AQA

A-LEVEL
Physics B

PHYB5 – Energy Under the Microscope
Mark scheme

2455
June 2015

Version 1.1 Final Mark Scheme

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 Assessment Writer.

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.

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Question	Part	Sub Part	Marking Guidance	Mark Type	Mark	Comments
1	a	i	Reads a pair of coordinates correctly <u>seen</u> attempted sub into $\eta = \frac{T_H - T_C}{T_H}$ for η and T_C (Converts) sink temperature (to) K and % efficiency to efficiency Must see kelvin temp and decimal efficiency Convincing manipulation (correctly) formula (making T_H subject) and calculates T_H to at least 3 sf (923 K) Range= 910 to 930 (K) Alternative: (4th mark) reverse must make statement that compares % efficiency achieved to value as read off	B1 B1 B1 B1	4	alternative: • reads <u>two sets of</u> coordinates <u>seen</u> or attempts to find gradient • determines gradient = – 0.107 or –0.00107 = $\frac{-6}{56}$ • sets gradient equal to $\frac{-1}{T_H}$ or $\frac{-100}{T_H}$ • calculates T_H to at least 3 sf (933K) range = 925 to 940
1	a	ii	• Only applies to Carnot engine / only applies to reversible engines / entropy increases in practical engines • energy loss due to friction <u>and</u> where or how • heat energy loss ***due to conduction*** • incomplete combustion of fuel-air mixture • turbulence in working fluid • working fluid dumped with increased internal energy • work done in opening and closing valves • working fluid is not an ideal gas	B1 B1	Max 2	Not simply heat is lost Not temperature of source decreases Not temperature of sink increases

1	b		Use of % efficiency = $\frac{useful\ power\ output}{total\ power\ input}$ $(\times 100)$ **or** Q_H = 79.5 (80) (kJ per second)	C1		Condone power 10 error in substitution
			ΔS_H = (–) 86.46 (86 or 86.5)(J K^{-1}) **or** use of $\Delta \boldsymbol{S} = \frac{\boldsymbol{their\ Q}}{\boldsymbol{920}}$ **or** $\frac{\boldsymbol{their\ Q}}{\boldsymbol{310}}$	C1		
			Q_C = 44.5×10^3 (J) **or** $\Delta S_C = 144\ (143.7)(J\ K^{-1})$	C1		
			(Difference found =) 57(.2) or 0.057(2) c.a.o **and** positive value on answer line Negative statement for entropy change is TO (watch for answers of 57.3 PE, is due to 35 $\times 10^3$ ÷ 610)	A1		**Answer must match unit for 5 marks otherwise maximum of 4 marks**
			Unit = J K^{-1} or kJ K^{-1}	B1		Condone WK^{-1} allow J/K etc.

1	c		B before A **or** B (is likely to have occurred first)	B1	3	
			<u>Entropy</u> is a measure of disorder in system / <u>Entropy</u> is a measure of the multiplicity of the system	B1		
			Tendency for a system to become more disordered (without input of energy from outside) / More ways of arranging the balls randomly as in A than in an orderly way such as in B/ entropy of an <u>isolated</u> system can never decrease (and usually increases)/ A is more disordered than B	B1		

2	a	i	Appreciates *pV* should be constant for isothermal change (by working or statement) $W = p\Delta V$ is TO Demonstrates *pV* = constant using 2 points (on the line) set equal to each other or conclusion made or **shows** that for V doubling that *p* halves *(worth 2 marks)* *need to see values for p and V* Demonstrates *pV* = constant using 3 points (on the line) <u>with conclusion</u> *need to see values for p and V*	M1 A1 A1	3	Allow only products seen where are approximately 150 for 1 mark Penalise J as unit here Products should equal 150 to 2 sf. Accept statement that products are slightly different so not quite isothermal Products should equal 150 to 2 sf. Accept statement that products are slightly different so not quite isothermal

2	a	ii	Adiabatic <u>therefore</u> no heat transfer **or** adiabatic <u>therefore</u> $Q = 0$ Work is done <u>by</u> gas <u>therefore</u> *W* is <u>negative</u> **or** Work is done <u>by</u> gas <u>therefore</u> energy is removed from the system <u>ΔU</u> is negative <u>therefore</u> internal energy of gas decreases **or** energy is removed from the system <u>therefore</u> internal energy of gas decreases or work done by the gas <u>so</u> internal energy decreases	B1 B1 B1	3	Allow $-\Delta U = -W$ or $\Delta U = -W$

2	a	iii	Uses pV/T = *constant* *or uses* $pV=nRT$ *or uses* $pV=NkT$ *e.g makes T subject or* substitutes into an equation with p_A and V_A or p_C and V_C (condone use of n=1) or their $\frac{(pV)_A}{(pV)_C}$ Correct substitution of coordinates (inside range) into $\frac{(pV)_A}{(pV)_C}$ With consistent use of powers of 10 $(pV)_A$ range is 150 to 156 and $(pV)_C$ range is 119 to 120.4 1.2(5) Allow range from 1.2 to 1.3 Accept decimal fraction : 1	C1 C1 A1	3	V_A *read off range* $= 2.5$ *to* $2.6\ (\times 10^{-4})$ $p_A = 600 \times 10^3$ V_C *read off range* $= 8.5$ *to* $8.6 (\times 10^{-4})$ $p_C = 140 \times 10^3$

2	b		Energy per large square = 10(J) **or** <u>states</u> that work done is equal to area under curve (between A and B) **or** energy per small square = 0.4(J) **or** square counting seen on correct area *Must be clear that area represents energy either by subject of formula or use of units on 10 or 0.4* Number of large squares = 10.5 to 11.5 seen <u>and</u> *(W) = number of squares ×area of one square (using numbers)* *Range = 105 to 115 (J)* *Or* Number of small squares = 263 to 287 seen <u>and</u> *(W) = number of squares ×area of one square (using numbers)* *Range = 105 to 115 (J)*	B1 B1	2	Alternative: W = area of a trapezium (with working) **or** W = $P_{mean} \times \Delta V$ **or** W = $450 \times 10^3 \times 2.5 \times 10^{-4}$ **or** W = area of a rectangle + area of a triangle (with working) States that actual work done would be lower because of curvature of line

2	c		(Total energy removed per s =) 4560 (J) **or** number of cycles per s = 40 **or** (Mass per second =) 114 ÷68400 in rearranged form **or** their energy ÷ (c ΔT) **or** their energy ÷68400 0.067 (kg) seen Allow 0.066 (kg) here **or** allow V / t = 1.67 x 10^{-3} ÷1100 **or** $(\frac{V}{t}) = \frac{E}{\rho c\, \Delta\theta}$ and correct **substitution** seen condone E = 114 (J) **or** temperature = 291(K) = 0.061 x 10^{-3} or 6.06×10^{-5} (m^3)	C1 C1 A1	3	
3	a	i	**Fallout:** <u>Radioactive isotopes</u> from nuclear weapons <u>testing</u> or reactor <u>accidents</u> (carried through the air) **Cosmic:** (mostly) <u>protons</u> from (outer) <u>space</u> or <u>atomic nuclei</u> from (outer) space or <u>high energy</u> radiation from stars or <u>high energy</u> radiation from (outer) space or <u>high energy</u> radiation from supernovae or <u>particles created</u> by collisions with (high energy) radiation in the upper atmosphere. or particles created by collisions with protons in the upper atmosphere	B1 B1	2	Allow <u>radiation</u> from nuclear weapons <u>testing</u> or reactor <u>accidents</u>

3	a	ii	increased exposure for patients, Any two from: • radiation therapy (<u>ionising</u> radiation used to treat cancer) • X-rays scanning / imaging (allow having an X-ray) • CAT scans or CT scans • PET scans • scans using high energy radiation (or ionising radiation) • tracers • targeted alpha therapy • I-131 thyroid treatment	B1 B1	MAX 2	
3	b	i	(Converts to J) 8.8×10^{-13} **or** divides energy(in MeV or J or eV) by 9×10^{16} **or** 5.5 ÷ 931 seen 9.8×10^{-30} (kg)	C1 A1	2	i.e. *m = an energy/c*^{2} allow an energy = m x 9×10^{16} condone error on conversion to joules in this sub
3	b	ii	Greater since energy of recoil nucleus not taken into account Or Greater since radiation is also produced (gamma emission) *Must describe a mechanism to account for the extra energy.*	B1	1	

3	c	i	4 circled	B1	1	

3	c	ii	2 circled	B1	1	

3	d	i	• Products of decay are <u>solid</u> matter and will <u>remain</u> in the lungs • Accumulation of radioactive material in lungs (increases activity more likely for ionisation of cells to occur)/ increasing likelihood of decaying inside body **or** • products are <u>solid</u> and can <u>attach</u> to cells • Increasing the likelihood of alpha being absorbed by cells **or** • Radon is a <u>gas</u> so it is exhaled (immediately)after it is inhaled / radon <u>gas</u> does not stay in lungs • as it is inert so will not be used biologically and stay in the body / allow has a shorter biological half-life **or** • Radon is a <u>gas</u> so it is exhaled (immediately) after inhalation / radon <u>gas</u> does not stay in lungs • no accumulation of radioactive material in lungs (no increase in activity less likely for ionisation of cells to occur))/ decreasing likelihood of decaying inside body	B1 B1	2	Any pair: Statement and Detail (B1,B1)

3	d	ii	Spend more time in the home than in school or workplace	B1	1	

3	e	i	use of $A = A_0\ e^{-\lambda t}$ must include 400 and 600 correctly identified or makes t subject of equation (decay constant =) 7.57(7.6) x 10^{-3} (hours^{-1}) or ln2÷3.8 (days^{-1}) or 0.182 (days-1) or 2.11 x 10-6 (s^{-1}) or t = 2.22 (days) or t = 1.92 x10^5 (s) 53 to 54 (hours)	C1 C1 A1	3	Or equivalent

3	e	ii	Use of A = λN Calculates decay constant in s^{-1} 2.1 x 10^{-6} or ln2 ÷ (3.8 x 24 x 60^2) 1.89 x 10^8 (Condone 1.90 x 10^8)	C1 C1 A1	3	Condone error on λ

3	e	iii	Use of *pV = NkT* *condone error on sub for T ecf* *(or PV=nRT* ***and*** *n = N/N$_A$)* Correct substitution ecf for *N* 7.56 x 10^{-13} to 7.60 x 10^{-13} ecf pascal or Pa or N m^{-2} or kg m^{-1} s^{-2}	C1 C1 A1 B1	4	*no sub for V then p must be subject of equation* ecf answer = their N ×4 ×10^{-21} correct symbols including case

3	f		ANY 2 Use extractors/open windows regularly or ensure good ventilation/have <u>solid</u> floors or <u>no gaps</u> in floors/positive ventilation (Blowing air into living space from loft)	B1 B1	2	

4	a		ANY 2 from • Slow moving neutrons or low (kinetic)energy neutrons • (They are in) thermal equilibrium with the moderator/ Are in thermal equilibrium with other material (at a temperature of about 300 K) • Have energies of order of 0.025 eV • Have (range of) KE similar to that of a gas at 300 K or room temperature	B1 B1	2	

4	b	i	Use of $mgh = ½\, mv^2$ by substitution or rearranges to make h the subject 0.086(1) (m) or 0.086(2) (m)	C1 A1	2	PE for use of equation of motion (constant acceleration)

4	b	ii	Correct equation for conservation of momentum $m_1u_1 (+ m_2u_2) = m_1v_1 + m_2v_2$ **or** states momentum before = momentum after **or** $p_{before} = p_{after}$ (Correct clear Manipulation =) 0.065 (+ 0) = $-0.0325 + 0.0975$ **o**r –0.065 (+ 0) = $0.0325 - 0.0975$ must see signs **States** initial kinetic energy = final kinetic energy **or** **states** kinetic energy is conserved (Correct clear Manipulation=) 0.04225 = 0.0105625 + 0.0316875 Or equivalent workings with numbers seen **and** 0.04225 = 0.04225 **/** KE before = KE after	B1 B1 B1 B1	4	Condone non-SI here: 65 (+0) = $-32.5 + 97.5$ Allow equivalent on RHS where masses are summed in one KE term.
4	b	iii	(percentage/fraction remaining after 1 collision =) ¼ = 25% **seen or** % remaining = 100 x ½ *m*($1.3^2 - 0.65^2$)/ ½ *m*1.3^2 **or** hockey ball = 0.0317 **and** initial ke = 0.04225 **or** their KE_{hb} / 0.04225 or their KE_{hb} / their KE_T 75(%) range 75 to 76	C1 A1	2	

4	b	iv	**Demonstrates:** Slowing down/loss of KE of golf ball is like neutrons slowed down/ Neutrons can lose KE by elastic collisions also **Differs:** collisions in a reactor are not always/rarely head-on **or** KE loss is variable or Collisions are not <u>always</u> elastic **or** Ratio of mass of neutron to mass of nucleus is usually much smaller in a reactor	B1 B1	2	
4	b	v	Water	B1	1	

4	c		The marking scheme for this question includes an overall assessment for the quality of written communication (QWC). There are no discrete marks for the assessment of QWC but the candidate's QWC in this answer will be one of the criteria used to assign a level and award the marks for this question. **Descriptor** – an answer will be expected to meet most of the criteria in the level descriptor. **Level 3 – good** -claims supported by an appropriate range of evidence -good use of information or ideas about physics, going beyond those given in the question -argument well-structured with minimal repetition or irrelevant points -accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling The candidate gives a coherent and logical description of the fission process, indicating the reason why there is energy produced. There is clear understanding of the fission process identifying suitable fissile material. The candidate also gives a coherent account of energy transfers that take place and the particles responsible for carrying the majority of the energy. The candidate is able to describe how the energy is transferred from the fuel rods to make steam, using terms like coolant and heat exchanger. The candidate is able to communicate the role of the turbine and generator in the production of electricity. **Level 2 – modest** -claims partly supported by evidence, -good use of information or ideas about physics given in the question but limited beyond this the argument shows some attempt at structure -the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling The candidate has a fair understanding of how energy is produced, but may not be entirely clear about mass decrease or increase in binding energy or the particles responsible for carrying most of the energy. Description of the production of electricity is likely to be only partially correct and may not be complete. **Level 1 – limited** -valid points but not clearly linked to an argument structure -limited use of information about physics -unstructured -errors in spelling, punctuation and grammar or lack of fluency The candidate is likely to be unclear about where the steam is generated and is unlikely to recognise the role of the generator in producing the electricity. The candidate will have only a very brief description of fission using imprecise terminology. The candidate may show some understanding of the energy transfers that take place. **Level 0** -incorrect, inappropriate or no response		6	A **Level 3** answer must contain correct physical statements including **most** of the following for **both** the energy production and electricity production. • increased binding energy or mass decrease • Energy released mainly as KE of fission fragments • moderator ensures that core is at critical mass • water is moderator and coolant • Pressurised water does not boil and heat is transferred using a heat exchanger • turbine and generator required A **Level 2** answer must contain correct physical statements **for both** the energy production and electricity production. A **Level 1** answer must contain a correct physical statement about **either** the energy production or the electricity production.

			The explanation expected in a competent answer should include a coherent selection of the following points concerning the physical principles involved and their consequences in this case. **Energy is produced**: • source of neutrons (alpha particles collide with a beryllium nucleus • Increase in binding energy so energy released • reduction in mass which appears as KE of products • $E=mc^2$ links energy to loss of mass • Good use of a diagram of BE/nucleon vs nucleon number to aid explanation • Mention of uranium-235 or plutonium-239 as fissile material • Water acts as moderator keeping core at critical mass • Neutron absorbed by nucleus • Nucleus that is formed is unstable so splits into 2 nuclei + 2 or more neutrons • Fission fragments carry majority of KE and transferred to internal inside the fuel rod. **Energy is used to generate electricity**: • Good use of a diagram explain heat exchanger(s) • Energy from reactor is extracted by the coolant • coolant (very hot water does not boil) heats other water by circulating through a heat exchanger. • Other water is used to generate steam • Steam drives turbine which is linked to a generator • further cooling takes place in heat exchanger using water from sea or river (need for cold side) • Useful block or other diagram of the system			

5	a	i	(Mass change in u=) 1.71×10^{-3} (u) **or** (mass Be-7) – (mass He-3) – (mass He-4) seen with numbers 2.84×10^{-30} (kg) **or** Converts their mass to kg Substitution in $E = mc^2$ *condone their mass <u>difference</u> in this sub but must have correct value for c^2 $(3x10^8)^2$ or $9x10^{16}$* 2.55×10^{-13} (J) to 2.6×10^{-13} (J)	C1 C1 C1 A1	4	Alternative 2nd mark: Allow conversion of 1.71×10^{-3} (u) to MeV by multiplying by 931 (=1.59 (MeV)) **seen** Alternative 3rd mark: Allow their MeV converted to joules ($\times$ 1.6×10^{-13}) **seen** Alternative 4th mark: Allow 2.5×10^{-13} (J) for this method

5	a	ii	Use of $E=hc/\lambda$ ***ecf*** Correct substitution in rearranged equation with λ *subject* ***ecf*** 7.65×10^{-13} (m) to 7.8×10^{-13} (m) ecf	C1 C1 A1	3	

5	b	i	Use of E_p formula : Correct charges for the nuclei **<u>and</u>** correct powers of 10 $2.6(3) \times 10^{-13}$ J	C1 C1 A1	3	
5	b	ii	Uses K*E* = 3/2 *kT*: ***or*** *halves* KE_T*, KE= 1.3 x* 10^{-13} *(J)* ***seen ecf*** Correct substitution of data **and** makes T subject **ecf** Or uses KE_T value **and** divides T by 2 6.35×10^9 (K) or 6.4 x 10^9 (K) or 6.28 x 10^9(K) or 6.3 x 10^9 (K) **ecf**	C1 C1 A1	3	
5	b	iii	(Red) giant / supergiant	B1	1	
5	c	i	deuteron/ deuterium / hydrogen-2 triton / tritium / hydrogen-3	B1 B1	2	
5	c	ii	electrical heating / electrical discharge /inducing a current in plasma / use of e-m radiation / using radio waves (causing charged particles to resonate)	B1	1	

6	a	i	7.5×10^{-6} (C) or 7.5 μ(C)	B1	1	

6	a	ii	Suitable scale and charge from 6ai correctly plotted at 2.5 V Only a Straight line drawn through or toward origin line must be straight, toward origin **and** only drawn between 2.5 V and 1.2 V (± 1/2 square on plotted points)	B1 C1 A1	3	Large square = 1 or 2 μC **or** With false origin then large square = 0.5 μC

6	b		Attempted use of E= ½ CV^2 Or attempted use of E=½ QV 9.38 (μJ) – 2.16 (μJ) seen **or** E = ½ $x\ 3\ x\ 10^{-6}\ x\ 2.5^2$ –½ $x\ 3\ x\ 10^{-6}\ x\ 1.2^2$ seen **or** E = ½ $x\ 3\ x\ 10^{-6}\ x\ (2.5^2 - 1.2^2)$ seen **or** E =½ x $7.5\ x\ 10^{-6}\ x\ 2.5$ – ½ × 3.6 x 10^{-6} x 1.2 seen 7.2×10^{-6} (J) c.a.o	C1 C1 A1	3	

6	c	i	$use\ of\ V = V_0 e^{-\frac{t}{RC}}$ R = $-\left(\frac{1.4\times10^{-3}}{ln\left(\frac{1.2}{2.5}\right)\times3\times10^{-6}}\right)$ or R =$-\left(\frac{t}{ln\left(\frac{V}{V_O}\right)\times C}\right)$ or R =$\left(\frac{t}{ln\left(\frac{V_O}{V}\right)\times C}\right)$ 636 or 640 (Ω)	C1 C1 A1	3	or equivalent with $Q = Q_0 e^{-\frac{t}{RC}}$

6	c	ii	current decreases (I=V/R) / describes rate of flow of electrons decreasing/ rate of flow of charge decreases Charge lost more slowly <u>so</u> pd falls more slowly <u>because</u> V∝Q or Q=CV where C is constant	M1 A1	MAX 2	