac{answer\ to\ (c)}{0.080 \text{ m}^2}$$

In part (e), they should get the same pressure as before, as the 10× larger area gives a larger volume (hence weight) of water, but this factor is divided out at part (d).

17.9 Students should find the numbers humbling. Very few submarines can go down this far! In part (a), they will notice that adding the atmospheric pressure (as in Example 2) to give the total pressure only affects the fourth significant figure. In part (b) we should only use the extra pressure ($\rho g h$) as there is atmospheric pressure in the submarine, and the inwards force depends on the pressure difference. The force can be calculated from $F = pA$ where $A = 0.01 \text{ m}^2$.

Section 18 – Moving in a Circle ♡

More challenging questions: 18.6, 18.7 Back to top

Recall and apply formulas:

$$F = ma$$

$$W = mg$$

The treatment of circular motion in current Physics GCSE specifications is qualitative, so requires no calculations using $F = mv^2/r$ (hence the heart symbol). Nonetheless, many students have a better grasp of the idea and get more out of this topic if they can do calculations. Do be careful before setting the whole sheet as the last two questions are very challenging.

18.3 Ensure that the speed in m/s is used.

18.4 As the question suggests, we need to work out the speed. The circumference = 2π × 5.3 m. Dividing this by the time for one rotation gives the speed of the riders.

18.5 Part (a) is a simple application of $W = mg$.

18.6 This is a challenge which not all A Level students find easy. The key fact is that weight can only provide a downwards acceleration of 10m/s^2, we use the formula $a = v^2/r$ with a = 10 m/s^2.

18.7 This is another challenging question. For (a), use $g = k/r^2 = v^2/r$ and re-arrange to make speed the subject. In (b), the time will be $T = 2\pi r/v$. In part (e) make sure that you give reference to the satellite never going below the horizon (so you have signal at all times) and the fact that the receiving 'dish' does not have to 'track' the satellite. Once the dish has been pointed in the correct direction, it needs no further adjustment.

Section 19 – Introducing Momentum and Impulse

More challenging questions: 19.7 - 19.10 [Back to top]

Recall and apply formulas:

$$p = m\,v$$

Select and apply formulas:

$$F = \frac{m\Delta v}{t}$$ *(this formula is not listed in OCR A, or Eduqas)*

These questions include straightforward applications of the formula $p = mv$. Students must remember that velocity and momentum have directions (using + or -, or by stating the direction). GCSE questions where masses are given in grams are not uncommon. It is generally safest to convert to kg first.

19.2 This is a reworking of Example 1 with new data. The aim is to convince the students that the change in momentum is equal to the force × the time.

19.3 This is a practice question. Note that the first row (the one which has been filled in) has been worked through in Example 2. You may wish to guide the students on the next row, perhaps working through the calculations together. I suggest the following approach: firstly, (b) is zero as the object is stationary to begin with; next calculate the change in momentum using $\Delta p = Ft$; then find the new momentum (d); finally, calculate the new velocity (a) $final\ velocity = \frac{final\ momentum}{mass}$.

19.4 This question can be answered by using $F = ma$ (first calculating the acceleration). However, encourage students to solve it using momentum, as this will help them apply their physics to problems which cannot be solved using $F = ma$. The final momentum is 300 000 kg × 90 m/s, and the plane is stationary at the start. If the momentum change is divided by the time (50s), the force is obtained.

19.6 Don't forget to convert 20 g to kg.

19.7 Don't forget to subtract the mass of the bike from the total mass to give the mass of the girl.

19.8 The momentum change (60.6 kg × 0.85 m/s) is the same for both parts. A diagram of the forces on the person will help students to see that the "force on each leg" is equal to the weight + the resultant force. The moral of the story is that you get smaller forces if you stop in greater periods of time. This is essential to the principle of, for example, the crumple zone in a car.

19.9 There is additional challenge here: once the momentum of each has been calculated, the student needs to find the ratio of the two momentums.

19.10 This requires a unit conversion from tonnes to kg.

Section 20 – Momentum Conservation

More challenging questions: 20.7, 20.9, 20.10 Back to top

Recall and apply formulas:

$$p = m\,v$$

$$E_k = ½\,m\,v^2$$

Select and apply formulas:

$$F = \frac{m\Delta v}{t}$$ *(this formula is not listed in OCR A, or Eduqas)*

Specifications differ in the level of detail required here.

Example 1 illustrates that conservation of momentum follows from Newton's Third Law. Examples 2 and 3 are worked examples of momentum conservation problems. Students must remember to convert masses into kg, and to take care with directions (and signs).

It is worth encouraging students to draw a diagram for every momentum conservation question.

20.4 The initial total momentum is zero; both trolleys were at rest. So the total momentum afterwards must also be zero. The left hand trolley has momentum -0.50 m/s × 2.0 kg = -1.0 kg m/s, and so the right hand trolley must have a momentum of +1.0 kg m/s. Its mass is 5.0 kg, so its velocity can be calculated $= p\,/\,m$. In part (b), calculate the total kinetic energy of the two trolleys (work them out separately and then add them up – they are both positive). This energy must have been stored by the compression of the spring.

20.6 This question gives lots of practice of the same physics as used in 20.4. Considering (c) as an example – the initial momentum = $(m_a + m_b) \times 5.0\ \mathrm{m/s}$. After the collision, trolley A has a momentum of 2.5 kg × (-4.0 m/s). The momentum of B can be written as $m_b v_b$. As momentum is conserved $m_a v_a + m_b v_b = total\ momentum$, so $m_b v_b = total\ momentum - m_a v_a$. The final velocity of B can then be calculated from its final momentum.

20.7 Without the need for modern technology, this is as good a method as any for working out the speed of bullets. As the sandbag is stationary at the beginning, the answers to (a) and (b) are the same. By the principle of conservation of momentum, (c) is the same as (b).

20.9 This question may help explain the statement made in 13.10. If the force is 3.5×10^8 N, this is the momentum change each second. So in one second, if the velocity is $2800\ \mathrm{m/s}$, the mass must be (3.5×10^8 / 2800) kg. This gives the mass consumed by the engine each second.

20.10 This is the kind of question (along with 20.9) which can be solved using $F = \Delta p/t$, but for which $F = ma$ is not appropriate ($F = ma$ can only be applied where the mass is constant). Every second we need to give 40 kg of coal an additional speed of 1.2 m/s. So the increase in momentum each second is mass of coal added each second × increase in velocity of added coal. The change in momentum per second is the same as force.

Section 21 – Motion with Constant Acceleration

More challenging questions: 21.7, 21.9, 21.10 [Back to top]

Recall and apply formulas:

$s = v\,t$ $\quad$ $distance\ travelled = (average)\ speed \times time$

$acceleration = change\ in\ velocity \div time\ taken$

{$a = \frac{\Delta v}{t}$ *OR* $a = \frac{(v - u)}{t}$ *according to exam board*}

Select and apply formulas:

$v^2 - u^2 = 2as$

$v = u + at$ *(listed in Eduqas specification only)*

$x = ½(u + v)t$ *(listed in Eduqas specification only)*

$x = ut + ½at^2$ *(listed in Eduqas specification only)*

Specifications differ in the content required – you may not want to teach the whole topic. Pages 62-63 show where the equations come from – the knowledge of these derivations is not needed for GCSE. Most students will prefer to use the equations to solve the questions rather than the 'basic principles' method. However, for those students who fancy a challenge, encourage them to solve questions using the basic principles.

Throughout these questions, students should look for 'hidden information'. An object that is 'dropped' (on Earth) has an initial velocity of zero and accelerates at g (9.8 m/s^2 or 10 m/s^2, according to your exam board). An object projected upwards that reaches a height will be stationary at that height, so final velocity is zero. Vehicles, people, objects may start from rest (initial velocity is zero), or may come to a halt/stop (final velocity is zero).

Unit conversions (e.g. km to m) add some extra challenge in some questions.

21.7 Here the distance travelled is given in miles. The conversion factor is included in the question, but students must calculate this distance in metres. More hidden information – the tanker stops. We use $v^2 - u^2 = 2as$ to find the deceleration. Again, the value obtained for the acceleration will be negative.

21.8 Hidden information in the word dropped (start velocity and acceleration can be understood from this wording). Use $v^2 - u^2 = 2as$.

21.9 Convert km to metres, final velocity and acceleration are hidden information.

21.10 Here, a time is needed, and the object is dropped, so we use $x = ½at^2$. Remember to take acceleration as 1.6 m/s^2 (for the Moon), as directed in the question, and not 10 m/s^2.

ELECTRICITY

Section 22 – Charge and Current

More challenging questions: 22.5, 22.6 Back to top

Recall and apply formulas:

$$Q = It$$

Many of the electrical questions in the book (and in GCSE) involve substitution into three-term equations such as $V = IR$. As such, this section makes a start by giving students lots of practice with $Q = It$ and its rearrangements.

Students may wonder 'why Q?' and 'why I?' We can't use C – there would be confusion as both charge and current begin with 'c'. Many of the original scientists who worked on circuit electricity (like Coulomb and Ampere) were French. The French term for charge is 'electrical quantity' and the term for current is 'electrical intensity'. To me, quantity and intensity are more easily visualised than the words 'charge' and 'current'. You may therefore wish to teach your students some French.

The one additional difficulty is the need to calculate number of electrons. Students generally find it simple to work out that you need 800 / 52 buses to carry 800 people if each bus can take 52. However, when you say that an 'electron bus' carries 1.6×10^{-19} C of charge and ask them how many 'electron buses' are needed to carry 0.0034 C, say, it seems harder. The approach is the same, however.

You may wish to teacher the skill of generating an equation from 'common sense':

> If 1 electron has charge of e, then the charge of 2 electrons is $2e$; the charge of 3 electrons would be $3e$; then the charge of n electrons is ne. We have generated the equation for the charge of n electrons $Q = ne$. This can be rearranged to find the number of electrons needed to deliver (or carry) a charge of Q.

Please encourage students to use the $\boxed{\times 10^x}$ button on their calculator when entering numbers in standard form. This prevents wrong answers if $0.0034 \div (1.6 \times 10^{-19})$ is put into a calculator without the use of brackets.

22.5,6 Watch out – the time must be in seconds.

Section 23 – Current and Voltage – Circuit Rules

More challenging questions: 23.8 – 23.10 Back to top

These questions are not mathematically difficult, but they lie at the heart of understanding electricity. Students may find it helpful to have a summary table:

	Current	**Voltage**
Components in Series	have equal current	have voltages which add to give the battery voltage
Components in Parallel	have currents which add to give the battery current	have equal voltages

In particular, remember:

- current is not 'used up' as it goes through a component. If 2 A go into a light bulb, 2 A will come out the other end. The only thing which can split current is a junction.
- when adding up voltages to get the battery voltage in a circuit with series components in parallel loops, remember to go around one 'circuit loop'. In other words, when you reach a junction, choose one path to take – don't try taking both.

Common mistakes/misconceptions include the following:

Current decreases ('gets tired') as it progresses through components in series.

At a junction, current will split equally (irrespective of the resistance of the parallel branches).

23.1 a) This is a simple series circuit, so $P = Q$.

b) Here 3.5 A splits at the junction, so P is the difference between 3.5 A and 2.0 A. Q can be found by either of two methods: it is in series with the point labelled 3.5 A; add the two parallel currents P and 2.0 A.

23.2 a) This is a simple parallel circuit, so the answer is the p.d.s sum to make the battery p.d.

b) Here, R2 is in parallel with the resistor showing 4V, so R2 has that same voltage across it. Drawing a current loop using the upper 'choice' at the junctions we have 6 V = voltage across R1 + 4 V. Note that the answer for R1 is not $6 - 4 - 4$ (subtracting 4 for each of the right hand resistors). The negative answer would show something was wrong! One particular electron on going round the circuit once can only go through ONE of the right hand resistors, so you only subtract the 4 V once.

23.8-10 These circuits include multiple p.d.s and currents. Students who are not very secure in their understanding might find these circuits more intimidating/challenging.

Section 24 – Resistance

More challenging questions: 24.9, 24.10 *Back to top*

Recall and apply formulas:

$$V = IR$$

Here we have plenty of practice of rearranging and using $V = IR$.

24.7 The largest current will come from the smallest resistance – namely 15 kΩ reduced by 2%, which is the same as 15 kΩ × 0.98.

24.8 Remember that the 0.83 A battery current needs to be halved to give the current in one lamp before we use $R = V/I$.

24.9 a) Read the current for 6V (from the resistor graph) and then do $R = V/I$.

b) A current of 0.2 A corresponds to 4 V on the graph. This is a resistor, obeying Ohm's Law (see the nice straight line on the graph, passing through the origin), so we should get the same answer for the resistance as in part (a).

c) 10 V is not on the graph, but knowing the resistance, we find the current from $I = V/R$.

d) The lamp's graph is not straight, so we **must** read the current which corresponds to 4 V before calculating $R = V/I$.

e) This is a parallel circuit. Both components are connected to 6V. The current drawn from the supply is the sum of the currents through each parallel branch.

f) Students who recall information from previous parts may spot that the current in part (d) through the lamp is the same as the current in part (c) through the resistor. The p.d.s for these components then conveniently sum to 14 V. If they don't spot this, then they can apply a trial-and-improvement approach. We guess a current, look up the voltage for the bulb and resistor for this current. If the two voltages sum to 14V, then we are correct. If not, we try again with a different guessed current.

24.10 First find the voltage across the resistor. Next work out the resistance using $R = V/I$, remembering that we have been told the current in mA.

Section 25 – Characteristics

More challenging questions: 25.3 – 25.5 Back to top

Recall and apply formulas:

$$V = IR$$

The basic point – characteristics are current vs voltage graphs for components.

Make it clear to classes that to calculate resistance we use $R = V \div I$. This is **only** the same as the gradient of the line for an ohmic conductor with V plotted on the y axis. Moreover, calculating a gradient involves more work than reading the corresponding current and voltage values and calculating $V \div I$. Those students progressing to A Level and beyond will learn that measuring the gradient of a V vs I graph of *experimentally obtained results* can be helpful to eliminate a zero error; for most students at this level, the key point remains: use the formula to find R, NOT the gradient of a graph.

25.3,5 Both questions are multiple choice. Both demand good understanding of the graph.

Section 26 – Power Calculations

More challenging questions: 26.9, 26.10 Back to top

Recall and apply formulas:

$$P = \frac{E}{t}$$

$$P = VI$$

$Q = It$ *(only in Qu 26.9)*

Two equations are used here: $P = E/t$ for 26.1 and $P = VI$ for 26.2. From then on, the student must choose which equation to use for each question.

26.9 b) This question requires $Q = It$.

26.10 With 'half strength electricity' (ie. 115 V rather than 230 V) we need twice as much of it. Put more scientifically, to get the same $P = IV$ with half the V we need twice the I.

Section 27 – Resistance and Power

More challenging questions: 27.6, 27.7 [Back to top]

Recall and apply formulas:

$$V = IR$$

$$P = IV$$

$$P = I^2R$$

The new concept here is the two-stage calculation, as demonstrated in the worked examples. Ensure that students lay out their working clearly and explicitly state the 'intermediate quantity' (e.g. in 27.1 they write down the voltage).

27.6 As the voltage across the lamp is half of the supply voltage, the voltage across the resistor must be the same. We are told the resistance of the lamp, and now know the p.d. across it. We can now calculate the current through the lamp and then the power dissipated in the lamp.

27.7 a) Use $I = P/V$ = 68 MW / 400 kV, remembering to take account of both unit prefixes.

b) Use $V = IR$, using the answer from part (a) as the current in the wire.

c) Use power $ssipated\ in\ wire = current\ in\ wire \times voltage\ across\ wire$. Current and voltage have both been calculated in the previous parts. Note that in this question we must not take V = 400 kV, as this is the voltage across the whole circuit not just the wire.

Section 28 – E-M Induction and Generators ♡

More challenging questions: 28.5 Back to top

Current GCSE specifications expect students to be able to describe electromagnetic induction including the factors that affect the size and direction of the induced potential difference. The questions in this section encourage students to make quantitative predictions (hence the heart symbol). This should help students to gain confidence in their understanding.

28.1 a) The direction of motion is now up (it was down) so current goes the other way, and the needle moves to the left while the wire is moving.

b) No motion, no induction, zero reading on meter.

28.2 To get a hint: what information was given in the diagram in 28.1 but is missing from the diagram of 28.2?

28.3-4 These are questions testing understanding of proportionality. Methods of handling these questions were presented in Section 7. Some cases should be intuitive – 28.3a has a speed doubling, so the voltage doubles.

28.5 An explanation for teachers: the potential difference induced in the coil is proportional to the rate of cutting flux (or field lines). At the instant shown in the diagram, the movement of the wire in the coil is along the field lines. Two alternative explanations:

1. At the moment shown in the diagram, for a brief moment, neither pole of the magnet is moving into or out of the coil (the poles are moving parallel to the plane of the coil, for an instant).

2. At this instant, the wires are moving along field lines, and not crossing them.

In (a) the induced potential difference is in the opposite sense (as the motion of the field is reversed). In (c) the max and min voltage will double (the zeros will remain zero), and the frequency of the alternating current will also double. The situation here is a very simplified version of what is going on in power station generators, which make alternating current. In a power station, if the frequency is right and the voltage is wrong, the magnet (which is an electromagnet) is made stronger or weaker to provide the correction.

Section 29 – Transformers

More challenging questions: 29.7, 29.9, 29.10 Back to top

Select and apply formulas:

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$V_p I_p = V_s I_s$$

This section gives plenty of practice of these two formulas. Students sometimes find it confusing that (in a step up transformer) V has increased, but I has decreased; it conflicts with $V = IR$. If you find students struggling with this, then highlight that $V = IR$ tells us the relationship between V, I and R for a (resistive) component. Meanwhile, $V_p I_p = V_s I_s$ follows from the assumption that the efficiency is 100% - $power\ in = power\ out$.

29.1 Students usually find this straightforward, but they forget what 'step up' means. If the voltage has gone up ($V_s > V_p$) then it is a step up transformer.

29.4 The frequency is a red herring. It does not affect the voltages, and when we come to (b), the output (secondary) frequency is the same as the input (primary) frequency.

29.6 Watch out – this is a battery, and gives out direct current (d.c.). The magnetic field produced by the current in the primary coil will be constant, so no voltage is induced in the secondary.

29.7 This question builds on 27.7. In (c) $P = IV$ where V is not 22 kV, but is the voltage across the wire (current in wire × resistance of wire).

29.9 Power needs to be the same in primary and secondary. Here the secondary voltage is one tenth of the primary voltage. To make the powers equal, the secondary current must be 10× larger than the primary current.

29.10 Work out what the current would be if the transformer were 100 % efficient, and then take 97% of the answer. Inefficiencies reduce the current, but not the voltage. As $P = IV$, and V has not changed when the inefficiency is taken into account, P reduces by the same percentage as I.

ENERGY

Section 30 – Thermal Energy

More challenging questions: 30.5, 30.6, 30.8, 30.9 Back to top

Recall and apply formulas:

$$P = \frac{E}{t} \;;\; E = Pt$$

Select and apply formulas:

$$\Delta E = mc\Delta\theta$$

The English exam boards use variations of the formula for specific heat capacity: some using ΔQ rather than ΔE; all use $\Delta\theta$.

Most questions require straightforward application of the formula. Several questions require additional steps/complications. These include: unit conversions (e.g. g / kg); linking power, energy, time; linking volume, density, mass; accounting for thermal losses. You may wish to save the more challenging questions until students have learned about power as energy transfer per unit time.

30.5 This includes several steps: calculation of the volume of air in the room, the mass of air (from the density provided in the question), the energy change, and then the time taken for a 1 kW heater to warm the air by that amount.

30.6 Part (b) relates power, energy and time.

30.8 This requires students to take account of known thermal losses in calculating specific heat capacity. Energy must be calculated from power and time.

30.9 Energy must be calculated from power and time. The mass is given in grams.

Section 31 – Latent Heat

More challenging questions: 31.3, 31.4, 31.9 Back to top

Select and apply formulas:

$\Delta E = mc\Delta\theta$ *(for 31.3 only)*

$E = mL$

In the formula for specific latent heat, some boards use Q, others use E.

Questions throughout this section include conversion between grams and kilograms.

It may not be obvious to students that the mass in the calculation is the mass that changes state. In some questions, that mass might need to be used in a second step, e.g. to find the mass that remains after a mass m has evaporated.

31.3 In part (b) the water starts well below boiling point, so the thermal energy of the water rises as its temperature rises.

31.4 Energy must be calculated from power and time. The time is given in hours.

31.9 Part (a) includes several steps – including several unit conversions and remembering that the question asks for mass remaining (not the mass that has evaporated).

Section 32 – Payback Times ♡

More challenging questions: 32.2, 32.3, 32.7, 32.8 [Back to top]

Recall and apply formulas:

$$P = \frac{E}{t} \ ; \ E = Pt$$

$$P = IV$$

No current GCSE specifications refer to payback times (hence the heart symbol). Nonetheless, this topic is an excellent one for students. It helps them to apply mathematical reasoning to an important everyday context - costs and savings to be made from installation of insulation, solar panels etc.

Payback time (years) = cost to install or fit ÷ annual saving.

32.2 A slight subtlety: time periods are mentioned in months and years.

32.3 The information is provided per square metre. The saving is for the installed total area.

32.7 Students need to calculate the number of hours in a year, in order to find the number of kWh generated in a year.

32.8 This involves several steps: calculate the power output of the charger; calculate the number of kWh generated per day (given the time window for which it can operate each day); find the daily monetary saving; then find the payback time.

Section 33 – Doing Work, Potential Energy and Power

More challenging questions: 33.6, 33.9, 33.10 Back to top

Recall and apply formulas:

$$W = mg$$

$$W = Fs$$

$$E_p = mgh$$

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

In this section, students practise using the formulas listed above.

Unit conversions are required for many of the questions (cm / m; g / k etc).

Some questions highlight the equivalence (when lifting objects vertically) of work = weight x height lifted ($W = Fs$) and change in gravitational potential energy = mass x g x height ($E_p = mgh$).

Two questions (33.6 and 33.9) go beyond the requirements of GCSE specifications, hence the heart symbol for these questions – see comments below for details.

33.1 Some unit conversions required in this question.

33.6 This question introduces the term "gravitational potential". This is normally introduced at A Level.

33.8 The note underneath the question highlights that power = force (parallel to motion) x speed. Students are not expected in any current GCSE specifications to know this shortcut; it would be normal to calculate the power output in such a case by calculating the distance moved (from the speed), calculating the work done and then the power.

33.9 This is easy for any student applying the formula developed above, but does not provide any scaffolding to answer the question without using $P = Fv$.

33.10 Unit conversions are the only subtlety in this question.

Section 34 – Kinetic Energy

More challenging questions: 34.7, 34.9, 34.10 Back to top

Recall and apply formulas:

$$E_k = \frac{1}{2}\, m\, v^2$$

$$E_p \ = mgh$$

This section gives plenty of practice of kinetic energy calculations, including some unit conversions (tonnes and g to kg). Students need to be clear in the meaning of the formula: that speed is squared (but mass is not). Students should also notice that kinetic energy is (clearly) not proportional to speed.

34.4 This begins with a GPE calculation. If you just want KE calculations, you may miss this out.

34.7 The question asks for the loss in KE when the car slows to half of its starting speed. There is a hint to find the KE at each speed and to find the difference. Of course, this is NOT the same as half of the KE at the higher speed.

34.9 This helps students to see that the formula for kinetic energy is equal to the work done by a constant force that accelerates an object to speed v.

34.10 Students must compare the KE and GPE of an airliner. For some, there will be additional challenge, as they are asked to express their answer of KE as a percentage of total energy (i.e. GPE + KE).

Section 35 – Efficiency

More challenging questions: 35.5 [Back to top](#)

Recall and apply formulas:

$$efficiency = \frac{useful\ output\ energy\ transfer}{total\ energy\ input\ transfer}$$

$$efficiency = \frac{useful\ power\ output}{total\ power\ input}$$ *(this formula only explicit in AQA spec)*

$$P = \frac{E}{t}$$

Select and apply formulas:

$E = mc\theta$ *(for 35.5d only)*

The formula for efficiency is worded slightly differently by the different exam boards. Also, AQA explicitly include a version in terms of power; other English boards do not. Students need to be confident to express efficiency as a decimal fraction or as a percentage (e.g. 0.63 or 63%). There is sometimes a need to exercise judgement when considering what counts as useful energy transfer, or useful work done.

35.5 This question includes different calculations in each step: (a) simple efficiency; (b) calculate the increase in thermal energy in one hour (assuming thermal = difference between electrical work done and increase in the chemical store); (c) scales the previous answer for 1 minute; (d) find the temperature rise of the battery.

35.6 Two steps required, but not scaffolded: efficiency and $E = Pt$.

35.8-10 Two steps required, but not scaffolded: efficiency and $E = Pt$.

Section 36 – Power and the Human Body ♡

More challenging questions: 36.4, 36.7 [Back to top]

Recall and apply formulas:

$$W = mg$$

$$W = Fs$$

$$E_p = mgh$$

$$P = \frac{E}{t}$$

$$P = \frac{W}{t}$$

The first two calculations in this section are applications of the standard formulas, though they will require care/thought for most students. Other questions include calculations relating to BMR (basal metabolic rate); BMR calculations are not included in any GCSE Physics specifications. Some questions involve unit conversions e.g. joules to kilocalories, MJ/day to watts.

No current GCSE Physics specifications expect familiarity with BMR or familiarity with these conversions, hence the heart symbol.

36.4 Two steps are required: find the total power supplied to the muscles from their stated efficiency; add the BMR to find the total power needed by the cyclist.

36.7 This requires varied mathematical reasoning: calculating thermal power loss per square metre; a comparison of the two children (assuming Fred is a linearly scaled enlargement of his baby sister). This second notion is subtle given the values in the question. As Fred's area is 10 times larger than that of his sister, we can assume a linear scale factor of $\sqrt{10} \cong 3.1$. Fred's mass is proportional to his volume, so it scales by the cube of the linear scale factor. We reason that Fred's basal metabolic rate is proportional to his mass. In summary, his mass is about 30 x the mass of his baby sister, whilst his surface area is 10 x bigger than hers. It is easier for him to keep warm.

Section 37 – Springs and Elastic Deformation

More challenging questions: 37.4, 37.8, 37.9 Back to top

Recall and apply formulas:

$F = kx$ *OR* $F = ke$

$W = mg$ *(37.4 only)*

Select and apply formulas:

$E = \frac{1}{2}kx^2$ *OR* $E = \frac{1}{2}ke^2$

This section covers Hooke's Law (questions 37.1-37.4) and energy stored in a stretched spring (questions 37.5-37.9). All specifications limit their scope to springs within the limit of proportionality, so the work done in stretching the spring is equal to the energy stored.

Edexcel and Eduqas specifications use x for extension; AQA uses e.

Extensions are often given in cm, so unit conversions are common (and essential to calculate energy values).

37.4 This question guides students through two situations that are more commonly met at A Level; 2 springs in series; 2 springs in parallel. In addition, students need to find the weight of the mass that hangs from the springs.

37.8 Here students must find the spring constant. The previous question includes an explicit prompt to do so; this question leaves the students to figure it out for themselves.

37.9 Part (a) asks for the energy stored with an extension of $3.0\ \mathrm{cm}$. Part (b) asks for the change in energy when the spring is released to half that extension. Many students will find the energy stored with extension $1.5\ \mathrm{cm}$, and find the difference. Some students may spot that the extension is half of its previous value, so the energy stored will be ¼ of its previous value (as $E \propto x^2$); and hence find the change in energy as ¾ of the initial energy stored. Note the units used for the force – kN.

WAVES and OPTICS

Section 38 – Wave Properties and Basic Equations

More challenging questions: 38.9, 38.10 [Back to top]

Recall and apply formulas:

$$v = f\lambda$$

Select and apply formulas:

$$T = \frac{1}{f}$$

(Only one GCSE Physics specification explicitly lists this formula, but all current GCSE specifications expect students to know the meaning of time period and frequency.)

The teacher's cloze text version is worth using here in class, as the students can discuss the answers and a discussion can ensue. It may also be worth preparing a match-up exercise for the terms and their definitions.

Please point out to students the difference between the two waves shown – particularly to recognize that 'time period' and 'wavelength' look the same. It all depends on what you are plotting – the position of the wave at one point as time develops, or the state of the wave all along its length at one particular time.

Some students will want to know the reason for the equations – if so, you may wish to expand on the text in italics below the formulae on p117. Students do find the link between frequency and time period to be clearer if a few examples have been given (e.g. T = 0.5 s, f = 2 Hz; T = 0.2 s, f = 5 Hz etc). The questions are straightforward applications of $f = 1/T$ and $v = f\lambda$. Ensure that students realise that as $f = 1/T$, $T = 1/f$ (not $f/1$).

38.6 Implicit information here is that the speed of the waves remains constant (they are all sound waves in air), so the wavelength is inversely proportional to the frequency.

38.8 Students need to remember that the frequency will not change (otherwise you have more oscillations coming into the boundary each second than coming out).

38.9 Work out the speed first (applying $v = s/t$) before substituting into the formula $f = v/\lambda$.

38.10 Remember that the wavelength must be converted from cm to m. The frequency can be calculated ($f = v/\lambda$), and then use $T = 1/f$ to find the period.

38.14 Point out that the speed of sound in solids is typically higher than that in liquids, which in turn is typically higher than that in gases – this may seem counterintuitive to the students.

38.16,17 All electromagnetic waves travel at the speed of light.

Section 39 – Reflection – Plane Mirrors ♡

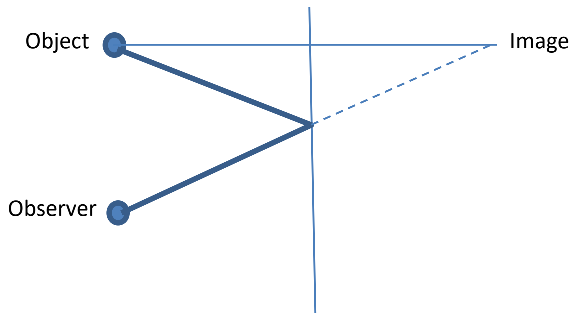
More challenging questions: 39.4 – 39.6 [Back to top](#)

Current specifications refer to qualitative drawing of ray diagrams for plane mirrors, and to the 'law of reflection'. Many of the questions in this section require students to draw more complex diagrams and to apply quantitative reasoning beyond that likely in a GCSE Physics examination (e.g. the calculation of the length of the path of a ray, by Pythagoras's Theorem), hence the heart symbol.

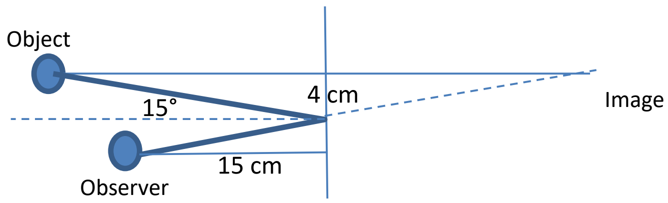
Ensure that students always draw the angles to the NORMAL, not to the surface.

39.3 After drawing the reflected rays, students should continue the lines of the reflected rays as dotted lines behind the mirror. They should meet at a point in line with the source just as far behind the mirror as the source is in front of it. This is a virtual image.

39.4 Requires a clear diagram, and a good use of Pythagoras's Theorem.



39.5 Again, the first requirement is a nice, clear, large diagram.



39.5 This builds on question 39.4.

Section 40 – Reflection – Concave Mirrors ♡

More challenging questions: NA – all multiple choice [Back to top]

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students. GCSE specifications require students to be able to draw a reflected ray or wave at a surface, but none require students to be able to infer the position, orientation, size etc of an image for a concave mirror.

Questions 1-3 require simple application of the three rules. Questions 4-7 require rays to be drawn to determine image size, position and orientation.

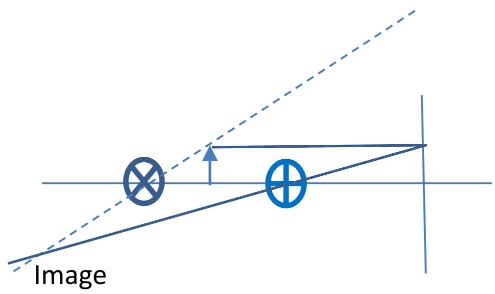
40.1 a) All reflected rays pass through F.

b) The bottom ray will be reflected back upon itself and pass through C – rays travelling along a radius are incident on the mirror along the normal line. The middle ray (which passes through F) will be reflected to travel horizontally. The top ray will reflect to pass through the point where the previous two rays cross.

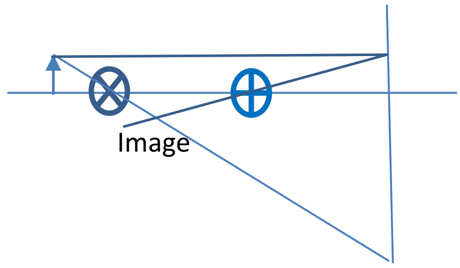
40.3 Think about the reversibility of light and the diagram in p123. All rays will end up parallel and pass down the paper.

40.4 Rays from C will bounce back to C, so the image is at C (and is real). The lateral effect of reflection ensures that the image is inverted, but the symmetry (object-mirror distance = image-mirror distance) ensures it is the same size.

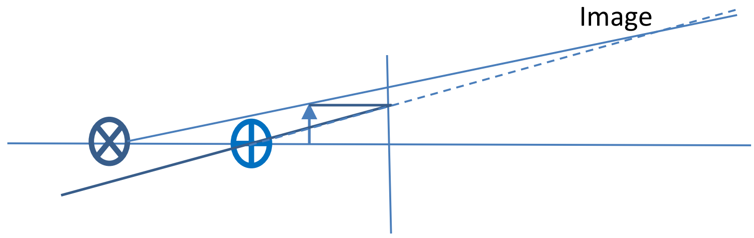
40.5 A diagram helps here, and make sure that the object is off axis, otherwise it is very difficult to work out what is going on. Draw one ray which passes through C and the object. Draw a second ray which travels horizontally from the object to the mirror (i.e. parallel to the principal axis of the mirror), and then passes through F after reflection. The image is where these two rays cross.



40.6 A diagram also helps here.



40.7 A diagram also helps here.



If you wish to use equations to predict the location of the image, the lens equation derived in section 48 also works for mirrors ($1/f = 1/u + 1/v$), although, here we regard 'v' as positive if the image is to the left of the mirror. Here u = distance from mirror to object, v = distance from mirror to image, f = focal length = half of the radius of curvature.

Please note that the diagrams are not quite 'accurate'. In practice, a spherical mirror will not focus accurately (either a parabola or ellipsoid is needed for exact work) - only the rays near the axis follow the rules given.

Section 41 – Reflection – Convex Mirrors ♡

More challenging questions: 41.2, 41.3 [Back to top]

The heart symbol in the title implies that this section is not usually examined at GCSE, so would usually only be set when wishing to extend the experience of students. GCSE specifications require students to be able to draw a reflected ray or wave at a surface, but none require students to be able to infer the position, orientation, size etc of an image for a convex mirror.

41.1 In this situation, the rays all reflect so that they appear to come from F.

41.2,3 If the teacher wants to check answers, they may use the formula $1/f = 1/u + 1/v$.

For a convex mirror, we take f as negative (so here, $f = -7.0$ cm), and the negative sign of v indicates that the [virtual] image is to the right of the mirror. The magnification is given by v/u just as in lens work.

Section 42 – Refraction ♡

More challenging questions: 42.1, 42.4, 42.5

[Back to top]

All specifications suggest that students should be able to describe refraction at material interfaces, but none expect calculations of refractive index (neither relating to wave speeds, nor to wavelengths), hence the heart symbol. However, all specifications do suggest that students should refer (in their explanation/description of refraction) to the change of wavelength and wave speed (on entering a denser medium). Students should be able to explain dispersion in terms of different wavelengths (of different colours) in glass.

42.1 These calculations are beyond the requirements of all GCSE specifications. However, this quantitative work can help students to understand the phenomenon of refraction. Ensure that students have a good understanding of standard form. The exercises in section 2 might help. It is probably a good idea for students to use brackets when keying questions into the calculator – e.g. in (b) to explicitly key in $(3.0 \times 10^8) \div (1.9 \times 10^8)$. Warn students that if they get a refractive index smaller than 1.00, they have probably made a mistake. It is perhaps worth pointing out that denser materials usually have a higher refractive index (and a slower speed of light) than less dense materials; but there are exceptions. Turpentine has a higher refractive index than water, but it is less dense.

42.3 If they reckon it slows down (i.e. refractive index gets larger), then put T, otherwise put A.

42.4 Hint: the more it slows down, the more it will bend. The theory is explained in section 46.

42.5 This question requires the student to have read 42.4 and to know that violet light is slower in glass than red light.

Section 43 – Total Internal Reflection ♡

More challenging questions: 43.4 [Back to top]

The heart symbol appears on this page, as only one specification (Edexcel) mentions total internal reflection (“Explain, with the aid of ray diagrams, reflection, refraction and total internal reflection (TIR), including the law of reflection and critical angle”). No calculations are required by this specification; there are no calculations in this section. These questions require students repeatedly to decide what occurs: refraction, or total internal reflection.

43.1 If students get stuck, they should be pointed to the sentence immediately above the question.

43.2 This point is often not taken seriously enough by students. You ONLY get total internal reflection if the light approaches the boundary from the side with the slower speed of light.

43.3 A checklist may help:

Is the light moving from a ‘fast’ place to a ‘slow’ place? If so, it will REFRACT regardless of its angle of incidence (there is no need to look up the critical angle).

If it is moving from ‘slow’ to ‘fast’, then check the angle of incidence. If it is larger than the critical angle, then you will have total internal reflection. Otherwise it will refract.

43.4 Here students apply their knowledge to a number of situations. They must pay attention to the direction of the ray. Reflected rays need to obey the rules of reflection. Refracted rays need to bend the right way (if they bend). Consistency is tested also, so parallel rays before refraction would bend by the same amount after refraction.

Section 44 – Diffraction ♡

More challenging questions: 44.4, 44.7

Back to top

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students.

Current GCSE specifications do not mention diffraction at all.

44.1 In this question, it is very simple because the aperture is either much bigger or much smaller than the wavelength. If the aperture is much bigger than the wavelength, you will not see the diffraction; if it is much smaller, diffraction will be complete (waves spread out equally in all directions with no possibility of any kind of shadow).

44.2 An 'obvious shadow' means 'not much diffraction', and accordingly, the aperture must be larger than the wavelength.

44.3 The diffraction angle is the angle between the 'straight through' direction and the first dark region (which we could even think of as the beginning of the shadow). As students will find out at A Level, this angle is given by $sin^{-1}(\lambda/a)$ where a is the width of the aperture. So, in this question, we put the situations in order of λ/a with the largest first.

44.4 In a really good telescope, the sharpness of the images is only limited by diffraction. To gain equal precision, the quotient λ/a must be the same for the two telescopes (ie. $\frac{500\text{ nm}}{6.0\text{ cm}} = \frac{30\text{ cm}}{W}$ where W is the width of the dish).

44.5,6 The distance between the wave fronts should be kept the same, whereas in part (a) there will be less spreading out; in (c) there will be lots of diffraction; and in 44.6c the obstruction will have hardly any effect.

44.7 Here the diffraction angle is again $sin^{-1}(\lambda/a)$ where the angle made by the pixel at the eye is $tan^{-1}(W/d)$ where *W* is the width of the pixel and *d* is the distance from eye to pixel. For small angles, like these, the sine and tangent of an angle are very similar, so we can write $\lambda/a = W/d$, so $d = Wa/\lambda$. Here *W* = 1 mm in both cases, and λ is the wavelength of light, so *d* is proportional to *a* (the width of the pupil/lens). In the second case, *W* has got bigger by a fraction 25 / 7 = 3.37, so the distance will increase by the same factor.

44.8 'Most parallel' means 'least diffraction' so we want *λ/a* to be as small as possible. Therefore, we list the situations in increasing order of *λ/a*.

Section 45 – Seismic Waves and Earthquakes ♡

More challenging questions: 45.1, 45.2 [Back to top]

Recall and apply formulas:

$$s = v\,t \qquad distance\ travelled = (average)\ speed \times time$$

Current GCSE specifications refer to qualitative understanding of the application of waves to investigating the structure of the Earth. Calculations in this page help students to see how this knowledge is applied in practice, and how it can yield information such as the thickness of the mantle.

45.1 (a) The question gives the depth of the mantle as 2900 km, so the distance travelled to the boundary and back again is $2 \times 2900\ \mathrm{km} = 5800\ \mathrm{km}$, and the time will accordingly be $5800\ \mathrm{km}\ \div\ (6\ \mathrm{km/s})$.

(b) We use a similar method to that in (a) to get the time for a P wave, then subtract this from the answer in part (a). Please note that the answer is NOT given by dividing 5800 km by the difference between the speeds of P and S waves of 5 km/s.

45.2 Always work out the delay by subtracting the P wave time from the S wave time. The final row can either be calculated as in Example 2 (harder than GCSE questions tend to be), or by using proportionality arguments from one of the previous rows; e.g. if 200 km has a P wave time of 40 s, an S wave time of 25 s, and a delay of $40\ \mathrm{s} - 25\ \mathrm{s} = 15\ \mathrm{s}$, then a situation where the delay is 8 s will have distances and times equal to those of the 200 km situation multiplied by $\frac{8}{15}$.

45.3 This is best drawn. You know the distance from each seismometer – and draw all the points at this distance (e.g. using a pair of compasses). The circles will generally intersect at two places, and the third circle (from the third seismometer) helps you work out which is origin of the waves. In practice, the circles won't all touch at this point – this could be because of inaccuracies (and this gives us an idea of the uncertainty in the measurement), or because the actual focus is below the surface of the Earth, and a precise calculation can enable us to work out how deep it is.

Section 46 – Refractive Index and Snell's Law ♡

More challenging questions: 46.8, 46.10

[Back to top](#)

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students.

All specifications suggest that students should be able to describe refraction at material interfaces, but none expect calculations of refractive index (neither relating to wave speeds, nor to wavelengths). However, all specifications do suggest that students should refer (in their explanation/description of refraction) to the change in wavelength and wave speed (on entering a denser medium). Students should be able to explain dispersion in terms of different wavelengths (of different colours) in glass. Furthermore, GCSE standard practical tasks include refraction of light through a Perspex/glass block. Some students will find that Snell's law explains what is otherwise a mathematical mystery. Edexcel International GCSE and Cambridge IGCSE both expect students to be able to use Snell's Law.

46.1 We use the method of Example 1: speed = 3×10^8 / refractive index.

46.2 We rearrange the formula $n = 3{\times}10^8 / (1.59 \times 10^8)$. Students who get $n < 1$ put the numbers in the formula the wrong way round. Anyone who gets an answer of the order 10^{16} has not worked carefully with their calculator. Encourage them to (i) use the [×10x] button, and (ii) to put the denominator in brackets.

46.3 Here we use the exact method of Example 2.

46.4 Here the light is leaving, so in (a) we do $\sin^{-1}\{1.50 \times \sin(20°)\}$. Notice that we multiply by the refractive index rather than divide to ensure that the angle is made larger rather than smaller.

46.8 In this question, do not be tempted to use a short cut with an n = 0.04. It will not work. Work out the angles of refraction of both colours to about 5 significant figures, and then subtract to get the difference.

46.10 Using the hint, we would say that the angle in the air gap would be $A = \sin^{-1}\{1.34 \times \sin(40°)\}$, and then the angle in the glass would be $B = \sin^{-1}\{\sin(A)/1.50\}$. Putting the two equations together, you get an angle of $B = \sin^{-1}\{1.34 \times \sin(40°) / 1.50\}$. It is easier to forget the air gap, and use the general formula given just below 46.10. With this we can write $1.34 \times \sin(40°) = 1.50 \times \sin(B)$ and work it out from there.

Section 47 – Calculating Critical Angles ♡

More challenging questions: 47.5 – 47.9

[Back to top]

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students. Edexcel International GCSE and Cambridge IGCSE both expect students to be able to calculate critical angles.

47.1,2 In the first two questions, we use $i_c = sin^{-1}(1/n)$.

47.3,4 Here we use $n = 1/sin(i_c)$.

47.5 Without air involved, we have to use the more general version of Snell's Law given just above q47.4, namely $i_c = sin^{-1}(n_2/n_1)$. Note that the smaller refractive index has to go on top if you are to get a critical angle. This is because if light is travelling through a boundary to a higher refractive index material, you will never get total internal reflection (only refraction).

47.6 This has similar methodology to the previous question.

47.7 Speed is proportional to frequency, so the new speed is $\left(\frac{451}{600}\right) \times 3 \times 10^8 \text{ m/s}$. This enables you to calculate the refractive index – which turns out to be the same as 600/451.

47.8 This can be done using the same equation and methodology as q47.6.

47.9 This is a two-stage problem. The angles enable you to work out the refractive index of ice. Once you know this, you can use the same formula as in q47.1 to get the critical angle.

Section 48 – Convex Lenses ♡

More challenging questions: 48.9, 48.10 Back to top

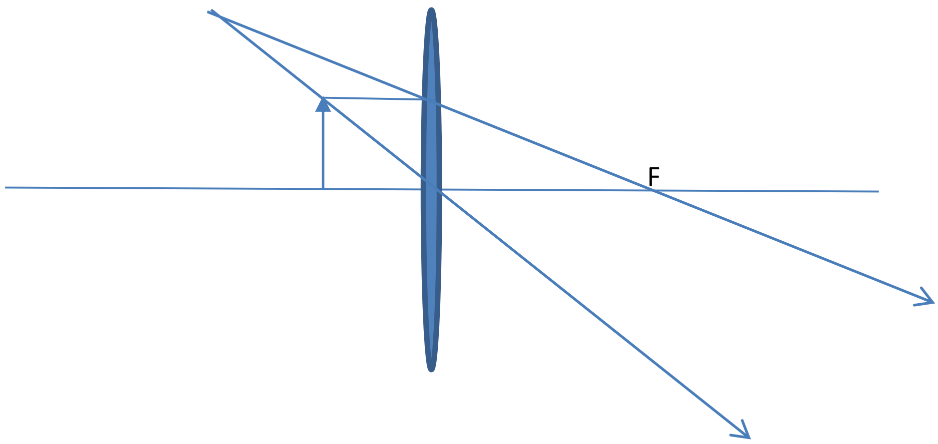
Recall and apply formulas:

$$magnification = \frac{image\ height}{object\ height}$$ *(AQA only)*

The heart symbol appears on this page, as many of the questions in this section lie beyond the scope of current GCSE specifications. The table below shows the level of coverage expected by each specification, for the questions in this section.

Qus	AQA	Edexcel	OCR A	OCR B	Eduqas
48.1	Ray diagrams including scale diagrams	Use ray diagrams to show the similarities and differences in the refraction of light by converging and diverging lenses	Qualitative use of ray diagrams		
48.2-6	These questions apply $P = \frac{1}{f}$. This formula is not mentioned in any specification.				
48.7-9	These questions apply $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$. This formula is not mentioned in any specification.				
48.10	Application of formula for magnification	No mention of formula for magnification			

48.1 In cases (a) to (c) the diagram will be very similar to the large diagram above the pink box. In case (d), the rays to the right of the lens diverge, so they do not form an image to the right of the lens. The image can be found by extending the rays to the left of the lens where they will meet, as shown below. This is a virtual image.



48.9 These can be worked out using the same formula as in Example 2. The simplest is to key it into a calculator as $(f^{-1} - u^{-1})^{-1}$. Thus, the answer to (a) becomes $(5^{-1} - 20^{-1})^{-1}$. Notice that our formula is quite happy with distances in centimetres as long as ALL the lengths are in centimetres.

48.10 In (b) and (d) you will need to work out the focal length first, or notice that our equation for image distance $v = (1/f - 1/u)^{-1} = (P - 1/u)^{-1}$. If the image distance has a negative value for v, then the image is virtual. Once v has been calculated the magnification is given by v/u (where we ignore any minus sign).

Section 49 – Concave Lenses ♡

More challenging questions: 49.4, 49.5 Back to top

Recall and apply formulas:

$$magnification = \frac{image\ height}{object\ height}$$ *(AQA only)*

The heart symbol appears on this page, as many of the questions in this section lie beyond the scope of current GCSE specifications. The table below shows the level of coverage expected by each specification, for the questions in this section.

Qus	AQA	Edexcel	OCR A	OCR B	Eduqas
49.1,4	Ray diagrams including scale diagrams	Use ray diagrams to show the similarities and differences in the refraction of light by converging and diverging lenses	Qualitative use of ray diagrams		
49.2,3	These questions apply $P = \frac{1}{f}$. This formula is not mentioned in any specification.				
49.5	These questions apply $\frac{1}{v} = \frac{1}{f} - \frac{1}{u}$. This formula is not mentioned in any specification.				
	Application of formula for magnification	No mention of formula for magnification			

49.1 Situation (a) is very similar to the large diagram just above the pink box. Situation (b) is drawn the same way – unlike with convex lenses, the fact that the object is the other side of the focal point F makes little difference.

49.2 Remember to put focal length into metres before using $= \frac{1}{f}$, and ensure that all concave lenses are given negative signs.

49.3 When using $f = \frac{1}{D}$ the focal lengths come out in metres.

49.4 Here we use the same formula as in Section 48 (e.g. 48.9 – namely $v = (\frac{1}{f} - \frac{1}{u})^{-1}$. Here f is negative – when putting this into the calculator, it is better to use the ‘negation’ as opposed to the ‘minus’ key to ensure that your intentions are not misunderstood (‘1 divided by negative 5’ is nice and clear: ‘1 divide minus 5’ is not: imagine if the calculator could speak “subtract or divide – one or the other I can do – please make up your mind”).

49.5 This question can be approached in the same way as 48.10. If the lens is convex, put the focal length as positive; if the lens is concave, put the focal length as negative. If v comes out negative, the image is virtual.

Section 50 – Intensity and Radiation ♡

More challenging questions: 50.4, 50.5 [Back to top]

Recall and apply formulas:

$$efficiency = \frac{useful\ output\ energy\ transfer}{total\ energy\ input\ transfer}$$

$$efficiency = \frac{useful\ power\ output}{total\ power\ input}$$ *(this formula is only explicit in AQA spec)*

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students. No specifications include calculations of intensity. One question in this section includes an efficiency calculation.

50.1 This question aims to lead the student through the reasoning given at the top of p152 to justify the formula $I = \frac{P}{4\pi\, r^2}$.

(a) Use $Intensity = Power\ /\ Area$.

(c) The area is the surface area of the sphere $A = 4\pi r^2$ with $r = 3$ m.

(e) $Intensity = \frac{Power}{Area} = \frac{60\ \mathrm{W}}{area\ calculated\ in\ part\ (c)}$

50.2 (a) Use $Intensity = Power\ /\ Area$, where Area = surface area of sphere of radius 400 m.

50.4 For (a) use the same method as in 50.2. Part (b) is equal to part (a) [they are equally bright], and for (d) the answer is very large.

50.5 In (a), we rearrange $I = \frac{P}{A}$ to give $= \frac{P}{I}$, where the power is 2×10^9 W and the intensity comes from 50.4(b).

In (b) we will need an appropriately increased area to make up for the 20% efficiency.

NUCLEAR

Section 51 – Atomic Numbers and Nomenclature ♡

More challenging questions: 51.3 – 51.7 Back to top

Current GCSE specifications require students to be able to use nuclear notation. Questions 51.1 – 51.3 give practice of interpreting and using nuclear notation. The heart symbol appears on this page, as questions 51.4 – 51.7 go beyond the scope of current specifications – by considering the quark composition of protons and neutrons; and by explaining beta decays in terms of quarks (Edexcel does specifically include beta plus decay, but not the quark composition of nucleons).

51.3 As this is an ion, the number of electrons is not the same as the proton number.

51.4 Quark composition of a proton.

51.5 Quark composition of a neutron.

51.6 Explanation of beta minus decay in terms of quarks.

51.7 Explanation of beta plus decay in terms of quarks.

Section 52 – Radioactive Decay ♡

More challenging questions: 52.5, 52.10 Back to top

This section gives students practice of using nuclear notation to describe some common decays. These include several alpha and beta minus decays; also included is one gamma emission and two beta plus decays, hence the heart symbol for questions 52.5 and 52.10. Beta plus decay is included explicitly in Edexcel's specification, but not in any other GCSE specifications; OCR B and AQA explicitly state that a beta particle is an electron.

52.3 Gamma emission – gamma has no mass or charge.

52.5 Beta plus.

52.10 Beta plus.

Section 53 – Half-Life

More challenging questions: 53.4, 53.5 *Back to top*

Most GCSE specifications refer to expressing the decline, expressed as a ratio, in the radioactive emission after a given (integer) number of half-lives. Most questions in this section cover exactly that requirement. Question 53.5 goes beyond this level by considering a non-integer number of half-lives, hence the heart symbol for this question.

53.4 Part (f) asks for the fraction after n half-lives. For some this symbolic approach will be challenging, but this question is preparation for question 53.5.

53.5 Question 53.4 prepares the ground for this question. Here, students are given the initial activity of a sample and they are asked to calculate the activity after one half of one half-life has passed. Those who are confident with exponents in maths may be quite happy with 2^x where x is a rational fraction.

Section 54 – Fission – The Process

More challenging questions: 54.1(e), 54.4, 54.10 Back to top

GCSE specifications require students to be able to write balanced equations and to understand that the total number of protons remains the same after a nuclear process (and likewise for neutrons). This section gives practice of applying this knowledge. Some questions require students to look up information from a periodic table, and others test factual recall. All questions beyond the standard nuclear decay equations are described below.

54.1 In part (e), students will need to look up two of the atomic numbers to be able to calculate the third.

54.4 Students will need to calculate the atomic number and look up the symbol for the element.

54.5 Know two viable fuels for nuclear fission.

54.6 Know why so many different isotopes are among the fission products and why this makes nuclear waste management more challenging.

54.7 What happens to excess neutrons? Edexcel makes explicit reference to the action of control rods and moderators. Meanwhile, Eduqas states “details of control mechanism not required”.

54.8 This asks why we miss out intermediate steps in nuclear equations.

54.9 In part (c), students need to identify an element from the atomic number; some GCSE specifications state that this is required for common elements and particles. This element appears elsewhere on the page, so most students will not need to look it up in a periodic table.

54.10 Several parts of these questions include processes that would not normally be studied at GCSE level.

Section 55 – Fission – The Reactor ♡

More challenging questions: NA – all are multiple choice Back to top

This section consists of questions asking for short descriptions and short explanations relating to fission reactors. The level of detail may be more than is required of some specifications.

Section 56 – Energy from the Nucleus – Radioactivity and Fission ♡

More challenging questions: 56.1, 56.2, 56.3 Back to top

All questions here require the application of $E = mc^2$. This is not included in any GCSE specifications, hence the heart symbol. However, some students will find satisfaction in being able to apply this widely known equation.

Dealing with nuclear masses requires confidence with standard form (or with other exponential notation). The changes in masses are small fractions of these small masses, so students need to keep all decimal places in their calculations (especially before completing the subtraction to find the change in mass), only rounding as a final step.

56.2, described in more detail below, is a structured question that compares the quantities of waste produced by (a) a fission reactor and (b) a coal fired power station.

56.1 Calculations of $E = mc^2$ for 5 different alpha emissions.

56.2 Parts (a) to (d) end in a calculation of energy provided by one fission. Parts (e) to (g) lead to the mass of uranium that is needed for one year of operation of a 3.0 GW power station. In parts (i) to (l), we calculate the size of the storage facility needed to store 20 years' worth of used fuel. In parts (m) and (n), we calculate (for a comparable coal burning power station) the mass of waste products and the volume of oxygen needed to burn the coal for *1 day* of operation.

56.3 A calculation of $E = mc^2$ for one fission reaction.

Section 57 – Fusion – The Process ♡

More challenging questions: 57.2 [Back to top]

All GCSE specifications expect students to be able to describe nuclear fusion. The level of detail expected may differ between specifications, but all refer to decrease in mass and the release of energy when fusion occurs. These questions expect students to know that high temperatures / pressures are required in order to overcome the electrostatic repulsion between the positively charged nuclei. The questions described below go beyond this level of knowledge – some students will appreciate the extra detail.

57.2 In part (c) students will need to understand that protons can transform into neutrons by emitting a positively charged particle. In part (d) they are asked what happens to this particle after it is emitted. Most specifications make no mention of any antimatter particles.

57.3 This asks for the temperature for fusion to occur.

57.4 The purpose of the first fusion device (tested in the 1950s).

57.5 CNO cycle.

Section 58 – Energy from the Nucleus – Fusion ♡

More challenging questions: 58.1, 58.5 [Back to top]

All questions here require the application of $E = mc^2$. This is not included in any GCSE specifications, hence the heart symbol. Fission and fusion are compared - energy from one reaction, and energy per kilogram.

58.1 This question guides students to calculate the mass of hydrogen fuel required per year by a 3 GW fusion reactor.

58.2 We find energy per reaction (using results from 56.2d and 58.1d).

58.3 We find energy per kilogram (using results from 56.2e and 58.1f).

58.5 Calculation of $E = mc^2$ for several fusion reactions, including fusion of Fe and Fe to Te (an endothermic reaction).

GAS

Section 59 – Boyle's Law

More challenging questions: 59.2, 59.4, 59.8 [Back to top]

Recall and apply formulas:

$P = \frac{F}{A}$ *(This is in Physics specifications, but not in those for Science.)*

Select and apply formulas:

$pV = k$ *(This is in Physics specifications, but not in those for Science.)*

This section gives practice converting between temperatures in degrees Celsius and kelvin; it helps students to relate pressure and area to force; it applies the formula for Boyle's Law.

59.2 This includes conversion from the non-standard unit mbar to pascal. Then students have to calculate a difference between the force applied for two different pressures. This can be achieved by using the pressure difference. A slightly longer alternative is to calculate the force applied by each pressure and find the difference between those forces.

59.3 Here, students must order phrases to create an explanation of how a gas exerts a pressure on the walls of its container.

59.4 Parts (a)-(c) are simple applications of $pV = k$ (or proportionality). In parts (d) and (e), students must consider (qualitatively) the effect of squashing the gas quickly, in terms of the speed of the molecules of the gas and in terms of the pressure exerted by the gas.

59.8 This asks what graph (showing p on the y-axis) would give a straight line.

59.10 Straightforward conversions between degrees C and kelvin.

Section 60 – The Pressure Law ♡

More challenging questions: 60.5, 60.6 Back to top

The heart symbol appears on this page as the treatment of the pressure law in current Physics GCSE specifications is qualitative (apart from Edexcel International GCSE), so requires no calculations using $\frac{p_{after}}{T_{after}} = \frac{p_{before}}{T_{before}}$. Nonetheless, many students have a better grasp of the idea and get more out of this topic if they can do calculations. Students are expected to be able to use the particle model to explain qualitatively the relationship between the temperature of a gas and its pressure at constant volume.

60.5, 6 These questions ask for the answer in terms of percentage change in pressure when heating or cooling a gas. This adds an extra step, or requires students to confidently handle percentages and proportion.

Section 61 – Charles' Law ♡

More challenging questions: 61.5 Back to top

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students. (A qualitative understanding of Charles' Law is mentioned in the IGCSE specification.)

61.5 This includes several challenges. First it helps to draw a diagram to understand that the volume is proportional to the length of the air column; thus students can work in terms of the proportionality $l \propto T$. The cross section of the tube is not explicitly mentioned (and there is certainly not a value provided), so working algebraically is essential here. In parts (d) and (e), students have to calculate the change in length, rather than the length at a certain temperature. For some this will be an extra step, others will use proportionality.

Section 62 – The General Gas Law ♡

More challenging questions: 62.5, 62.10 [Back to top]

The heart symbol in the title implies that this section is not examined at GCSE, so would usually only be set when wishing to extend the experience of students.

62.5 This question gives the percentage change in volume, along with initial and final temperatures. Given the initial pressure, students have to find the final pressure. This adds an extra step, or it requires students to confidently handle percentages and proportion.

62.10 Again the pressure change is given in terms of percentage change. The volume change is not provided directly – students are told the percentage increase in the radius of the spherical balloon. Students will have to be able to work algebraically and to be able to deal confidently with proportion and percentage.