OXFORD
INTERNATIONAL
AQA EXAMINATIONS

INTERNATIONAL A-LEVEL PHYSICS

(PH04)

Unit 4: Energy and energy resources

Example responses with commentary

For teaching from September 2016 onwards
For A-level exams in May/June 2018 onwards

This guide includes some examples of student responses to a selection of questions from the summer 2018 PH04 unit.

The question parts are reproduced, along with the final mark scheme, student responses and a commentary from the Lead Examiner on each of the students' answers.

QUESTION

01.1

0 1 . 1 A farmer uses a wind turbine to provide power. The blades of the turbine sweep out a circle of diameter 3.70 m. At a given instant, the maximum power available from the wind is 7.7 kW.

Calculate the wind speed at this instant.

The density of air is $1.2\ \mathrm{kg\ m^{-3}}$

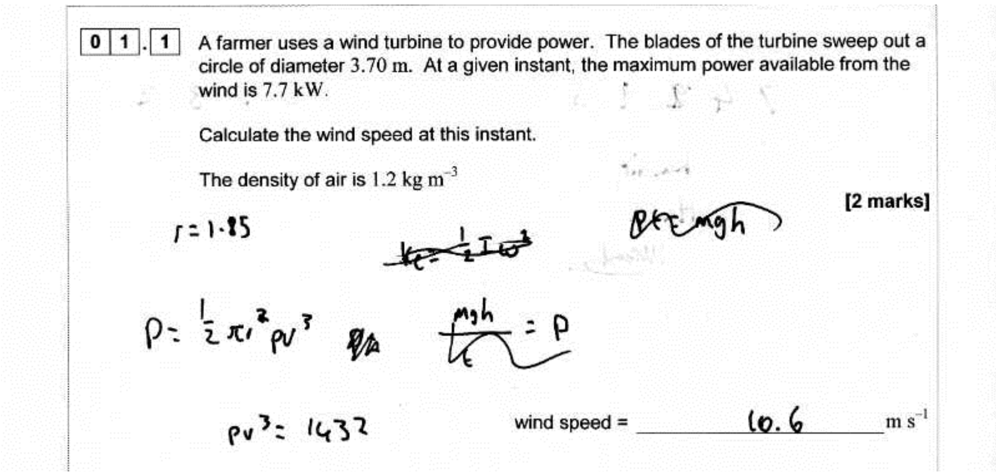
[2 marks]

wind speed = ____________________ $\mathrm{m\ s^{-1}}$

MARK SCHEME

Question	Marking guidance	Mark	Comments
01.1	Use of $\frac{1}{2}\pi r^2 \rho v^3 = 7700$ ✓ $v = 10.6$ m s^{-1} ✓	2	

STUDENT A



0 1 . 1 A farmer uses a wind turbine to provide power. The blades of the turbine sweep out a circle of diameter 3.70 m. At a given instant, the maximum power available from the wind is 7.7 kW.

Calculate the wind speed at this instant.

The density of air is $1.2\ \text{kg m}^{-3}$

[2 marks]

$r = 1.85$

$P = \frac{1}{2}\pi r^2 \rho v^3$

$\rho v^3 = 1432$

wind speed = 10.6 m s^{-1}

EXAMINER COMMENTARY

The level of explanation in the solution is poor. The maximum power (as a value) does not appear explicitly anywhere in the solution neither does the conversion from diameter to radius. The working is a jumble of unsupported letters and numbers. Only the correct answer appearing on the answer line saves it and allows full credit.

2 marks awarded.

STUDENT B

0 1 . 1 A farmer uses a wind turbine to provide power. The blades of the turbine sweep out a circle of diameter 3.70 m. At a given instant, the maximum power available from the wind is 7.7 kW.

Calculate the wind speed at this instant.

The density of air is 1.2 kg m^{-3}

[2 marks]

$P = \frac{1}{2}\pi r^2 \rho v^3$

$7700 = \frac{1}{2}\pi \times 1.85 \times V^3$

$V^3 = 2650$

$V = \sqrt[3]{2650}$

$= 13.838$

wind speed = 13.8 m s^{-1}

EXAMINER COMMENTARY

Although this scores no marks, the work does illustrate how students can make their working plain to the examiner. The correct equation is shown but equally clear are the failures to incorporate the density of air into the calculation and also to square the radius of the turbine blades.

0 marks awarded.

QUESTION

01.2

0 1 . 2 Explain why the electrical power output from the turbine is significantly less than 7.7 kW.

[2 marks]

MARK SCHEME

Question	Marking guidance	Mark	Comments
01.2	Not all of the (kinetic) energy of the wind is recovered ✓ Correct identification of a mechanical or electrical inefficiency ✓ **or** Explanation of why all of the KE is not used in terms of continuity or Betz's Law ✓	2	e.g. friction at a named point or electrical heating at a named point

STUDENT A

0 1 . 2 Explain why the electrical power output from the turbine is significantly less than 7.7 kW.

[2 marks]

This is due to wind shadowing as some turbines will take less energy due to other wind mills generating more energy from wind, Also if the full power output was created the turbines wouldn't move as they would have to use 100% of the wind energy.

EXAMINER COMMENTARY

The first sentence answers the question posed in Question 1.3 (not shown here) but is not an argument for the reduction in electrical power output. The second sentence is close to a sensible answer for the inability of the turbine to recover all the kinetic energy of the wind. However, it does not go far enough and muddles the ideas by suggesting that a 100% usage would mean that the turbine blades cannot rotate.

Note that ‘back marking’ (marking work that is written as a response to the wrong question) is not used.

0 marks awarded.

STUDENT B

0 1 . 2 Explain why the electrical power output from the turbine is significantly less than 7.7 kW.

[2 marks]

As the wind turbine does not have 100% efficieny. This is due to some is lost to the surrounding by wind mill and components of forces of the turbines reduce the energy produce as it reduces the speed of the turbine.

EXAMINER COMMENTARY

Again there is no credit here. The student is moving towards some credit but the reference to energy losses in the turbine mechanism is too vague.

0 marks awarded.

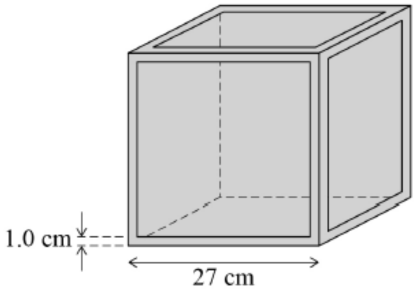
QUESTION

02.1

0 2 **Figure 1** shows a hollow cube of external dimension 27 cm.

The walls and lid of the cube are made from an insulating material which is 1.0 cm thick.

Figure 1



The cube is filled with 14.3 kg of ice at 0 °C.

The outer surface of the cube is maintained at 25 °C.

It takes 2 days for all the ice to melt.

The specific latent heat of fusion of ice is 334 kJ kg^{-1}

0 2 . 1 Show that the energy needed to melt the ice is about 5×10^6 J.

[1 mark]

energy = ____________________ J

MARK SCHEME

Question	Marking guidance	Mark	Comments
02.1	Q (= ml = 14.3 × 334000) = 4.7(8)x10^6 J ✓	1	Answer to 2 or more sf

STUDENT A

0 2 . 1 Show that the energy needed to melt the ice is about 5×10^6 J.

[1 mark]

~~$Q = mc\Delta\theta$~~

$Q = mL$

$Q = 14.3 \times 334 \times 10^3$

$Q = 4.7 \times 10^6$

energy = 4.7×10^6 J

EXAMINER COMMENTARY

This response scores full marks. This was the case for the whole cohort of students. The working here is clear.

Only one example of Question 2.1 is shown as answers were similar.

QUESTION

02.2

0 2 . 2 Calculate the thermal conductivity of the insulating material used to make the cube.

[4 marks]

thermal conductivity = ______________________ $W\ m^{-1}\ K^{-1}$

MARK SCHEME

Question	Marking guidance	Mark	Comments
02.2	Calculation of surface area $A = 6 \times 0.25 \times 0.25 = 0.375\ m^2$ ✓ Rate of energy transfer = $\frac{4776200}{2 \times 24 \times 60 \times 60}$ = 27.64 W ✓ Use of Rate of energy transfer = $\frac{kA\Delta\theta}{L}$ ✓ k = 0.025 - 0.030 $W\ m^{-1}\ K^{-1}$ ✓	4	Condone use of 0.26 or 0.27 in calculating area Condone a recognisable attempt at time e.g. 24x60x60 or 2x24x60 for second mark ecf their rate and their area for third mark no ecf for final mark

STUDENT A

5

0 2 . 2 Calculate the thermal conductivity of the insulating material used to make the cube. **[4 marks]**

Do not write outside the box

$60 \times 60 \times 24 = 86400 \times 2 = 172800 = t$

$\frac{Q}{t} = \frac{kA\Delta\theta}{L}$

$A = 29 \times 27 = 783 \times 10^{-2}$ m

$Q = 4.7 \times 10^{6}$

$L = 1 \times 10^{-2}$

$\frac{4.7 \times 10^{6}}{172800} = \frac{k \times 783 \times 10^{-2} \times 25}{1 \times 10^{-2}}$

$k = 1.339 \times 10^{-3}$

$k = 1.4 \times 10^{-3}$

thermal conductivity = 1.4×10^{-3} W m^{-1} K^{-1}

EXAMINER COMMENTARY

In this response there are two errors:

- The calculation of surface area is incorrect (the factor 6 is missing and no allowance has been made for the thickness of the walls).
- The answer is out of the tolerated range even though there are no further substitution errors.

2 marks awarded.

STUDENT B

0 2 . 2 Calculate the thermal conductivity of the insulating material used to make the cube.

[4 marks]

$\frac{Q}{t} = \frac{kA\Delta\theta}{L}$ $= \varepsilon$ $\quad A = \frac{\pi d^2}{4}$

2 days → 48 hours = 172800 s $\quad \frac{\pi(27)^2}{4}$

$\frac{(k)(573)(25° - 0°)}{} = \frac{4.776\times10^6}{172800}$ $= \frac{729}{4}\pi$ $= 573$

$\frac{(k)(573)(25°-0°)}{27} = 27.64$ $\quad k = \frac{L \times Q}{A \times \Delta\theta \times t}$

$k = 0.05$

thermal conductivity = 0.05 W m^{-1} K^{-1}

EXAMINER COMMENTARY

Again, there is an error in the calculation of the area where a circular shape has been assumed. However the continuing substitution is correct but the answer is out of range.

2 marks awarded.

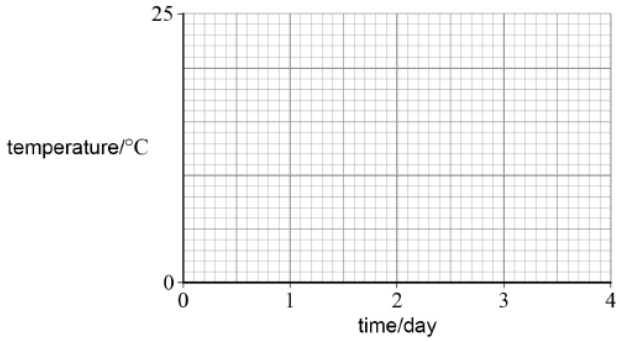
QUESTION

02.3

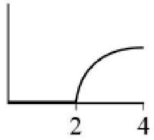
0 2 . 3 After the ice has melted, the cube is left in the same conditions for 2 more days.

Sketch a graph to show the variation with time of the temperature of the contents of the cube over the 4-day period.

[2 marks]



MARK SCHEME

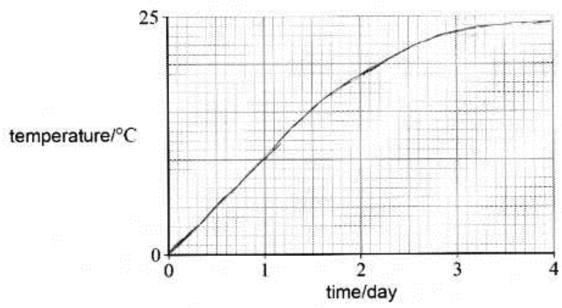
Question	Marking guidance	Mark	Comments
02.3	Temperature = 0 °C for 2 days ✓ Curve with decreasing gradient from 2–4 days ✓ 	2	

STUDENT A

0 2 . 3 After the ice has melted, the cube is left in the same conditions for 2 more days.

Sketch a graph to show the variation with time of the temperature of the contents of the cube over the 4-day period.

[2 marks]



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EXAMINER COMMENTARY

The student has forgotten that the cube will remain at 0°C while it is melting and that this process takes two days. Only after that does the temperature begin to increase and the closer the cube temperature approaches the room temperature the smaller the gradient of the graph will be.

1 mark awarded.

Only one example of question 2.3 is shown as answers were similar.

QUESTION

03.1

0 3 . 1 An alpha particle, with an initial kinetic energy of 8.0 MeV, approaches the centre of a nucleus of gold–197 ($^{197}_{79}\mathrm{Au}$).

Calculate the distance of closest approach between the alpha particle and the nucleus.

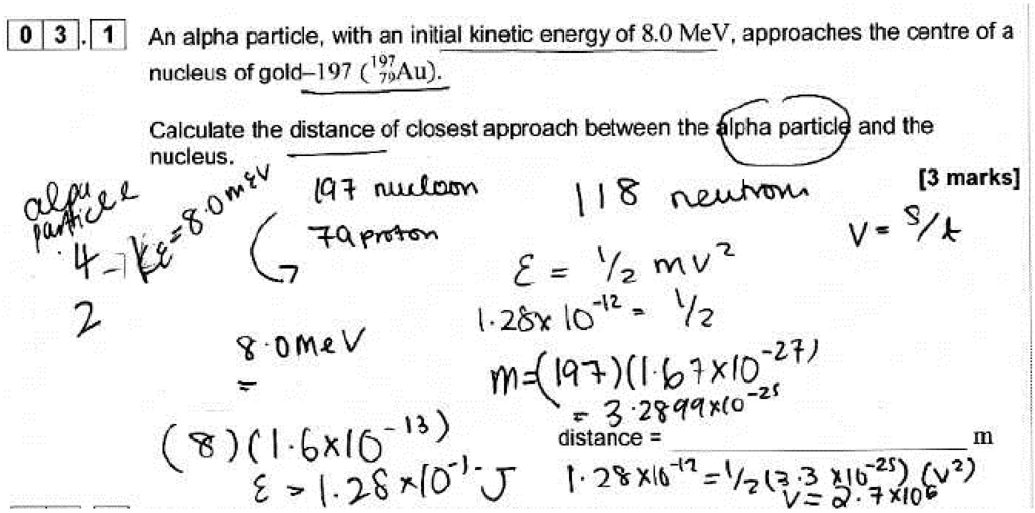
[3 marks]

distance = ______________________ m

MARK SCHEME

Question	Marking guidance	Mark	Comments
03.1	Use of $E_K = \frac{1}{4\pi\varepsilon_0}\frac{qQ}{R}$ ✓ Converts 8 MeV to J ✓ R = 2.84 × 10^{-14} m ✓	3	

STUDENT A



0 3 . 1 An alpha particle, with an initial kinetic energy of 8.0 MeV, approaches the centre of a nucleus of gold–197 ($^{197}_{79}Au$).

Calculate the distance of closest approach between the alpha particle and the nucleus.

[3 marks]

alpu particle 4 → KE = 8.0 MeV
2

197 nucleon
↳ 79 proton

118 neutron

$V = S/t$

$E = \frac{1}{2}mv^2$

$1.28 \times 10^{-12} = \frac{1}{2}$

8.0 MeV =

$m = (197)(1.67 \times 10^{-27})$
$= 3.2899 \times 10^{-25}$

$(8)(1.6 \times 10^{-13})$

$E = 1.28 \times 10^{-1}$ J

distance = ____________________ m

$1.28 \times 10^{-12} = \frac{1}{2}(3.3 \times 10^{-25})(v^2)$
$v = 2.7 \times 10^{6}$

EXAMINER COMMENTARY

Only 1 mark is scored in this confused account. The conversion from 8.0 MeV to its joule equivalent is correct. There is no clear attempt to equate the electrostatic potential energy stored in the system at closest approach to the kinetic energy of the alpha particle when well away from the nucleus.

1 mark awarded.

STUDENT B

0 3 . 1 An alpha particle, with an initial kinetic energy of 8.0 MeV, approaches the centre of a nucleus of gold–197 ($^{197}_{79}Au$).

Calculate the distance of closest approach between the alpha particle and the nucleus.

[3 marks]

$E = 8\,\text{Mev}$ $\qquad R_n = G_g \left(\frac{A_n}{A_g}\right)^{1/3}$

$ke = \frac{1}{2} mv^2$

~~ke~~ =

$8 \times 10^{6} \times 1.9 \times 10^{-19} = 1.52 \times 10^{-12}$

distance = ____________________ m

EXAMINER COMMENTARY

Student B is attempting a solution via the use of the equation $R = R_0 A^{\frac{1}{3}}$. However, this is not appropriate where the expectation is that the kinetic energy and electric potential energy will be equated.

0 marks awarded.

QUESTION

03.2

0 3 . 2 **Table 1** shows the nuclear radii R of three stable nuclides measured using electron diffraction.

Table 1

Nuclide	R / fm
$^{9}_{4}Be$	2.52
$^{12}_{6}C$	2.79
$^{16}_{8}O$	3.02

A model of the nucleus predicts that the nuclear radius is proportional to the cube root of the nucleon number.

Comment on the degree to which the data in **Table 1** are consistent with this prediction.

[3 marks]

MARK SCHEME

Question	Marking guidance	Mark	Comments
03.2	Calculates two values of R_0 ✓ Calculates three values of R_0 ✓ Concludes that the values are consistent ✓ OR Uses one data row to calculate R_0 and from that predicts the value of R for another data row. ✓ Predicts the value of R for a third data row. ✓ Concludes that the predicted values of R are close to those in the table. ✓ OR Shows that $R_1 / R_2 = A_1^{1/3} / A_2^{1/3}$ for a pair of data rows.✓ Repeats for another pair of data rows.✓ Concludes that the ratios support R being proportional to the cube root of A.✓	3	Ignore powers of ten.

STUDENT A

0 3 . 2 **Table 1** shows the nuclear radii *R* of three stable nuclides measured using electron diffraction.

Table 1

Nuclide	*R* / fm
$^{9}_{4}Be$	2.52
$^{12}_{6}C$	2.79
$^{16}_{8}O$	3.02

A model of the nucleus predicts that the nuclear radius is proportional to the cube root of the nucleon number.

Comment on the degree to which the data in **Table 1** are consistent with this prediction.

[3 marks]

$\frac{2.52}{\sqrt[3]{9}} = 1.21$ $\frac{2.79}{\sqrt[3]{12}} = 1.22$ $\frac{3.02}{\sqrt[3]{16}} = 1.2$

The R_0 value for all the data in the table is extremely close with $\frac{R}{\sqrt[3]{A}}$ being around 1.2. Therefore ~~this~~ the radius is proportional to the cube root to an accurate degree.

EXAMINER COMMENTARY

The student uses the third approach in the mark scheme and uses the known equation essentially to calculate R_0. The method is well explained and the calculations are accurate. Full credit is obtained from this approach.

3 marks awarded.

STUDENT B

0 3 . 2 **Table 1** shows the nuclear radii R of three stable nuclides measured using electron diffraction.

Table 1

Nuclide	R / fm
${}^{9}_{4}Be$	2.52
${}^{12}_{6}C$	2.79
${}^{16}_{8}O$	3.02

A model of the nucleus predicts that the nuclear radius is proportional to the cube root of the nucleon number.

Comment on the degree to which the data in **Table 1** are consistent with this prediction.

[3 marks]

$\sqrt[3]{9} = 2.08$ -> factor of 0.44

$\sqrt[3]{12} = 2.29$ -> factor of 0.5

$\sqrt[3]{16} = 2.52$ -> factor of 0.5

$\frac{0.5 + 0.5 + 0.44}{3} = 0.48$

-> the results are inaccurate by a mean value of 0.48

EXAMINER COMMENTARY

The approach is confused and the calculation has no physical significance. This method does not approximate to any of the three mark scheme methods and scores no credit.

0 marks awarded.

QUESTION

03.3

0 3 . 3 Discuss why electron diffraction gives a more accurate value of nuclear radius than using the distance of closest approach of alpha particles.

[3 marks]

MARK SCHEME

Question	Marking guidance	Mark	Comments
03.3	Alpha particles have mass of the same order of magnitude as the target nucleus ✓ Results affected by nuclear recoil **or** momentum transfer ✓ Distance of closest approach depends on the alpha particle energy ✓ Closest approach ≠ (or must be bigger than) the nuclear radius ✓ The de Broglie wavelength of high energy electrons is of the order of the nuclear radius ✓ Providing large diffraction angles ✓ Max 3	3	

STUDENT A

0 3 . 3 Discuss why electron diffraction gives a more accurate value of nuclear radius than using the distance of closest approach of alpha particles.

[3 marks]

Electron diffraction allows the ~~electrons~~ particles to travel a much greater distance as they can be fired with a higher speed than alpha particles. This means it is more accurate as they reach the whole distance instead of the closest approach. Alpha particles are also more likely to be deflected back when striking the nucleus where as electrons can travel through.

EXAMINER COMMENTARY

Only one comment corresponds to the six possible points in the mark scheme. The student suggests that the electrons can travel faster than the alpha particle and this is close to the energy comment (marking point three). One mark is awarded with some benefit of the doubt.

1 mark awarded.

STUDENT B

0 3 . 3 Discuss why electron diffraction gives a more accurate value of nuclear radius than using the distance of closest approach of alpha particles.

[3 marks]

because with electron diffraction electrons have very high speed and very short wavelentgh, therefore they get much closer to the neucleus, while when we shoot alpha particles on the neucleus it gets repelled by the electrostatic force therefor we get the distance of closest appoch and we don't get a very accurate answer

EXAMINER COMMENTARY

The 'very short wavelength' is not good enough for the fifth marking point as there is lack of technical vocabulary here (no mention of the de Broglie wavelength, for example). The comment regarding electrostatic repulsion, although not explicitly mentioned on the mark scheme, is good physics and a point well made. Credit is given for an alternative correct answer.

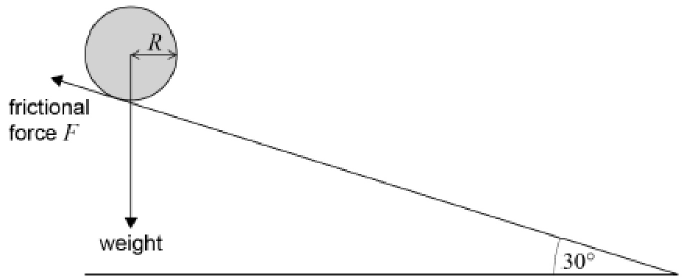
1 mark awarded.

QUESTION

04

0 4 **Figure 2** shows a solid sphere of uniform density with a radius R of 0.14 m. The sphere is at the top of a ramp inclined at 30° to the horizontal. The sphere, initially at rest, is released and rolls down the ramp without slipping. The frictional torque produces an angular acceleration on the sphere of 25 rad s^{-2}

Figure 2



The mass M of the sphere is 1.8 kg.

The moment of inertia of a solid sphere is $\frac{2}{5}MR^2$

0 4 . 1 Calculate the frictional force F.

[3 marks]

frictional force = ________________ N

0 4 . 2 Calculate the angular speed of the sphere 1.5 s after its release.

[1 mark]

angular speed = ________________ rad s^{-1}

0 4 . 3 Show that the sphere travels approximately 3.9 m along the ramp in the first 1.5 s of its motion.

[4 marks]

0 4 . 4 Calculate the reduction in gravitational potential energy of the sphere during the first 1.5 s.

[2 marks]

reduction in gravitational potential energy = ____________ J

0 4 . 5 Calculate the increase in the rotational kinetic energy of the sphere during the first 1.5 s.

[2 marks]

increase in rotational kinetic energy = ____________ J

0 4 . 6 The sphere is now placed on a similar frictionless ramp.

State and explain how the lack of friction will affect the change in rotational kinetic energy.

[2 marks]

MARK SCHEME

Question	Marking guidance	Mark	Comments
04.1	Use of $T = I\alpha$ ✓ Use of $T = Fr$ ✓ R = 2.52 N ✓	3	
04.2	ω (= 0 + 25.0 × 1.5) = 37.5 rad s^{-1} ✓	1	
04.3	$\theta = \frac{1}{2}\alpha t^2$ ✓ = 28.125 rad ✓ Number of revolutions $= \frac{28.125}{2\pi} = 4.48$ ✓ Distance = 4.48 × 2 × π × 0.14 = 3.94 m ✓ OR $\theta = \frac{1}{2}\alpha t^2$ ✓ = 28.125 rad ✓ Use of $s = r\theta$ ✓ Distance = 3.94 m ✓ OR (For a point on circumference) Use of $v = \omega r$ ✓ v = 5.25 ms^{-1} ✓ Use of $s = \left(\frac{u+v}{2}\right)t$ Or $v^2 = u^2 + 2as$ ✓ Distance = 3.94 m ✓ ✓	4	Must see unrounded answer for final mark
04.4	Δh = 3.94 sin(30) = 1.97 m ✓ Loss of GPE = $mg\Delta h$ = 34.8 J ✓	2	If use s = 3.9 m from 4.3 then Loss of GPE = 34.4 J

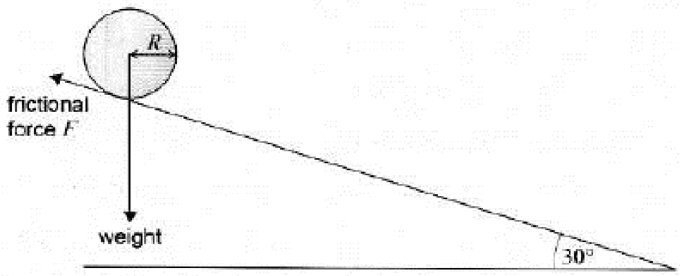
04.5	Use of $E_{k(rot)} = \frac{1}{2} I \omega^2$ ✓ = 9.9 J ✓	2	ecf their ω from 4.2 and any previously calculated incorrect value for I.

04.6	There will be no (change in) rotational kinetic energy There is no frictional torque producing an angular acceleration **or** All the GPE lost is transferred into translational kinetic energy	2	Accept the (change in) rotational kinetic energy will be reduced Accept the sphere will roll or slide for second mark.

STUDENT A

0 4 **Figure 2** shows a solid sphere of uniform density with a radius R of 0.14 m. The sphere is at the top of a ramp inclined at 30° to the horizontal. The sphere, initially at rest, is released and rolls down the ramp without slipping. The frictional torque produces an angular acceleration on the sphere of 25 rad s^{-2}

Figure 2



The mass M of the sphere is 1.8 kg.

The moment of inertia of a solid sphere is $\frac{2}{5}MR^2$

0 4 . 1 Calculate the frictional force F.

[3 marks]

$T = Fr$ $\quad$ $F = \frac{T}{r}$

$T = I\alpha$

$T = \frac{2}{5} \times 1.8 \times (0.14)^2 \times 25$

$= 0.35 28$ Nm

$F = \frac{0.3528}{0.14} = 2.52$

...ictional force = 2.52 N

0 4 . 2 Calculate the angular speed of the sphere 1.5 s after its release.

[1 mark]

$\theta = ?$ $\quad \omega_0 = 0$ $\quad \omega = ?$ $\quad \alpha = 25$ $\quad t = 1.5$

$\omega = \omega_0 + \alpha t$

$= 25 \times 1.5$

$= 37.5$

angular speed = 37.5 rad s^{-1}

0 4 . 3 Show that the sphere travels approximately 3 ^ along the ramp in the first 1.5 s of its motion.

[4 marks]

$v = \omega r = 37.5 \times 0.14$

$s = ?$ $\quad u = 0$ $\quad v = 5.25$ $\quad \omega = ?$ $\quad t = 1.5$

$s = \left(\frac{u+v}{2}\right)t$

$= \left(\frac{5.25}{2}\right) \times 1.5$

$= 3.9375$ m

$\therefore \approx 3.9$ m

0 4 . 4 Calculate the reduction in gravitational potential energy of the sphere during the first 1.5 s.

[2 marks]

$\frac{1}{2}mr^2$ ~~tan~~ $\sin 30 = \frac{x}{3.9}$

$x = 3.9\sin 30$
$h = 1.95$

~~1.8~~ mgh
$= 1.8 \times 9.81 \times 1.95$
$= 34.4$

reduction in gravitational potential energy = 34.4 J

0 4 . 5 Calculate the increase in the rotational kinetic energy of the sphere during the first 1.5 s.

[2 marks]

$E_k = \frac{1}{2}I\omega^2$
$= \frac{1}{2} \times \frac{2}{5} \times 1.8 \times (0.141)^2 \times (37.5)^2$
$= 9.92$

increase in rotational kinetic energy = 9.92 J

0 4 . 6 The sphere is now placed on a similar frictionless ramp.

State and explain how the lack of friction will affect the change in rotational kinetic energy.

[2 marks]

It will reduce to 0J ∴ a frictionless ramp. This is because, with no friction the sphere will simply slide on the ramp without rotating. There will be no torque on it and therefore no rotation.

EXAMINER COMMENTARY

This set of answers to Question 4 shows a student in full control of the material.

For the calculations (Questions 4.1–4.5), the methodology is clear although always expressed in equation form without definition of symbols. However, the student uses conventional symbols as used in the *Formula and relationship* sheet. Answers are quoted to three significant figures throughout with rounding apparent where necessary.

In Question 4.6 there is the recognition that sliding does not allow rotational kinetic energy (this is an acceptable alternative answer to that in the mark scheme) and therefore the quantity of energy in this mode remains zero throughout the motion.

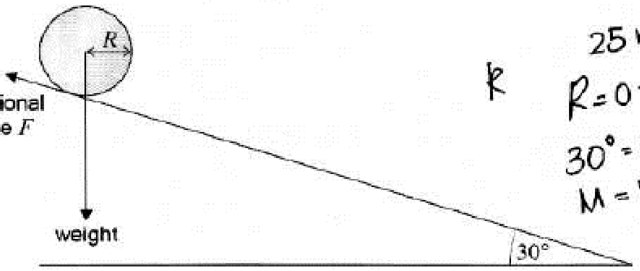
Each response earned full marks. 14 marks awarded in total.

STUDENT B

0 4 **Figure 2** shows a solid sphere of uniform density with a radius R of 0.14 m. The sphere is at the top of a ramp inclined at 30° to the horizontal. The sphere, initially at rest, is released and rolls down the ramp without slipping. The frictional torque produces an angular acceleration on the sphere of 25 rad s^{-2}

Figure 2

s = θ
u = ω_0
v = ω
a = α
T = Fr (Nm)
T = I α
I = moment of inertia



25 rad s^{-2}
R = 0.14 m
30° = θ
M = 1.8 kg

The mass M of the sphere is 1.8 kg.

The moment of inertia of a solid sphere is $\frac{2}{5}MR^2$

a = ω/t

0 4 . 1 Calculate the frictional force F.

[3 marks]

F =

R = 0.14
30°

I = 2/5 (1.8)(0.14)^2
= 0.014

25 × 0.014
= 0.35

0.35 / 0.14
= 2.5

α = 25

frictional force = ______________ N

0 4 . 2 Calculate the angular speed of the sphere 1.5 s after its release.

[1 mark]

2π / t   2π / 1.5
= 4.2

α = ω / t
25 = ω / 1.5
ω = 37.5

angular speed = 4.2 rad s^{-1}

ω = v/r   ω = 2π f

0 4 . 3 Show that the sphere travels approximately 3.9 m along the ramp in the first 1.5 s of its motion.

[4 marks]

$\alpha = 2.8$

$\theta = 3.9$

$(\omega, 1.5) + \frac{1}{2}(25)(1.5)^2$

$\theta = \frac{(\omega_0 + \omega)}{2} t$ =

$t = 1.5$

$\frac{2\pi}{1.5} = \omega$

$= 4.2$

0 4 . 4 Calculate the reduction in gravitational potential energy of the sphere during the first 1.5 s.

[2 marks]

gpe = m × g × h

$m = 1.8$

$\alpha = 25$

$h = 3.9$

$(1.8)(25)(3.9)$

$= 175.5$

reduction in gravitational potential energy = 175.5 J

0 4 . 5 Calculate the increase in the rotational kinetic energy of the sphere during the first 1.5 s.

[2 marks]

$I = 0.014$

$\frac{\omega}{1.5} = 25$

$\omega = 37.5$

$E_k = \frac{1}{2} I \omega^2$

$\frac{1}{2}(0.014)(37.5)^2$

=

increase in rotational kinetic energy = 9.84

0 4 . 6 The sphere is now placed on a similar frictionless ramp.

State and explain how the lack of friction will affect the change in rotational kinetic energy.

[2 marks]

less force ~~eq~~ opposing it therefore ~~ke~~ rotational kinetic energy is increased.

EXAMINER COMMENTARY

Question 4.1 scores full marks albeit for a somewhat jumbled and poorly explained answer. The student pays heavily for a systematic lack of coherence in the answer from then on.

Question 4.2 seems to use an incorrect approach and the correct answer appears but is then discarded in favour of the value 4.2 rad s^{-1}. In 4.3 the proposed equation $\theta = \omega_i t + \frac{1}{2}\alpha t^2$ should have led to a correct solution, but the student appears to be mis-applying the equation with a non-zero value for ω_I only partial credit is given for the recognition of the method.

In Question 4.4 there is no use of the required ramp angle and zero credit again.

Question 4.5 scores all the points as the student has used the correct value for ω (37.5 rad s^{-1}, presumably picked up from one of the results in 4.2) to arrive at an answer of 9.84 J (benefit of the doubt was given here as the correct value is 9.9 J).

The physics discussed in Question 4.6 is incorrect and no credit is given.

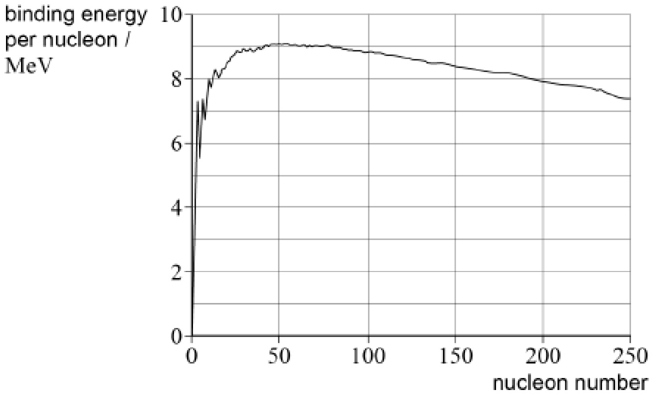
5 marks awarded.

QUESTION

05

0 5 **Figure 3** is a plot showing the variation with nucleon number of the binding energy per nucleon.

Figure 3



0 5 . 1 Explain with reference to **Figure 3** why nuclear fusion can lead to the release of energy.

[3 marks]

0 5 . 2 A uranium–235 nucleus undergoes induced fission to form two nuclei of equal mass.

Calculate, using **Figure 3**, the energy in J released by this fission event.

[5 marks]

energy released = ______________________ J

0 5 . 3 Describe, with reference to their energy, the role of neutrons in a thermal nuclear reactor.

[3 marks]

0 5 . 4 Describe the function of the control rods in a thermal nuclear reactor.

Your answer should include **one** example of a suitable material for a control rod and its properties.

[3 marks]

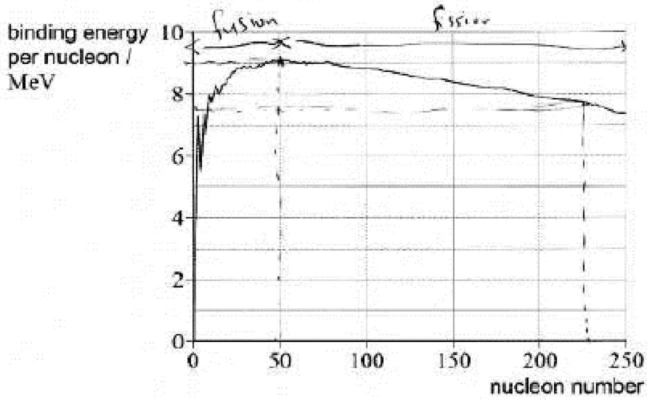
MARK SCHEME

Question	Marking guidance	Mark	Comments
05.1	Correctly identifies the region of the graph in which fusion occurs ✓ When light nuclei fuse to make heavier nuclei they move closer to the peak ✓ There is an increase in BE per N so energy is released ✓ Product has less mass than the combined mass of the two parents. ✓ MAX 3	3	
05.2	Identifies BE per N for uranium–235 at 7.5–7.8 MeV A ✓ Identifies BE per N for product at 8.6–8.9 MeV B ✓ Change in binding energy = (B–A) × 235 or 236 ✓ Answer in range 188–330 MeV ✓ Correctly converts their answer in MeV into J ✓	5	Condone use of 233 or 234 for the candidate that recognises that 2 or 3 neutrons are emitted in the fission
05.3	Release of (high-energy) neutrons from fission ✓ to cause (subsequent) fission neutrons need to be slowed ✓ Other relevant detail: For example, slowing is achieved by collision with moderator atoms **or** neutrons sustain the chain reaction **or** the number of neutrons available controls the rate of fissions ✓	3	
05.4	Suitable material named ✓ Absorb neutrons (without undergoing fission) ✓ Can be raised or lowered (into the core) to maintain the desired rate of fission (owtte) ✓ Can be lowered automatically in an emergency shutdown ✓ Max 3	3	eg (alloys of) boron **or** silver **or** indium **or** cadmium **or** hafnium Candidates can get the 1st mark and then any 2 out of 3

STUDENT A

0 5 **Figure 3** is a plot showing the variation with nucleon number of the binding energy per nucleon.

Figure 3



0 5 . 1 Explain with reference to **Figure 3** why nuclear fusion can lead to the release of energy.

[3 marks]

Due to the binding energy of the nucleus which is equal the energy released.
The process of making small nuclei fuse together to form large nucleus.
Binding energy per nucleon increases in nuclear fusion which provides the nucleon number of product nucleus not greater than 50.
Product nucleus has more binding energy ~~that~~ per nucleon than smaller nuclei.

0 5 . 2 A uranium–235 nucleus undergoes induced fission to form two nuclei of equal mass.

Calculate, using **Figure 3**, the energy in J released by this fission event.

[5 marks]

~~$Q = \Delta mc^2$~~

Energy released = change of binding energy
= 8.5 MeV – 7.5 MeV = 1 MeV

number of nucleon of uranium = 235

energy released = 235 x 1 MeV
= $235 \times 1.6 \times 10^{-19} \times 10^{6}$
= 376×10^{-13} J

energy released = 376×10^{-13}

0 5 . 3 Describe, with reference to their energy, the role of neutrons in a thermal nuclear reactor.

[3 marks]

Neutrons play a role in the change of the rate of release of fission energy. The rate of release of fission energy is reduced if the control rods are pushed in further.

Fission neutrons are slowed down to kinetic energies.

0 5 . 4 Describe the function of the control rods in a thermal nuclear reactor.

Your answer should include **one** example of a suitable material for a control rod and its properties.

[3 marks]

The function of the control rods in thermal nuclear reactor is to absorb neutrons. lso, ~~they~~ their depth is adjusted automatically to keep the number of neutrons in the core constant.

Suitable material : steel
properties : - metals
- Good conductors of heat and electricity.

EXAMINER COMMENTARY

In Question 5.1, Student A uses the printed grid to provide the region for fusion for the first marking point (going further and showing the fission region too). There is a description of the change in binding energy per nucleon which is also credited. However, the student has omitted any description of the movement of the position towards the graph peak of fusion products. Also omitted is any consideration of the mass of the nuclei before and after the process. 2 marks awarded.

The calculation in Question 5.2 uses an out-of-range value for the binding energy per nucleon of the product and therefore the second mark on the scheme is lost. Otherwise all steps are present and correct leading to the award of 4 marks. This is a clear solution with all steps notated reasonably well. 4 marks awarded.

Question 5.3 scores only 1 of the 2 marks available because the only relevant comment is the relatively low-level point regarding the slowing down of neutrons to what the student presumably meant to be thermal (rather than kinetic) energies. 1 mark awarded.

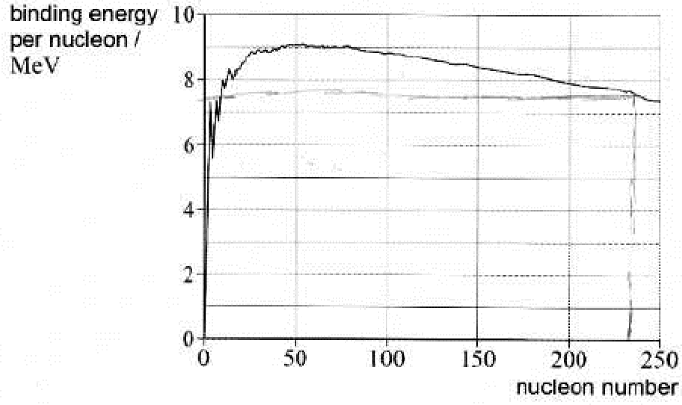
The absorption properties of the control rods and the way in which control can be achieved are seen in the answer to Question 5.4. However, steel is not regarded as a suitable absorber (except as an alloy with an appropriate named absorber). The technique of automatic insertion of control material in an emergency was not mentioned by the student. 2 marks are therefore awarded.

9 marks awarded in total.

STUDENT B

0 5 **Figure 3** is a plot showing the variation with nucleon number of the binding energy per nucleon.

Figure 3



0 5 . 1 Explain with reference to **Figure 3** why nuclear fusion can lead to the release of energy.

[3 marks]

~~when an unstable neweler~~ Un
when a neucli undergo fussion they are traveling at each other with very high speed, there fore when they join together this releases binding energy

0 5 . 2 A uranium–235 nucleus undergoes induced fission to form two nuclei of equal mass.

Calculate, using **Figure 3**, the energy in J released by this fission event.

[5 marks]

binding energy per neucleon
= 7.5 mev

7.5 × 235 = 1762.5 Mev

1762.5 × 1.6×10⁻¹³ = 2.82×10⁻¹⁰

energy released = ____________ J

0 5 . 3 Describe, with reference to their energy, the role of neutrons in a thermal nuclear reactor.

[3 marks]

in a thermal neuclear reactor neutrons are released, they are then colided with the moderator until they ~~are~~ meet a suitable ke for ~~the~~ fission to happen, at this point these neutrons are absorbed by U^{235} and this U^{235} split into 2 smaller atoms releasing more neutrons, these neutrons carry on a chain reaction and produce energy.

0 5 . 4 Describe the function of the control rods in a thermal nuclear reactor.

Your answer should include **one** example of a suitable material for a control rod and its properties.

[3 marks]

The function of control rods is to control the flow of neutrons, if they are inserted deeper then they allow less neutrons to flow

EXAMINER COMMENTARY

In Question 5.1 the only suggestion is that fusion occurs when nuclei collide at high speed. While there is truth in this statement, there is no reference at all to the graph (contrary to the question itself) and no credit is awarded.

Question 5.2 gives an identification of the binding energy per nucleon for U-235 that is just in range together with a conversion of this to joule. No further identifications or manipulations are shown so 2 marks are awarded.

The release of neutrons to induce further fission is shown in the answer to Question 5.3. However the student says that these emitted neutrons need to '…meet a suitable ke…' and this is not enough to imply loss of kinetic energy or a much reduced speed. There is further detail (relating to the energy change produced through collisions with the moderator) which is given credit. 2 marks are given overall for this question.

In Question 5.4 no suitable control material is named, and the process of absorption is not mentioned. Neither is there a consideration of the emergency function. The phrase '…if they are inserted deeper then they allow less neutrons to flow' is not enough to satisfy the detail required in the third marking point.

4 marks awarded in total.

FURTHER GUIDANCE AND CONTACTS

You can contact the subject team directly at **science@oxfordaqaexams.org.uk**

Please note: We aim to respond to all email enquiries within two working days.

Our UK office hours are Monday to Friday, 8am – 5pm local time.

OXFORD
INTERNATIONAL
AQA EXAMINATIONS

OXFORD INTERNATIONAL AQA EXAMINATIONS
GREAT CLARENDON STREET, OXFORD, OX2 6DP
UNITED KINGDOM

enquiries@oxfordaqaexams.org.uk
oxfordaqaexams.org.uk