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# Examiners' Report
# January 2013

# GCE Physics 6PH05 01

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# Introduction

The paper gave candidates the opportunity to demonstrate their understanding of a wide range of topics from this unit, with all of the questions eliciting responses across the range of marks. However, marks for Q14, Q16b, Q16c, Q17a, Q17b, Q17d and Q18a(iv) tended to be clustered at the lower end of the scale.

Calculation and 'show that' questions gave candidates an opportunity to demonstrate their problem-solving skills to good effect. Some very good responses were seen for such questions, although some candidates have difficulty in appreciating the magnitudes that they calculate, accepting their answer irrespective of whether or not it is sensible. In Q12a, answers ranging from a few milliseconds through to17 million years were an indication of this. Similarly in Q13, values of $10^{-12}$ K for the surface temperature of a star and $10^{-11}$ m for the radius of a star indicate a lack of appreciation of the scale of things.

Most candidates understood the convention that in a "show that" question it is necessary to give the final answer to at least one more significant figure than the value quoted in the question.

Occasionally in calculation questions the final mark was lost due to an incorrect or missing unit, as in Q13, where some candidates gave the ratio a unit of m. More common than this was the unnecessary conversion of units. This was apparent in Q12a, in which many candidates converted the half life in seconds to calculate a value for the decay constant in $s^{-1}$. They then worked out a value for the age of the sample in seconds and had to convert this back into years. In a similar vein, in Q16a, a number of candidates worked out the age of the universe in seconds and then converted it into years, even though the unit in which age was to be calculated was not specified. Such unnecessary conversions can sometimes lead to marks being lost as arithmetic errors often creep in.

As is often the case, candidates disadvantaged themselves by not actually answering the question, or in not expressing themselves using suitably precise language. This was particularly the case in extended answer questions such as Q14 Q16b and Q16c, where many candidates gave an answer to a question that had not actually been asked. In Q15, candidates were often imprecise in their definitions of simple harmonic motion, and incomplete in their descriptions of damping and resonance. Candidates could most improve by ensuring that they understand all aspects in sufficient detail and always use appropriate specialist terminology when giving descriptive answers. Reading the question carefully before attempting an answer is also to be recommended.

Questions requiring a discussion or a comparison to be made are common at this level. In Q17a, candidates were given a quotation from a paper by Arthur C. Clarke. Perhaps because they thought that the author could not make such a fundamental error, or perhaps because their own understanding of circular motion was quite insecure, many candidates accepted the idea of "centrifugal force" without question, as well as the erroneous assertion that circular motion is an example of balanced forces.

In some descriptive questions it is possible to gain credit for a reference to an appropriate equation e.g. the radiant flux equation in Q14 and the Doppler shift equation in Q16b. In such cases it is expected that the equation will either be given as a word equation or that every symbol in the equation is defined.

References to energy transfer can be problematic at this level. Candidates are prone to describe energy as being "lost", or to describe an energy transfer in the vaguest of terms. In situations where energy appears to be lost, candidates should be encouraged to think about the mechanism that allows energy transfer to occur, and to describe the transfer in as much detail as possible.

The space allowed for responses was usually sufficient. If candidates either need more space or want to replace an answer with a different one, they should indicate clearly where that response is to be found. It should be borne in mind that that the space provided does not have to be filled, nor is a response complete once the space has been filled. Candidates should be encouraged to look at the number of marks available for a question, and to formulate an answer with this in mind. For example, Q16b is worth 5 marks so candidates should realise that they should make at least 5 relevant statements.

The response to the multiple-choice questions was generally good, with 8 of the 10 questions having a correct response rate of much more than half, and only 1 question with a correct response rate of less than half.

Q6 tested understanding of the term "spontaneous" as applied to radioactive decay. Perhaps because the words "random" and "spontaneous" often occur together in descriptions of radioactive decay, many candidates selected answer key B ("random") as the correct response. The correct answer key is A ("nothing can influence the decay"). It may be useful to reinforce the meanings of these two terms when teaching radioactivity.

## *Question 11 (a)*

This was answered well, with most candidates thinking about the conditions inside the container. A small number of responses referred to the control of external conditions, and some candidates seemed to be unsure of the meaning of controlling a variable. This might explain the relatively large number of responses in which temperature was identified as a control variable. Similarly, experimenting on an ideal gas was chosen by some candidates as a control feature.

Some answers were quite vague e.g. a simple statement of "mass" rather than "mass of gas" , was not sufficient for a mark to be awarded.

**11** A student carries out an experiment to investigate how the volume occupied by a gas depends upon the temperature.

(a) What variables must the student control in this investigation?

**(2)**

In this experiment involving Charles' law, the prensure and the mass of the gas molecules must be constant

**ResultsPlus**
**Examiner Comments**

"mass of the gas molecules" is not a correct response.

1 mark

**ResultsPlus**
**Examiner Tip**

Use technical language carefully.

**11** A student carries out an experiment to investigate how the volume occupied by a gas depends upon the temperature.

(a) What variables must the student control in this investigation?

**(2)**

The ~~volume~~ pressure and the temperature

**ResultsPlus**
**Examiner Comments**

Temperature is the independent variable, not a control variable.

1 mark

**ResultsPlus**
**Examiner Tip**

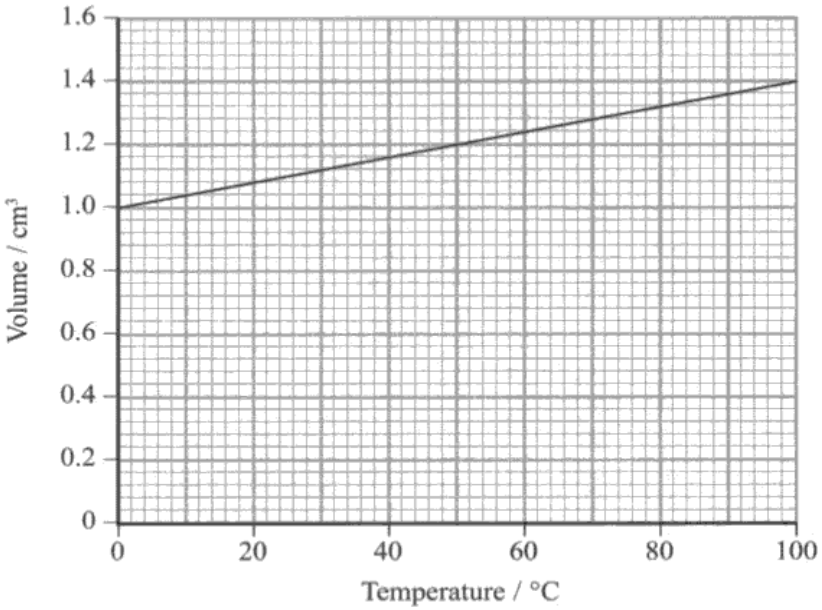
Know the meanings of the terms "independent variable", "dependent variable", "control variable" and be able to identify these variables in an experimental situation.

## *Question 11 (b)*

Many candidates missed the point of the question and only wrote about the conditions at absolute zero, e.g. there were many instances of candidates referring to absolute zero as the temperature where molecular KE fell to zero. However, the question required a reference to the graph, and hence candidates needed to express the idea that extending the line backwards would indicate zero volume at this temperature.

A few candidates described finding the x-intercept by correctly calculating the gradient. However, vague references to y = mx + c were treated as insufficient, because this would not on its own lead to an x-intercept.

(b) The following graph is obtained.




Explain how graphs such as this provide evidence for an absolute zero of temperature.

(2)

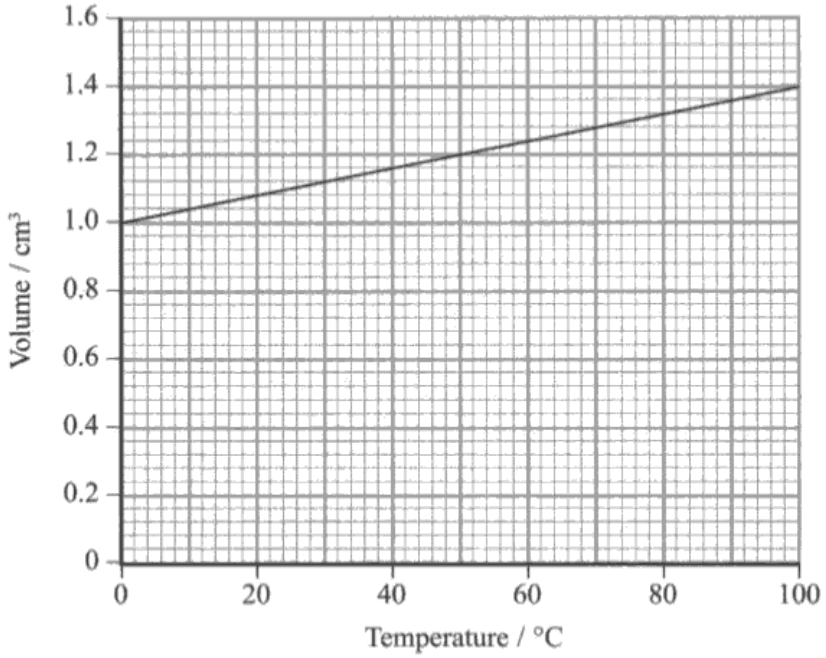
The graph donot pass through the origin so if the line is extended to the negative x-axis, the line will reach an x-intercept which provides evidence of the absolute zero temperature. (i.e -273°C)

**ResultsPlus**
**Examiner Comments**

The response does not make it clear that at the absolute zero of temperature the volume occupied would be zero.

1 mark

(b) The following graph is obtained.




Explain how graphs such as this provide evidence for an absolute zero of temperature.

(2)

The graph doesn't reach the orgin. The volume of the gas molecules is negligible so at it lowest volume the temperature must be a lot lower as it doesn't poses any kinetic energy. So the graph provides evidence for absolute zero.

**(Total for Question 11 = 4 marks)**

**ResultsPlus**
**Examiner Comments**

There is little in this response that indicates that the line should be extrapolated backwards, to locate a temperature at which the volume occupied would be zero.

0 marks

## *Question 12 (a)*

Although exponential decay equations can be a difficult mathematical challenge, this question was generally done well. The vast majority of candidates were able to calculate a value for the decay constant, although some candidates did not think through the units and hence wasted time by changing the half-life to seconds (or minutes), only to have to change the final answer back to years. Sometimes, this final conversion was done incorrectly, and hence the final mark was not awarded. A small number of candidates were careless and interchanged A and $A_o$ in the formula $A = A_o e^{-\lambda t}$. Although this led to the correct magnitude of the time, it demonstrated a lack of understanding of the physical situation and hence full credit was not gained in such cases.

**12** All living organisms contain $^{12}C$ and radioactive $^{14}C$. The concentration of $^{14}C$ in the organism is maintained whilst the organism is alive, but starts to fall once death has occurred.

(a) The count rate obtained from wood from an old Viking ship is 14.7 $min^{-1}$ per gram of wood, after being corrected for background radiation. The corrected count rate from similar living wood is 16.5 $min^{-1}$ per gram of wood.

Calculate the age of the ship in years.

$^{14}C$ has a half life of 5700 years.

(4)

$t_{1/2} = 5700 \times 365 \times 24 \times 3600 = 1.798 \times 10^{11}$ s

$t_{1/2} = \frac{\ln 2}{\lambda}$ $\lambda = \frac{\ln 2}{1.798 \times 10^{11}} = 3.855 \times 10^{-12}$

$A = A_0 e^{-\lambda t}$

$\frac{A}{A_0} = e^{-\lambda t}$

$\frac{16.5}{14.7} = e^{-3.855 \times 10^{-12} t}$ → $1.12 = e^{-3.855 \times 10^{-12} t}$

Age of ship = ..... years

**ResultsPlus**
**Examiner Comments**

Initial and present activities of the sample have been mixed up.

2 marks

**12** All living organisms contain $^{12}C$ and radioactive $^{14}C$. The concentration of $^{14}C$ in the organism is maintained whilst the organism is alive, but starts to fall once death has occurred.

(a) The count rate obtained from wood from an old Viking ship is 14.7 $min^{-1}$ per gram of wood, after being corrected for background radiation. The corrected count rate from similar living wood is 16.5 $min^{-1}$ per gram of wood.

Calculate the age of the ship in years.

$^{14}C$ has a half life of 5700 years.

**(4)**

$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

$= \frac{\ln 2}{5700 \times 365 \times 24 \times 60}$

$= 2 \cdot 313 \times 10^{-10}\ min^{-1}$

$\therefore N = N_0 e^{-\lambda t}$

$\ln\left(\frac{N}{N_0}\right) = \ln e^{-\lambda t}$

$t = \frac{\ln\left(\frac{N}{N_0}\right)}{-2 \cdot 313 \times 10^{-10}}$

$t = \frac{\ln\left(\frac{14 \cdot 7}{16 \cdot 5}\right)}{-2 \cdot 313 \times 10^{-10}}$

$= 499 \cdot 407 \times 10^6\ min$

$= \frac{499 \cdot 407 \times 10^6}{60 \times 24 \times 365}$

$= 950 \cdot 2\ years$

Age of ship = 950 years

**ResultsPlus**
**Examiner Comments**

The calculation is worked through correctly. However, the conversion of half-life from years to seconds means that the age has to be converted from seconds to years at the end.

4 marks

**ResultsPlus**
**Examiner Tip**

Always check that quantities are expressed in appropriate units before you substitute into equations. These may not always be the usual SI units.

## *Question 12 (b)*

This was a more challenging question for most candidates, since it needed an ability to explain, rather than just calculate. In many responses, much more clarity was needed, because candidates' statements concerning "how this would affect the age you have calculated" could often be ambiguous.

Those who commented on the age successfully often failed to explain that the initial activity was less. Typically, they often repeated the stem of the question and commented on the concentration.

A few candidates interpreted the change in concentration in the past as affecting the value of activity, A, in the present sample, whilst others stated that having an increased concentration in the past would also increase the value of the decay constant.

(b) The concentration of $^{14}C$ in living organisms might have been greater in the past.

Explain how this would affect the age that you have calculated.

(2)

The ratio of C-14 to C-12 ~~in~~ would have been ~~smaller~~ greater in the past.
This will lead to an under-estimate of the age of ship

**ResultsPlus**
**Examiner Comments**

The phrase *the ratio of C-14 to C-12 would have been greater in the past* is just a re-statement of the information given in the question.

1 mark

**ResultsPlus**
**Examiner Tip**

Do not just repeat what the question tells you - you have to interpret this information.

(b) The concentration of $^{14}C$ in living organisms might have been greater in the past.

Explain how this would affect the age that you have calculated.

(2)

~~The calculated age would~~
If the concentration was more, the age would be less than the calculated value.

**ResultsPlus**
**Examiner Comments**

This response restates information about the concentration and expresses the conclusion so poorly that it is difficult to know if the candidate has under-estimated or over-estimated the age of the sample.

0 marks

**ResultsPlus**
**Examiner Tip**

Read through your answers to ensure that what you have written makes sense.

## *Question 13*

There were many correct answers with the formulae used appropriately. Almost everyone used Wien's displacement law correctly to work out the temperature.

Common errors in the calculation for $r_B$ were to use T instead of $T^4$ or to misquote (or even omit) a value for σ. Some candidates substituted into the correct equation, but then forgot to raise the substituted temperature to the power of 4 when performing the calculation.

Some candidates did not use the fourth power - perhaps teachers need to give students more practice in this unusual power relationship.

**13** Betelgeuse is our nearest red giant. It has a luminosity of $4.49 \times 10^{31}$ W and emits radiation with a peak energy emission occurring at a wavelength of 850 nm.

Show that Betelgeuse has a surface temperature of about 3000 K. Hence calculate the ratio of the radius of Betelgeuse, $r_B$ to the radius of the Sun, $r_S$.

$r_S = 6.95 \times 10^8$ m

(5)

$\lambda_{max} T = 2.898 \times 10^{-3}$ mK

$T = \frac{2.898 \times 10^{-3}\ m.K}{850 \times 10^{-9}\ m}$

$= 3409$ K

$L = 4\pi r^2 \sigma T^4$

$r^2 = \frac{L}{4\pi\sigma T^4}$

$r^2 = \frac{4.49 \times 10^{31}}{4\pi \times 5.67 \times 10^{-8} \times (3409)^4}$

$r^2 = 4.666 \times 10^{-39}$

$r = \sqrt{4.666 \times 10^{-39}}$

$= 6.83 \times 10^{-20}$ m

$\therefore r_B / r_S = 6.83 \times 10^{-20} / 6.95 \times 10^8$

$= 9.83 \times 10^{-29}$

$r_B/r_S = 9.83 \times 10^{-29}$

**ResultsPlus**
**Examiner Comments**

The candidate has made an arithmetic error, calculating the radius of Betelgeuse to be a tiny fraction of a nuclear diameter!

3 marks

**ResultsPlus**
**Examiner Tip**

Check your answers for obvious mistakes. Does your calculated value fall within a reasonable range for the quantity you are finding?

**13** Betelgeuse is our nearest red giant. It has a luminosity of $4.49 \times 10^{31}$ W and emits radiation with a peak energy emission occurring at a wavelength of 850 nm.

Show that Betelgeuse has a surface temperature of about 3000 K. Hence calculate the ratio of the radius of Betelgeuse, $r_B$ to the radius of the Sun, $r_S$.

$r_S = 6.95 \times 10^8$ m

$L = 4\pi r^2 \sigma T^4$ (5)

$4.49 \times 10^{31} = 4\pi r^2 \sigma T^4$

$\Rightarrow 4.49 \times 10^{31} = 4\pi$

$\lambda_{max} T = 2.898 \times 10^{-3}$

$\therefore T = \frac{2.898 \times 10^{-3}}{850 \times 10^{-9}} = 3409\ K$

$\therefore 4.49 \times 10^{31} = 4\pi (r^2) \times 5.67 \times 10^{-8} \times 3409$

$\Rightarrow r^2 = \frac{4.49 \times 10^{31}}{4\pi \times 5.67 \times 10^{-8} \times 3409}$

$\Rightarrow r^2 = 1.85 \times 10^{34}$

$\Rightarrow r = \sqrt{1.85 \times 10^{34}}$

$\Rightarrow r = 1.4 \times 10^7$

$\therefore$ ratio $= \frac{1.4 \times 10^7}{6.95 \times 10^8} = \frac{1.4}{695} = \frac{0.02}{1}$

$r_B / r_S =$ 0.02 : 1

**ResultsPlus**
**Examiner Comments**

Although the temperature has been correctly worked out, when substituting this value into the Stefan's law equation, the power of 4 is missing. Hence there are no marks for the second part of the question here.

2 marks

**ResultsPlus**
**Examiner Tip**

Take care when substituting numbers into equations - be sure to look for powers and roots.

## *Question 14*

This question was generally poorly-answered.

A large number of answers were written in terms of finding the distance to a star by comparing it to the standard candle, rather than describing how the distance to a given standard candle is determined.

A number of candidates thought that they had to describe how the luminosity of the standard candle would be determined from variations in the brightness of the candle, even though this does not appear in the specification and was not implied in the wording of the question. Most candidates knew that standard candles had a known luminosity, but many did not say that the flux (or brightness) of the standard candle must be measured on Earth for a comparison to be made. References to the inverse square law or the formula $F = L/4\pi d^2$ were common, although many did not say that the distance was calculated nor did they say that the distance was to the standard candle.

In the final part of the question, the most common mistake was to confuse brightness with luminosity. Hence many incorrect answers stated that the luminosity of Cepheid was reduced. Most candidates correctly deduced that the Cepheid would appear further away, although some thought that it would appear to be nearer.

***14** Cepheid variable stars have long been seen as examples of standard candles. Recent measurements have indicated that the movement of the star through interstellar material might result in the formation of a layer of dust around the star. This affects how bright the star appears.

Explain how standard candles are used in astronomy, and suggest how the existence of a layer of dust around a Cepheid variable star might affect the conclusions drawn by astronomers.

**(6)**

standard candles are used to compare with the luminosity of other stars, as they emit a constant ~~for~~ luminosity: so when a layer of dust is accumulated the ~~to~~ luminosity measured would not be equal to the actual ~~to~~ luminosity emitted so when they use this apparent wavelength to calculate the surface temperature, or the surface area, the calculated values would be wrong and when these are compared with the other ~~luminosity~~ ~~the~~ stars the approximate values calculated would also have a high margin of error and if this layer of dust increases in thickness, the brightness will decrease more and hence the calculated value would further have an increase in errors.

**ResultsPlus**
**Examiner Comments**

This response indicates a misunderstanding of the ways in which standard candles are used. In addition, there is only a vague description of the effects of the dust cloud.

2 marks

**ResultsPlus**
**Examiner Tip**

When asked to say what will happen if something is changed, be sure to indicate if a value will increase or decrease, rather than just saying that it will change.

*14 Cepheid variable stars have long been seen as examples of standard candles. Recent measurements have indicated that the movement of the star through interstellar material might result in the formation of a layer of dust around the star. This affects how bright the star appears.

Explain how standard candles are used in astronomy, and suggest how the existence of a layer of dust around a Cepheid variable star might affect the conclusions drawn by astronomers.

(6)

Standard candles are stars with known luminosity. If the luminosity is known distance can be calculated using $F = \frac{L}{4\pi d^2}$. A layer of dust around a cepheid variable star results in a reduction of radiation flux that falls on the earth. Therefore the calculated value will not be accurate.

**ResultsPlus**
**Examiner Comments**

Although this is a very brief response it hits most of the marking points. The need to measure the flux at the Earth is not specified, and the equation for radiation flux is not defined at all.

4 marks

**ResultsPlus**
**Examiner Tip**

Always remember to define the meanings of symbols that you use in an answer.

## *Question 15 (a) (i)*

The most common error was failing to find T and using value of 10T instead.

Some candidates assumed that the time of 6.2 s was an outlier, and then found an average with the 2 remaining times.

**15** A garden ornament consists of a plastic dragonfly mounted on a stick. The dragonfly's wings are attached to the body with springs, and they flutter up and down in a gentle breeze.

(a) When the air is not moving and the wings are displaced through a small vertical distance, they oscillate. The time for 10 oscillations is recorded. This is repeated twice more.

| Time / s | | |
|---|---|---|
| $t_1$ | $t_2$ | $t_3$ |
| 6.2 | 6.6 | 6.9 |

(i) Calculate the frequency of oscillation of the wings.

**(3)**

Average time taken $= \frac{6.2+6.6+6.9}{3} = 6.6\text{s}$

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

$= \frac{1}{6.6} = 0.15\text{ Hz}$

**ResultsPlus**
**Examiner Comments**

The calculated value for frequency is 10 times too small, because 10T has been used instead of T.

2 marks

(b) The amplitude of the wings' oscillation dies down after only a small number of oscillations.

Explain why this happens.

(2)

Frictional force acts on the wings. This causes the oscillation ~~wings~~ to decrease and hence, slowly dies away.

**ResultsPlus**
**Examiner Comments**

The candidate has left their value for the frequency as a quotient, and so the mark for the final answer is not awarded.

2 marks

**ResultsPlus**
**Examiner Tip**

Always work out final answer values fully.

## *Question 15 (a) (ii)*

Some candidates scored full marks here, although a significant number did not receive the mark for displacement . They did not specify that it was measured from the equilibrium position. When candidates did attempt to relate displacement to the equilibrium position, they sometimes referred simply to *equilibrium.* Some candidates gave a formula but did not explain the symbols and so scored zero marks.

Statements such as *time period is independent of amplitude* and *follows a sine curve* are observations, not definitions.

Some candidates referred to a *fixed position,* instead of the *equilibrium/centre/rest position*. In the context of a fully-expressed definition this can be acceptable. However, candidates were often not doing this and so the words *fixed point* really did not specify enough about the situation.

In a definition of simple harmonic motion, it is recommended that candidates refer to 'equilibrium position' with 'centre position' or 'rest position' being acceptable alternatives.

(ii) The oscillation of the wings is thought to be simple harmonic motion.

State the conditions required for the oscillations to be simple harmonic.

(2)

The acceleration is always proportional to the displacement and ~~always~~ is directed towards the equilibrium point.

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**Examiner Comments**

The displacement is not specified as being measured from the equilibrium point.

1 mark

(ii) The oscillation of the wings is thought to be simple harmonic motion.

State the conditions required for the oscillations to be simple harmonic.

(2)

The resultant force is directly proportional to the distance of the oscillator from equilibrium

**ResultsPlus**
**Examiner Comments**

*Distance of the oscillator from equilibrium* is too vague.

0 marks

**ResultsPlus**
**Examiner Tip**

Use technical language carefully in answering questions such as this.

## *Question 15 (b)*

The term *damping* was frequently seen but with no specific reference to what had been damped. In referring to the energy transfer, the idea that 'energy is lost' was often seen. When trying to express the idea that energy leaves the system, candidates often described the energy transfers within the system with no reference to the surroundings e.g. kinetic energy transfers to the internal energy of the wings.

(b) The amplitude of the wings' oscillation dies down after only a small number of oscillations.

Explain why this happens.

(2)

Frictional force acts on the wings. This causes the oscillation ~~wings~~ to decrease and hence, slowly dies away.

**ResultsPlus**
**Examiner Comments**

This response comes close with *frictional force,* but at this level the candidate should really be referring to 'drag or 'air resistance'. There is no reference to energy transfer here.

0 marks

**ResultsPlus**
**Examiner Tip**

Be specific and use correct technical terms wherever possible.

## *Question 15 (c)*

The vast majority of candidates was able to name resonance as the phenomenon. The most common incorrect response for the second marking point was to omit any reference to the system being forced or driven.

(c) In certain breezy conditions the wings are seen to oscillate with a very large amplitude.

Name this effect and state the condition for it to occur.

(2)

Resonance. The frequency of the vibrating air molecules should be equal to the natural frequency of the wings.

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**Examiner Comments**

There is no specific reference to the air molecules driving the wings into oscillation.

1 mark

(c) In certain breezy conditions the wings are seen to oscillate with a very large amplitude.

Name this effect and state the condition for it to occur.

(2)

Resonance. The breeze needs to force the wings to oscillate with a frequency close / equal to its natural frequency.

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**Examiner Comments**

Although the idea of the breeze forcing the wings is clear, it is unclear as to whether this is at the natural frequency of the breeze or the wings.

1 mark

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**Examiner Tip**

Learn the conditions for effects such as s.h.m., resonance etc.

## *Question 16 (a)*

Most candidates worked through this question with a good understanding of the principles involved. A minority made an error with powers of 10, so did not get the correct final answer.

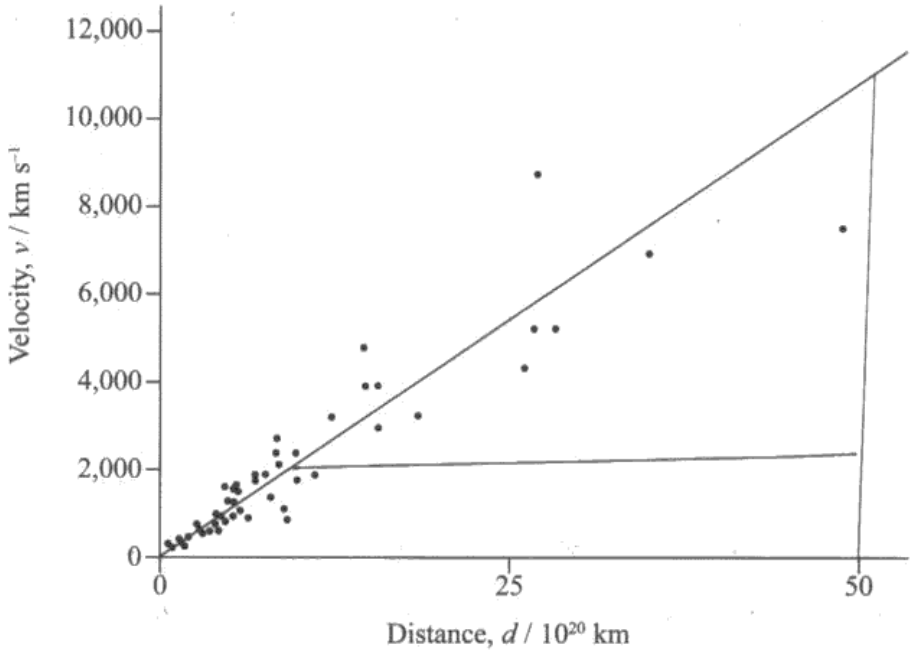
The minimalist grid provided meant that candidates' values for the gradient were accepted over quite a wide range. Nonetheless, a large number of candidates did not draw lines that were even approximately parallel to the axes.

Surprisingly, given that a trend line had been drawn, some candidates chose to use values of d and v from a point off the line.

Having worked out the gradient and identified the Hubble constant correctly, some candidates then quoted the value of the Hubble constant as the age of the universe, despite its inappropriate magnitude.

A minority wasted time changing time in years to seconds and then back again.

**16** The graph shows how the velocity varies with distance for a number of distant galaxies. All the galaxies are receding from Earth, and there appears to be a linear relationship between the velocity of recession and the distance to the galaxy.



(a) Use the graph to estimate an age for the Universe.

(4)

~~$z = v/c$~~ ~~$v = H_0 d$~~ $V = H_0 d$ ~~$H_0 =$~~

~~12000 k~~ $v/d$ $ms^{-1}$ / m

=

Gradient of the graph gives ~~hod~~ hubble Constant = $\frac{11000\ kms^{-1} - 2000\ kms^{-1}}{50 \times 10^{22}\ km - 10 \times 10^{22}\ km}$

Age of the Universe = $\frac{1}{H_0}$ $= \frac{9000\ kms^{-1}}{4 \times 10^{23}\ km}$

$= \frac{1}{2.25 \times 10^{-20}}$ $H_0 = 2.25 \times 10^{-20}$

$= 4.444 \times 10^{19}$ Age of the Universe = $4.444 \times 10^{19}$ $s^{-1}$

**ResultsPlus**
**Examiner Comments**

The candidate has made a power of 10 error in reading values from the graph, and so the final answer is 100 times too big. In addition, the units quoted appear to be $s^{-1}$ rather than s.

3 marks

**ResultsPlus**
**Examiner Tip**

Always check units for quantities that you calculate. Know the standard SI units for all commonly-met quantities.

## *Question 16 (b)*

This was a poorly-answered question, with many candidates describing inappropriate methods of measuring distances to galaxies. Perhaps getting carried away by part (a), some candidates thought that Hubble's law would be a suitable method.

References to using trigonometric parallax for finding the distance appeared more often than might have been expected.

Of those candidates who tried to describe a Doppler shift method, essential detail was often missing from their description.

Very few candidates referred to spectral lines and the idea of measuring the observed wavelength was often missing. Equations were often quoted, but not explained, with candidates either not defining the symbols of a Doppler equation or not writing a word equation.

Some candidates' understanding of how D l is found was very weak. There were a few suggestions that the wavelength received from the galaxy might be measured at two different times and then the difference between the wavelengths subtracted. There were even suggestions that radiation of a known wavelength is transmitted to the galaxy and then the radiation that is reflected back from the galaxy is measured.

*(b) Describe how astronomers would have determined the velocity of each galaxy.

(5)

The astronomer would have determined the velocity of each galaxy by red shift. when light source relatively moves away from the observer the observer will find greatest wavelegth. greatest wavelength red colour will occur this is called red shift.

Red shift = $\frac{V}{C}$ from thes astronomer find the velocity of ~~the~~ each galaxy.

**ResultsPlus**
**Examiner Comments**

The detail given in this response is minimal. The identification of redshift is the only aspect to receive credit.

1 mark

*(b) Describe how astronomers would have determined the velocity of each galaxy.

(5)

Velocity is determied by analysing the Spectrum. which give shifting of wavelength which is called a red shift. we can find the red shift by finding the difference in wavelength $z = \frac{\Delta\lambda}{\lambda}$ using red shift we can find the velocity $V = ZC$

**ResultsPlus**
**Examiner Comments**

The use of an equation, but without any symbols being defined, does not add any credit to this response. Again, the idea of redshift is the only part of the response that can be given a mark.

1 mark

**ResultsPlus**
**Examiner Tip**

When outlining a process you need to be clear what is happening at each stage. A bulleted list is often helpful.

## *Question 16 (c)*

Surprisingly many candidates' responses simply described the 3 taught models for the fate of the universe, and hence failed to answer the question. A few students gained marks about the uncertainty in the value of the Hubble constant and the difficulty of determining distances to distant galaxies accurately.

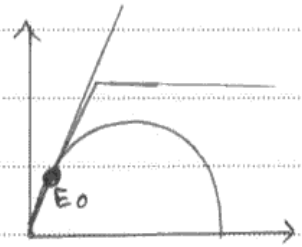
Most students achieved two marks by explaining that the density is uncertain because the amount of dark matter is unknown. Responses worthy of full marks were seen only rarely. References to dark energy were seen, but these were often linked with dark matter, rather than leading to a separate discussion about the repulsive force produced by it.

*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

(3)

Our universe is not old enough to ~~determine~~ say exactly if is it would result in a flat universe a open universe or a closed universe.




as in the diagram the ~~earth is~~ universe is in that position. so the scientists are yet uncertain about the fate of the universe.

**ResultsPlus**
**Examiner Comments**

This response is typical of many, in that the focus is on the uncertainty rather than the reasons for the uncertainty.

0 marks

**ResultsPlus**
**Examiner Tip**

Make sure that you answer the question asked, rather than what you think is being asked. Careful reading of the question is needed.

*(c) Scientists are uncertain about the ultimate fate of the Universe.

Explain why.

(3)

The fate of the Universe depends upon its critical density, however it is difficult to estimate the value of this density due to the presence of dark energy or dark matter within the universe. This dark matter does not emmit radiation of any kind and is difficult to estimate a value for it. Thus scientists till now are unaware if the Milky way is an open, flat or closed universe.

**ResultsPlus**
**Examiner Comments**

This is a typical good answer to this question. There is a reference to dark energy in addition to dark matter, but the two are just linked together as being part of the same phenomenon.

2 marks

## *Question 17 (a)*

Candidates found this question very difficult; perhaps because they are unused to being critical of a scientific argument. The question also highlighted how poorly many candidates understand circular motion.

The first marking point was generally gained  Some candidates lost this mark because although they said that gravitational force decreases with height, they omitted to say what the gravitational force acts on.

It was surprising to see how infrequently the concept of a centrifugal force was refuted by candidates.

A significant number of candidates was quite happy to discuss centrifugal and centripetal forces as if these were equal. Indeed, some candidates linked the two terms as elements of a Newton's 3rd law pair. Of those gaining the second marking point, the idea that 'centrifugal' was incorrect was often implied by use of 'centripetal', rather than being clearly stated.

Very few students noticed the problem with balanced forces. Most candidates failed to appreciate that circular motion is accelerated motion and hence the forces acting on the satellite cannot be in balance.

**17** Communications satellites were first proposed in 1945 by the science fiction author Arthur C. Clarke. In an article published in the magazine Wireless World he asked whether rocket stations could give worldwide radio coverage.

In the article Clarke states:

"There are an infinite number of possible stable orbits, circular and elliptical, in which a rocket would remain if the initial conditions were correct. A velocity of 8 km $s^{-1}$ applies only to the closest possible orbit, one just outside the atmosphere, and the period of revolution would be about 90 minutes. As the radius of the orbit increases the velocity decreases, since gravity is diminishing and less centrifugal force is needed to balance it."



(a) State what is meant in the article by the phrase "gravity is diminishing", and criticise the statement that "less centrifugal force is needed to balance (the satellite)".

**(3)**

what he means is the gravitational field strength of the earth decreases as you move away from the surface of the earth therfore the weight you feel decreases. The gravitational force towards the earth decreases as you move away as the radius of orbit increase $F \propto 1/r^2$

~~To balance if the centrepetal force should equal the centrifugal force.~~

It is the mass centrepetal force that is becomes less. and this is the force that balances in circular orbit this force is equal to the gravitational force.

**ResultsPlus**
**Examiner Comments**

This is quite a good response. The candidate has explained clearly why gravity can be said to be diminishing, and they have replaced "centrifugal" with "centripetal". However, they seem to believe that the satellite is in balance (despite the fact that we know that its velocity is changing).

2 marks

**ResultsPlus**
**Examiner Tip**

Always base your explanations on physical principles. Circular motion is an example of a resultant force causing an acceleration.

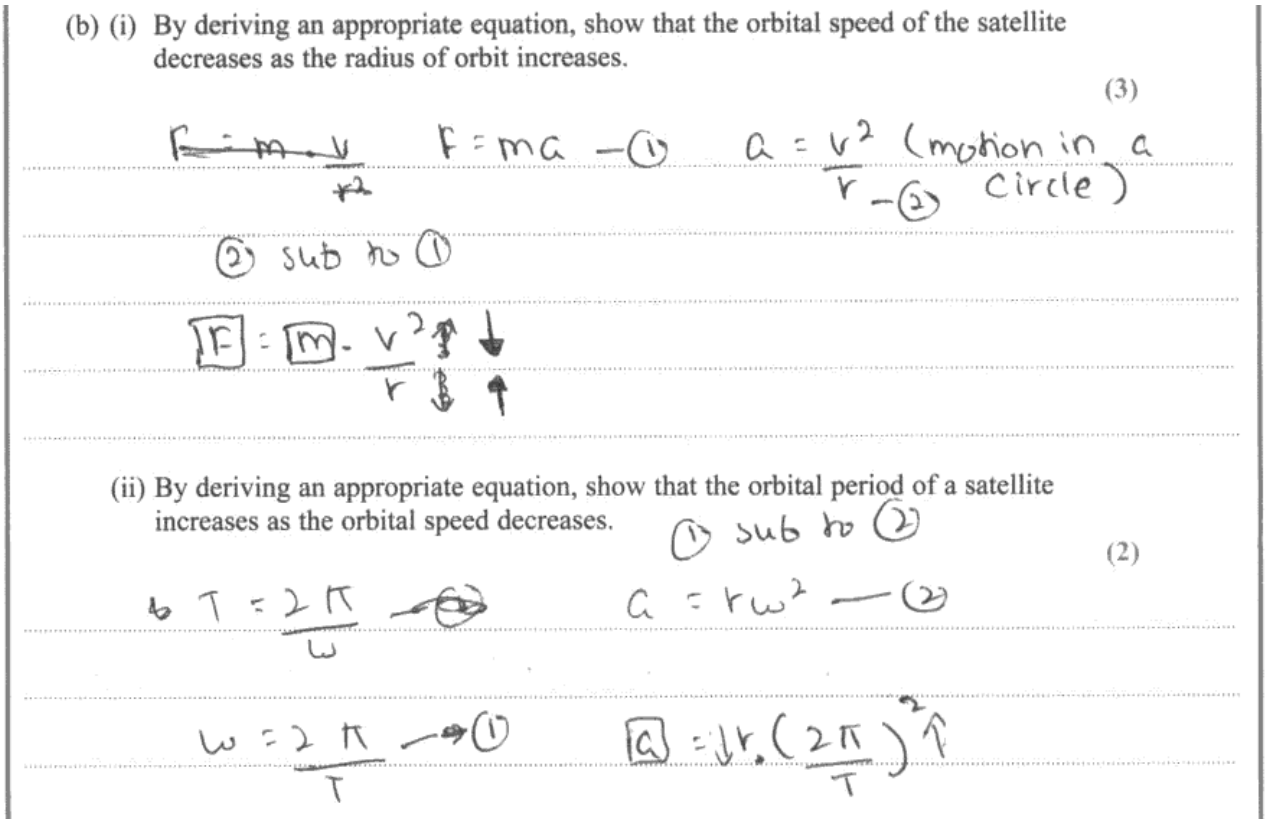
## *Question 17 (b)*

This was generally well-answered, although a small number of candidates did not appreciate the requirement to derive the expression.

Those candidates who did not know where to begin with either part of this question wrote down a variety of expressions which led nowhere.

In part (i), some candidates interpreted *orbital speed* as angular velocity.

Of those candidates who succeeded with the derivation, many stopped at the equation and did not make the final jump from the equation to the statement that as the radius decreases, the velocity increases.




**ResultsPlus**
**Examiner Comments**

This response is typical of that of many candidates who were unable to select appropriate equations.

0 marks

## *Question 17 (c)*

The most common error was failing to add the Earth's radius to satellite's altitude, although some forgot to add the satellite's altitude to the Earth's radius. Common arithmetic errors included forgetting to cube r and forgetting to take the square root.

(c) The period $T$ of a satellite in a circular orbit is given by the equation

$$T = \sqrt{\frac{4\pi^2 r^3}{GM}}$$

where $r$ is the radius of orbit and $M$ is the mass of the Earth.

Calculate the period of a satellite in an orbit $4.0 \times 10^5$ m above the surface of the Earth.

mass of the Earth = $5.98 \times 10^{24}$ kg

radius of the Earth = $6.36 \times 10^6$ m

(2)

$T = \sqrt{\dfrac{4\pi^2 (6.36 \times 10^6 - 4 \times 10^5)^3}{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}}$

$= \cancel{20.95} \; 2.095 \times 10^6$ s

$= \cancel{6 \text{ months}}$

Period of satellite = 24 days ~~6 months~~

**ResultsPlus**
**Examiner Comments**

The candidate has subtracted, rather than added, the altitude to the radius of the Earth. Nonetheless, they gain a mark for substituting physically correct quantities into the equation.

1 mark

## *Question 17 (d)*

This question was poorly-done, with most candidates attempting to explain the transfer of GPE to KE, but very few making correct reference to the transfer of energy into thermal energy.

Many omitted to qualify the potential energy as "gravitational" and if thermal energy was mentioned, the source of it, or mechanism by which it arose, was not specific enough to award the second mark.

Some candidates did not read the question properly and wrote about forces rather than energy.

(d) After a time the radius of the satellite's orbit will start to decrease due to the resistive forces acting on the satellite from the atmosphere. As this happens the satellite speeds up.

Describe the energy changes occurring as the radius of the orbit decreases.

**(2)**

As resistive forces act, the satellite comes close to its centre of mass as a result the radius of the orbit decreases. We know, centripetal force, $F_c = \frac{mv^2}{r}$, so due to force as the radius decreases, the time period still remains constant. So Here the speed of satellite decreases so K.E $\frac{1}{2}mv^2$ decreases as ~~speed~~ velocity decreases.

**(Total for Question 17 = 12 marks)**

**ResultsPlus**
**Examiner Comments**

The candidate has concentrated on forces, rather than referring to energy. The reference to kinetic energy decreasing is based on the candidate's assumption that the satellite is slowing down, even though the question says that the satellite speeds up.

0 marks

**ResultsPlus**
**Examiner Tip**

Try to relate questions to relevant theory.

## *Question 18 (a) (i)*

As is to be expected, this question was well-answered by the vast majority of candidates. However, there were some candidates who thought that protons had a proton number of 0. In addition, some candidates tried to balance the equation with two protons rather than one.

**18** Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said:

"The energy produced by the breaking down of the atom is a very poor kind of thing. Anyone who expects a source of power from the transformation of these atoms is talking moonshine."

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Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

**(1)**

$$^{14}_{7}N + ^{4}_{2}\alpha \rightarrow ^{17}_{9}O + ^{1}_{0}p$$

**ResultsPlus**
**Examiner Comments**

Although the equation has been balanced, the proton has been given a proton number of zero.

0 marks

18 Electrical power generated by nuclear fission makes an important contribution to world energy needs. However Rutherford, who is credited with the discovery and first splitting of the nuclear atom, later said:

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Rutherford carried out experiments that involved firing alpha particles at nitrogen atoms.

(a) (i) Complete the equation for the interaction between nitrogen and alpha particles.

(1)

$$^{14}_{7}N + ^{4}_{2}\alpha \rightarrow ^{16}_{8}O + 2\,^{1}_{0}p$$

**ResultsPlus**
**Examiner Comments**

Again the equation is balanced, this time with two protons.

0 marks

## *Question 18 (a) (ii)*

A significant number of candidates wrote about mass deficit or binding energy. Some tried to relate their responses to Einstein's equation. Others commented that the energy released was already a large amount. The most common way to gain the mark was by making a correct statement about a chain reaction and large amount of energy.

(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

(1)

As nuclear fission will release heat during reaction.

**ResultsPlus**
**Examiner Comments**

The candidate refers to nuclear fission, but there is no mention of a chain reaction.

0 marks

(ii) This interaction requires a small energy input. Other similar nuclear reactions may give an energy output of no more than 20 MeV, giving some justification to Rutherford's statement. Suggest why Rutherford's statement eventually turned out to be very inaccurate.

**(1)**

Very little energy required to start the reaction. Chain reaction occur and large amount of energy will be given out.

**ResultsPlus**
**Examiner Comments**

In this response there is a reference to a chain reaction, but not to fission.

**ResultsPlus**
**Examiner Tip**

Make sure that all essential detail is included in your answer. Check your answer against the wording of the question to ensure that key points are covered.

1 mark

## *Question 18 (b)*

A large majority of candidates achieved full marks for this question. Some had difficulty with the mass deficit calculation so did not get the final mark, due to a wrong energy value. A common mistake was to think that masses were given in u and not kg.

$\Delta m = 390.29989 - 233.99404 - 152.64708 - (3 \times 1.67493^{3})$

$= -1.36602 \times 10^{-27}$ kg

$E = \Delta m c^2$

$= (1.36602 \times 10^{-27}) \times (3 \times 10^{8})^2$

$= 1.229418 \times 10^{-10}$ J $\times 1.60 \times 10^{-19}$

$= 1.9671 \times 10^{-29}$ eV

**ResultsPlus**
**Examiner Comments**

The mass difference has been calculated incorrectly, and the conversion from J to eV is performed incorrectly. However, the response gains marks for an attempt at a mass difference and use of the Einstein mass-energy equation.

2 marks

**ResultsPlus**
**Examiner Tip**

Always complete calculations fully – particularly in a "show that" question.

## Question 18 (c) (i)

This question was well-answered by most, although candidates lost marks by referring to labels such as atomic number, mass number, proton number etc. rather than describing the constituents of the nucleus.

(i) Give **one** similarity and **one** difference between the nuclei of uranium-238 and uranium-235.

**(2)**

Similarity ..... Same atomic number .....

Difference ..... Different mass number. .....

**ResultsPlus**
**Examiner Comments**

This answer scores zero as it tells us nothing about the nuclei.

0 marks

**ResultsPlus**
**Examiner Tip**

Know and use technical words correctly.

## Question 18 (c) (ii)

Although quite a straightforward calculation, a variety of errors was seen. These ranged from miscalculation of ω (often through the omission of p), forgetting to square ω, through to arithmetic errors from poor calculator use. A common reason for not obtaining a correct value for the final answer was by forgetting to halve the diameter to obtain the radius.

(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute.

Calculate the centripetal acceleration at the rim of the rotor.

**(2)**

~~$a = v^2$~~ Too $a = \frac{v^2}{r}$

$a = r\omega^2$

$= 0.3 \left(\frac{2\pi}{1 \times 10^{-3}}\right)^2$

$= 11.8 \times 10^6 \text{ ms}^{-2}$

Centripetal acceleration = $11.8 \times 10^6 \text{ ms}^{-2}$

**ResultsPlus**
**Examiner Comments**

The diameter has been used instead of the radius.

1 mark

**ResultsPlus**
**Examiner Tip**

Check that you have carried out all of the numerical processes that the equation demands.

(ii) The rotor has a diameter of 30 cm and spins at a rate of 60,000 revolutions per minute.

Calculate the centripetal acceleration at the rim of the rotor.

(2)

$\omega = \frac{2\pi}{1000} = 6.28 \times 10^{-3}$ rad/s

$a = (6.28 \times 10^{-3})^2 \times \frac{15}{100}$

$= 5.9 \times 10^{-7}$ m/s²

Centripetal acceleration = $5.9 \times 10^{-7}$ m/s²

**ResultsPlus**
**Examiner Comments**

The angular frequency has been incorrectly calculated, because frequency has been used instead of time period in ω = 2p/T.

0 marks

**ResultsPlus**
**Examiner Tip**

Always use standard symbols in equations.

## *Question 18 (c) (iii)*

Several candidates described the properties without naming them. The most common wrong responses were 'tough', 'hard' and 'ductile'.

Many had not realised that this was not part of the reactor and assumed that it would have to have a high melting-point as well.

(iii) The rotor is subjected to huge forces because of the high spin rate.

Give **two** mechanical properties essential for the material from which the rotor is made.

(2)

Property 1 Should be able to withstand the centripetal force.

Property 2 It must be stable, it should not be radioactive

**ResultsPlus**
**Examiner Comments**

*Should be able to withstand the centripetal force* is insufficient for 'strong'. The reference to stability is not relevant, because the question asks for mechanical properties.

0 marks

**ResultsPlus**
**Examiner Tip**

Answer the question. If 2 mechanical properties are required, then state 2 mechanical properties.

## *Question 18 (d)*

Most candidates carried out the 'show that' correctly, with only a very small number failing to give the answer to more than 1 significant figure. However, most candidates had not fully understood the energy values given and thought that the total power produced was 3,100 MW (instead of 5,300 MW). Hence the most common value seen for the efficiency was 71% instead of 42%.

Show that the rate at which energy is removed from the reactors is about 3000 MW, and hence estimate a value for the efficiency of the electrical power generation process.

specific heat capacity of the sea water = 3990 J kg$^{-1}$ K$^{-1}$

(4)

$E = mc\Delta\theta$

$= 7.0 \times 10^4 \times 3990 \times 11$

$= 3.0 \times 10^9$ J

Efficiency = $\frac{\text{output}}{\text{Input}} \times 100\%$

$= \frac{2200 \times 10^6}{3.0 \times 10^9} \times 100\%$

$= 73\%$

**ResultsPlus**
**Examiner Comments**

It was acceptable for candidates to assume that t = 1 s and calculate an energy. This candidate has not calculated the energy (they have written down the 'show that' value). With an energy value of 3.1 × 10$^9$ J and an efficiency of 73% this candidate would have scored 3 marks. However, the lack of evidence of a calculation in the 'show that' brings the score down to 2 marks.

2 marks

**ResultsPlus**
**Examiner Tip**

Always complete calculations fully - particularly in a 'show that' question.

## Summary

Based on their performance on this paper, candidates are offered the following advice:

- Ensure that you have a thorough knowledge of the physics for this unit
- Read the question and answer what is asked
- For descriptive questions, make a note of the marks and include that number of different physics points
- Show all of your workings in calculations
- For descriptive questions, try to base the answer around a specific equation, which is quoted.

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