# A-LEVEL
# PHYSICS
# 7408/3BC

Paper 3 Section B Engineering physics

**Mark scheme**

June 2022

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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts. Alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Examiner.

It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of students' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

Further copies of this mark scheme are available from aqa.org.uk

# Physics - Mark scheme instructions to examiners

## 1. General

The mark scheme for each question shows:

- the marks available for each part of the question
- the total marks available for the question
- the typical answer or answers which are expected
- extra information to help the Examiner make his or her judgement and help to delineate what is acceptable or not worthy of credit or, in discursive answers, to give an overview of the area in which a mark or marks may be awarded.

The extra information is aligned to the appropriate answer in the left-hand part of the mark scheme and should only be applied to that item in the mark scheme.

At the beginning of a part of a question a reminder may be given, for example: where consequential marking needs to be considered in a calculation; or the answer may be on the diagram or at a different place on the script.

In general the right-hand side of the mark scheme is there to provide those extra details which confuse the main part of the mark scheme yet may be helpful in ensuring that marking is straightforward and consistent.

## 2. Emboldening

**2.1** In a list of acceptable answers where more than one mark is available 'any **two** from' is used, with the number of marks emboldened. Each of the following bullet points is a potential mark.
**2.2** A bold **and** is used to indicate that both parts of the answer are required to award the mark.
**2.3** Alternative answers acceptable for a mark are indicated by the use of **or**. Different terms in the mark scheme are shown by a / ; eg allow smooth / free movement.

## 3. Marking points

### 3.1 Marking of lists

This applies to questions requiring a set number of responses, but for which candidates have provided extra responses. The general principle to be followed in such a situation is that 'right + wrong = wrong'.

Each error / contradiction negates each correct response. So, if the number of errors / contradictions equals or exceeds the number of marks available for the question, no marks can be awarded.

However, responses considered to be neutral (often prefaced by 'Ignore' in the mark scheme) are not penalised.

### 3.2 Marking procedure for calculations

Full marks can usually be given for a correct numerical answer without working shown unless the question states 'Show your working'. However, if a correct numerical answer can be evaluated from incorrect physics then working will be required. The mark scheme will indicate both this and the credit (if any) that can be allowed for the incorrect approach.

However, if the answer is incorrect, mark(s) can usually be gained by correct substitution / working and this is shown in the 'extra information' column or by each stage of a longer calculation.

A calculation must be followed through to answer in decimal form. An answer in surd form is never acceptable for the final (evaluation) mark in a calculation and will therefore generally be denied one mark.

## 3.3 Interpretation of 'it'

Answers using the word 'it' should be given credit only if it is clear that the 'it' refers to the correct subject.

## 3.4 Errors carried forward, consequential marking and arithmetic errors

Allowances for errors carried forward are likely to be restricted to calculation questions and should be shown by the abbreviation ECF or *conseq* in the marking scheme.

An arithmetic error should be penalised for one mark only unless otherwise amplified in the marking scheme. Arithmetic errors may arise from a slip in a calculation or from an incorrect transfer of a numerical value from data given in a question.

## 3.5 Phonetic spelling

The phonetic spelling of correct scientific terminology should be credited (eg fizix) **unless** there is a possible confusion (eg defraction/refraction) with another technical term.

## 3.6 Brackets

(…..) are used to indicate information which is not essential for the mark to be awarded but is included to help the examiner identify the sense of the answer required.

## 3.7 Ignore / Insufficient / Do <u>not</u> allow

'Ignore' or 'insufficient' is used when the information given is irrelevant to the question or not enough to gain the marking point. Any further correct amplification could gain the marking point.

'Do **not** allow' means that this is a wrong answer which, even if the correct answer is given, will still mean that the mark is not awarded.

## 3.8 Significant figure penalties

Answers to questions in the practical sections (7407/2 – Section A and 7408/3A) should display an appropriate number of significant figures. For non-practical sections, an A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the **final** answer in a calculation to a specified number of significant figures (sf). This will generally be assessed to be the number of sf of the datum with the least number of sf from which the answer is determined. The mark scheme will give the range of sf that are acceptable but this will normally be the sf of the datum (or this sf -1).

An answer in surd form cannot gain the sf mark. An incorrect calculation **following some working** can gain the sf mark. For a question beginning with the command word 'Show that…', the answer should be quoted to **one more** sf than the sf quoted in the question eg 'Show that X is equal to about 2.1 cm' –

answer should be quoted to 3 sf. An answer to 1 sf will not normally be acceptable, unless the answer is an integer eg a number of objects. In non-practical sections, the need for a consideration will be indicated in the question by the use of 'Give your answer to an appropriate number of significant figures'.

## 3.9 Unit penalties

An A-level paper may contain up to 2 marks (1 mark for AS) that are contingent on the candidate quoting the correct unit for the answer to a calculation. The need for a unit to be quoted will be indicated in the question by the use of 'State an appropriate SI unit for your answer'. Unit answers will be expected to appear in the most commonly agreed form for the calculation concerned; strings of fundamental (base) units would not. For example, 1 tesla and 1 Wb $m^{-2}$ would both be acceptable units for magnetic flux density but 1 kg $m^2$ $s^{-2}$ $A^{-1}$ would not.

## 3.10 Level of response marking instructions

Level of response mark schemes are broken down into three levels, each of which has a descriptor. The descriptor for the level shows the average performance for the level. There are two marks in each level.

Before you apply the mark scheme to a student's answer read through the answer and annotate it (as instructed) to show the qualities that are being looked for. You can then apply the mark scheme.

## Determining a level

Start at the lowest level of the mark scheme and use it as a ladder to see whether the answer meets the descriptor for that level. The descriptor for the level indicates the different qualities that might be seen in the student's answer for that level. If it meets the lowest level then go to the next one and decide if it meets this level, and so on, until you have a match between the level descriptor and the answer. With practice and familiarity you will find that for better answers you will be able to quickly skip through the lower levels of the mark scheme.

When assigning a level you should look at the overall quality of the answer and not look to pick holes in small and specific parts of the answer where the student has not performed quite as well as the rest. If the answer covers different aspects of different levels of the mark scheme you should use a best fit approach for defining the level and then use the variability of the response to help decide the mark within the level. i.e. if the response is predominantly level 2 with a small amount of level 3 material it would be placed in level 2.

The exemplar materials used during standardisation will help you to determine the appropriate level. There will be an answer in the standardising materials which will correspond with each level of the mark scheme. This answer will have been awarded a mark by the Lead Examiner. You can compare the student's answer with the example to determine if it is the same standard, better or worse than the example. You can then use this to allocate a mark for the answer based on the Lead Examiner's mark on the example.

You may well need to read back through the answer as you apply the mark scheme to clarify points and assure yourself that the level and the mark are appropriate.

Indicative content in the mark scheme is provided as a guide for examiners. It is not intended to be exhaustive and you must credit other valid points. Students do not have to cover all of the points mentioned in the indicative content to reach the highest level of the mark scheme.

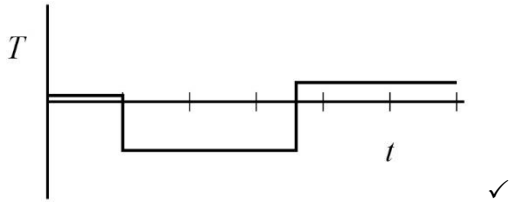
An answer which contains nothing of relevance to the question must be awarded no marks.

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **01.1** | Attempt at calculating area above or below $t$ axis or both ✓<br>(Ang displacement =) $2.80 + 2.10 - 3.15 = 1.75$ rad<br>$(\frac{1.75}{12.0} =) 0.15$ (rad s$^{-1}$) ✓ | Method must be valid<br><br>MP2: correct answer only<br>(calculator value = 0.145833)<br><br>MAX1 if counting square method used and answer rounds to $0.15$ (rad s$^{-1}$) | 2 | 2 x AO2 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **01.2** | $P = T\omega$ giving 546 (W) ✓ | Allow ecf for 590 (W) from<br>using $\omega_1 = 1.5$ rad s$^{-1}$ | 1 | AO2 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **01.3** | Selects steepest part of graph and<br>determines gradient $\alpha = \frac{1.40 - -0.90}{5.0} = 0.46$ (rad s$^{-2}$) ✓$_1$<br>$T = I\,\alpha = 9660$ N m ✓$_2$<br>**Adds** friction torque to give 10 100 (N m) ✓$_3$ | Accept any correct calculation of steepest graph slope: eg from 2 s to 5 s<br>$\alpha = \frac{1.4}{3.0}$ =0.467 giving $T = 9800$ N m<br>or 5 s to 7 s<br>$\alpha = \frac{0.9}{2.0} = 0.45$ giving $T = 9450$ N m<br>Allow ECF from MP2 to MP3<br>Treat 10 000 (Nm) as a 2 sf answer if consistent with their working. | 3 | 3 x AO2 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **01.4** | (net) $T \times t = 9660 \times 5.0 = 4.8 \times 10^4$ (N m s) ✓<br>OR<br>$\Delta(I\omega) = 2.1 \times 10^4\,(1.40 - (-0.90)) = 4.8 \times 10^4$ (N m s) ✓ | For first method allow ECF for torque ✓$_2$ from **01.3**, but not for ✓$_3$ value<br>(calculator value = 48300) | 1 | AO2 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| 01.5 |   ✓ | Tick (✓) against 3rd box | 1 | AO3 |
| **Total** | | | **8** | |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| 02.1 | Attempt to use work done = force × distance with either incline work or resistance work or both ✓1<br>Work done by flywheel<br>$= [(1.46 \times 10^4 \times 9.81 \times \sin 5^\circ) + 1.18 \times 10^3] \times 500$✓2<br>$(= 6.83 \times 10^6$ J )<br>$\frac{1}{2}I\omega^2 = 6.83 \times 10^6$ giving $\omega = 468$ (rad s$^{-1}$) ✓3 | MP1: award mark for valid attempt to calculate $mgh$ or $F \times s$ or both<br>$mgh = 6.24 \times 10^6$ J<br>$F \times s = 5.9 \times 10^5$ J<br>MP2 for correct calculation of work done.<br>MP3 for using their work done and $\frac{1}{2}I\omega^2$ to calculate $\omega$<br>ECF for ✓3 | 3 | 3 x AO2 |

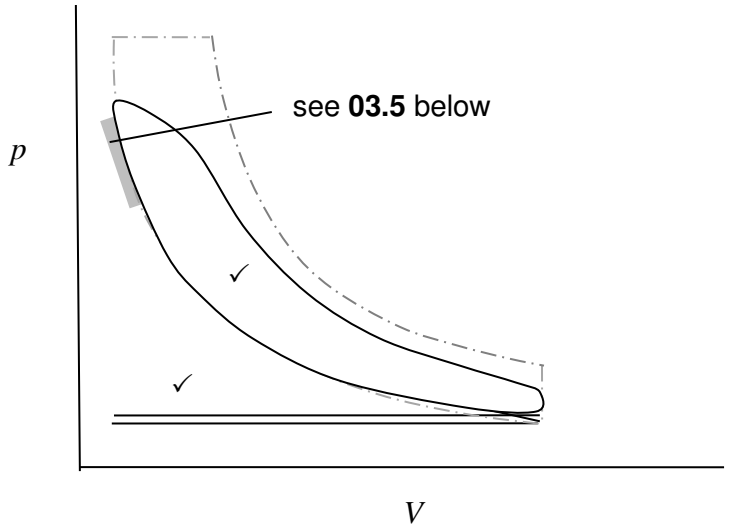
| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **02.2** | ✓$_1$ for idea of use of flywheel as brake<br>✓$_2$ for idea of storing and reusing this energy | $E_p$ change of tram can be converted to $E_k$ of flywheel so less energy transferred to brakes/brakes last longer/tram will not reach a high speed ✓$_1$<br>OR<br>Energy otherwise dissipated/lost in brakes can be fed back to flywheel ✓$_1$<br><br>Fly wheel is charged/stores energy and energy can be used for later acceleration/driving ✓$_2$<br>OR<br>Fly wheel is charged/stores energy and at next stop less recharging energy will be needed. ✓$_2$<br><br>Give two marks if both points covered in their answer to part 1<br><br>Treat as neutral answers in terms of providing a smoother ride or less wear on parts due to connecting and reconnecting flywheel.<br><br>If no other marks are given, allow 1 MAX for a correct reference to regenerative braking. | 2 | 2 x AO3 |

<table>
<tr><th>Question</th><th>Answers</th><th>Additional comments/Guidance</th><th>Mark</th><th>AO</th></tr>
<tr><td>02.3</td><td>The mark scheme gives some guidance as to what statements are expected to be seen in a 1 or 2 mark (L1), 3 or 4 mark (L2) and 5 or 6 mark (L3) answer.<br>Guidance provided in section 3.10 of the 'Mark Scheme Instructions' document should be used to assist in marking this question.<br><br>
<table>
<tr><th>Mark</th><th>Criteria</th></tr>
<tr><td>6</td><td>The factors which affect $E_k$ and all three areas of shape, material and design for high $\omega$ will be covered in some detail. 6 marks can be awarded even if there is an error and/or if parts of one aspect are missing.</td></tr>
<tr><td>5</td><td>The factors which affect $E_k$ and all three areas will be covered, at least two in detail.</td></tr>
<tr><td>4</td><td>Two areas successfully discussed, or one discussed and two others covered partially. Whilst there will be gaps, there should only be an occasional error.</td></tr>
<tr><td>3</td><td>One area discussed and one discussed partially, or all three covered partially. There are likely to be several errors and omissions in the discussion.</td></tr>
<tr><td>2</td><td>Only one area discussed or makes a partial attempt at two areas.</td></tr>
<tr><td>1</td><td>None of the three areas covered without significant error.</td></tr>
<tr><td>0</td><td>No relevant analysis.</td></tr>
</table></td><td>examples of the points made in the response<br>
• $E_k$ proportional to $\omega^2$<br>
• $E_k$ proportional to $I$<br>
• for same mass of tram $I$ or $\omega$ increased but not mass of flywheel<br><br>
<u>Shape</u><br>
• $I$ depends on mass and distribution of mass around axis<br>
• ($I = \Sigma mr^2$ so) arrange more $m$ at outer edge of flywheel<br>
• by using heavy rim and spokes/thin centre web<br>
• increase radius<br><br>
<u>Material</u><br>
• use higher density material at rim<br>
• use material of higher strength/ tensile strength/breaking stress<br>
• for higher speeds without bursting/to withstand rotational/centripetal stresses<br>
• eg titanium, CFRP<br><br>
<u>Design for high $\omega$</u> - increase $\omega$ by:<br>
• reduce friction at bearings<br>
• use lubrication or roller bearings/air bearings/magnetic bearings<br>
• smooth outer surfaces/encase in vacuum<br>
• small increase in $\omega$ gives large increase in $E_k$ (because $\omega^2$)<br><br>
Also allow<br>
• sketches which convey correct info clearly<br>
• use of 'depends on' for 'proportional to'<br>
• need for perfect balance<br>
• gyroscopic effects</td><td>6</td><td>4 x AO1<br>1 x AO2<br>1 x AO3</td></tr>
<tr><td>Total</td><td></td><td></td><td>11</td><td></td></tr>
</table>

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **03.1** | (A change in which there is) no energy/heat transfer to or from the gas/system ✓ | WTTE<br>Condone: no heat enters or leaves the system. | 1 | AO1 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **03.2** | $(p_1 V_1^{\gamma} = p_2 V_2^{\gamma})$<br>$1.0 \times 10^5 \times V_1^{1.4} = 67 \times 10^5 \times V_2^{1.4}$ ✓<br>$\underline{V_1} = 20(.2)$ ✓<br>$V_2$ | First mark for correct substitution of data into $p_1 V_1^{\gamma} = p_2 V_2^{\gamma}$ or $\frac{V1}{V2} = \left(\frac{p2}{p1}\right)^{1/1.4}$<br>Condone POT error in MP1<br>Accept answer as ratio $(20{:}1)$<br>(calculator value = $20.15297$) | 2 | 2 x AO2 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **03.3** | Diesel requires a high compression ratio to give a temperature high enough to ignite fuel / for fuel to self-ignite ✓<br>Petrol vapour–air mixture is ignited by spark at lower pressures/temperatures. ✓ | | 2 | 2 x AO1 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **03.4** |  | Look for:<br>• complete loop contained within/smaller than ideal loop with no sharp corners. Compression stroke may be below ideal cycle line.✓<br>• Two close parallel lines or one single line or one narrow loop parallel to $V$ axis at or near atmospheric pressure ✓<br>2 marks for both above points provided left-hand and right-hand edges of loop and induction/exhaust loop/lines are fairly close to correct $V_1$ and $V_2$. | 2 | 1 x AO1<br>1 x AO3 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **03.5** | **X** placed on/near curve anywhere in shaded area shown above | Near (but not at) top end of compression stroke on indicator diagram<br>Do not allow X on ideal cycle | 1 | AO1 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **03.6** | Any 2 from: ✓✓<br>• *curved corners*: because valves take finite time to open and close<br>• *no constant volume process*: because engine would have to stop/piston is constantly moving<br>• *compression and expansion not adiabatic curves*: because energy is lost by heat transfer<br>• *pumping loop/ the cycle is open* because engine needs to draw in air and expel exhaust<br>• *heating not at constant pressure*: because fuel injection and combustion cannot be exactly controlled<br>• *area of diagram is less* because energy is lost by heat transfer/incomplete combustion/CV of fuel not fully released<br>• *pressure not as high* because incomplete combustion/CV of fuel not fully released | The explanation of the difference must match the stated difference.<br>Do not accept answers which refer to smaller area as a result of friction in engine. | 2 | 2 x AO1 |
| **Total** | | | **10** | |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **04.1** | $Q_C = Q_H - W = 65 - 28 = 37$ W ✓1<br>COPref = $37/28 = 1.32$ ✓2<br>COPref for ideal refrigerator = $278/(308 - 278) = 9.3$ ✓3<br>Actual COP is very low compared to ideal so claim is valid ✓4 | If temperature not changed to K do not award marks ✓3 and ✓4<br>Condone consistent use of Celsius in the denominator.<br>No ECF for ✓4 from incorrect values of COP, unless from arithmetic error. | 4 | 4 x AO3 |

| Question | Answers | Additional comments/Guidance | Mark | AO |
|---|---|---|---|---|
| **04.2** | One factor from ✓1<br>• Thermoelectric cooler is small/convenient/of simple construction/(highly) portable<br>• can run off batteries/solar panel<br>• has no moving parts<br>• requires low maintenance<br>• no risk of leaking fluids<br>• temperature is about 5 °C, not cooler<br>• low energy/power consumption (28W)<br><br>For ✓2<br>• convenience outweighs poor COP<br>• any COP >1 means cooling power > power supplied<br>• waste of electrical energy from having low COP is acceptable | ✓1 for advantage from bullet point list<br><br>For ✓1 accept application, eg use in hot countries, by campers, climbers, walkers etc.<br><br>✓2 mark for relating answer to COP | 2 | 2 x AO3 |
| **Total** | | | **6** | |