Supplementary Material
Technology: A Second Level Course
Renewable Energy

T206

Marking Guide to the Examination 2008

Introduction

These examination marking notes adopt a similar format to the tutor notes for the TMAs but with rather more explanatory material. The solutions and mark schemes for the short questions are in most cases accompanied by short comments on matters of detail, in an attempt to anticipate as many as possible of the small points where there could be uncertainty in awarding or deducting marks. In the case of the essay questions, we have tried to give comprehensive lists of all the most important items that might appear in an answer, and then to indicate how much might reasonably be expected in order to achieve a good mark.

The University Scale

Band	*University Scale score*	*Performance standard*
A	85 to 100	Pass 1
B	70 to 84	Pass 2
C	55 to 69	Pass 3
D	40 to 54	Pass 4
E	30 to 39	Bare fail
F	15 to 29	Fail
G	1 to 14	Bad fail

Completing the forms

Please note

- Leading zeros must be used for single-digit numbers (04, 06, etc.).
- If you have awarded an overall mark of 100, this should be entered as **HU.**
- Half marks or decimal fractions are not accepted. Please round half marks up.
- Please check your marks against the maximum for each question.

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PART A

Notes

- **Some non-integral marks (0.5, 1.5, etc.) are used where necessary in these short questions. If the resulting total for the question includes an odd half mark, please round it UP to meet the University requirement for integers only.**
- **Items in [*square brackets*] in the suggested answers below are not perhaps essential, but might influence the mark in marginal cases.**

Question 1

(a) Explain what is meant by the *energy self-sufficiency* of a country.

(2 marks)

(b) Describe and briefly explain ONE significant change in the energy self-sufficiency of each of the following two countries during the second half of the twentieth century.

(b1) The UK

(b2) The USA

(4 marks)

Q.1 Marking notes

Sources *Energy self-sufficiency is defined in Box 2.7 of Book 1 (p.76). Changes in the UK are discussed on pp.72–3 and in the USA on pp.80–1.*

Answers and marks

(a) The energy self-sufficiency of a country is defined as the total [*annual*] primary energy production divided by the total [*annual*] primary energy consumption [*usually expressed as a percentage*].

Total for 1(a) *For the above or equivalent*.....accept less precise. .... ***2 marks***

(b1) UK

Significant changes might include the following

- The fall in self-sufficiency [*down to little more than 50%*] between about 1950 and 1970, due to declining UK coal production and increasing consumption of imported oil
- The rapid increase towards 100% self-sufficiency during the 1970s, following the discovery and development of North Sea gas
- Further rises in self-sufficiency during the 1980s [*and resumed from about 1995*] due to high production of North Sea oil at times of falling or steady oil consumption.

(b1) For any ONE of the above........ *2 marks*

(b2) USA

For the **US** it is difficult to make a case for any major source other than oil, as demand and supply for all other sources have largely remained in step. So the following is suggested as effectively the only significant change:

- From the late 1950s, oil production [*which eventually peaked in about 1970*] failed to keep pace with consumption that rose almost continuously [*except during the oil crises of the mid- and late 1970s*]. This resulted in a significant fall in self-sufficiency over the second half of the twentieth century [*from 100% in the late 1950s to about 70% in 2000*].

(b2) For the above or equivalent........ *2 marks*

Total for 1(b)........ ***2 + 2 = 4 marks***

Total for Question 1 .... 2 + 4 = 6 marks

Question 2

Table 1 shows the world total electricity consumption and world total primary energy consumption for the years 2000 and 2005.

Table 1 World consumption of electricity and primary energy, 2000 and 2005

	world consumption	
year	electricity	primary energy
2000	**55.44**	**424**
2005	**65.46**	**490**

All data are in exajoules (EJ)

(a) Assuming that the average conversion efficiency of the world's power stations was 38.5% in both these years, determine the primary energy input for electricity generation in each year, in EJ.

Calculate the percentage of world total primary energy used for electricity generation in each year.

(4 marks)

(b) Show that the data in Table 1 support the view that world primary energy consumption was rising by about 3% per year during this five-year period.

(2 marks)

Q.2 Marking notes

Sources *Percentage efficiency is defined in Box 3.1 on p.94 of Book 1. Calculation based on percentage annual changes is introduced in the answer to SAQ14 of the Week 1 Study Guide.*

Answers and marks

(a) Table 1A World electricity and primary energy, 2000 and 2005

	world consumption		primary energy input	percentage of total primary energy
year	electricity	primary energy		
2000	55.44	424	**144.0 EJ**	**34.0%**
2005	65.46	490	**170.0 EJ**	**34.7%**

Method: percentage efficiency $= \dfrac{\text{output}}{\text{input}} \times 100$, so input $= \dfrac{\text{output}}{\text{percentage efficiency}} \times 100$

For primary inputs - method and arithmetic.. *2 marks*

For percentages of total - method and arithmetic .... *2 marks*

Total for 2(a). .... ***2 + 2 = 4 marks***

(b) With an increase of 3% per year, consumption in each year is 1.03 times that in the previous year.

So consumption in 2005 would be $1.03^5 \times 424 = 1.159 \times 424 =$ **491.5 EJ**,

which is slightly greater than the 490 EJ in Table 1.

***Alternative method**:*

490 / 424 = 1.156 $1.156^{1/5}$ (or $1.156^{0.2}$) = 1.029(4) which is slightly under **3%** per year.

Total for 2(b) *for valid method, correct result & brief comment*.. ***2 marks***

Total for Question 2 .... **4 + 2 = 6 marks**

Question 3

A coal-fired power station might release nearly twice as much carbon dioxide per kilowatt-hour of electrical output as a combined-cycle gas turbine (CCGT) plant.

Explain TWO fundamental reasons for this difference.

(6 marks)

Q.3 Marking notes

Sources *Many references, including Box 9.11 (p.382) and Table 7.8 (p.259), both Book 1.*

Answers and marks

Notes:

1. *For the full mark, the answer should include two **different** reasons. The suggestions below identify plant efficiency and CO_2 per unit of heat, but these could of course be expressed in other ways. However, an answer offering two that derive from essentially the same fundamental reason should not attract the full mark.*
2. *Explanation is required. The following suggest roughly what might be needed for the full mark.*

Reason 1: plant efficiency

CCGT plants have a higher heat-to-power efficiency than coal-fired plants because the gas enters the turbine at higher temperature than the steam in coal-fired plant [*and the efficiency of a heat engine depends on the input and output temperatures*]

For the above or equivalent .... 3 marks

Reason 2: CO_2 per unit of heat

In combustion, one kilogram of coal releases more carbon dioxide and generates less heat than one kilogram of natural gas [*methane*]

OR the combustion of coal releases more carbon dioxide per unit of heat generated than natural gas.

For either of the above or equivalent .... 3 marks

Total for Question 3 .... 3 + 3 = 6 marks

Question 4

(a) Describe what is meant by a *hydrogen economy,* and explain why a change to a hydrogen economy could be a means of reducing carbon emissions.

(4 marks)

(b) Briefly describe TWO obstacles to the full development of a hydrogen-fuelled system for road transport.

(2 marks)

Q.4 Marking notes

Sources *Section 14.4 of Book 1 (pp.587–93) and Section 10.6 of Book 2 (pp.406–10). For the transport context: Book 3, Managing Transport Energy, (p.60 and pp.76 et sec).*

Answers and marks

(a) In a hydrogen economy, hydrogen would replace the fossil fuels at present used directly by final consumers [*in the household, for instance, or in road vehicles*], with a hydrogen distribution system replacing the present distribution systems for oil and gas.

For the above or equivalent .... *2 marks*

The combustion of hydrogen releases no CO_2, so a hydrogen economy should lead to a reduction in overall emissions provided that the hydrogen is produced from renewable sources or from fossil fuels with CO_2 sequestration, or by electrolysis using electricity from nuclear plants.

For the above or equivalent .... *2 marks*

Total for 4(a) .... ***2 + 2 = 4 marks***

(b) Obstacles might include the need for...

- changes to vehicle propulsion systems,
- large hydrogen tanks in vehicles – or very high pressures,
- a distribution network,
- large-scale production facilities.

Total for 4(b) *for any TWO valid suggestions relevant to road transport*.. ***2 marks***

Total for Question 4 .... **4 + 2 = 6 marks**

Question 5

Briefly explaining your reasoning, identify the isotope in Table 2 that is described in each of the following cases.

(a) The isotope that is produced when polonium-212 emits an alpha particle

(2 marks)

(b) The isotope that is produced when strontium-90 emits a beta particle.

(2 marks)

(c) A fissile isotope that is produced in a uranium reactor.

(2 marks)

Table 2 Atomic numbers and mass numbers of various isotopes

name of element	atomic number of element	mass number of isotope
krypton	36	86
strontium	38	90
yttrium	39	90
lead	82	208
polonium	84	212
radon	86	222
uranium	92	235
plutonium	94	239

Q.5 Marking notes

Sources *Alpha and beta particles and the results of their emission are introduced in Section 10.2 of Book 1 (pp.397–8). The production of Pu-239 is described on p.409.*

Answers and marks

(a) An **alpha particle** is a He nucleus [*two protons and two neutrons*] so alpha emission from Po-212 reduces the atomic number by 2 and the mass number by 4, resulting in **lead-208**.

Total for 5(a) *correct identification and brief explanation* .... **2 marks**

(b) A **beta particle** is an electron [*with negative electric charge and very small mass*], so beta emission from Sr-90 increases the atomic number by 1 and does not affect the mass number, leading to **yttrium-90**.

Total for 5(b) *correct identification and brief explanation* .... **2 marks**

(c) The only **fissile** isotope listed (other than U-235) is **plutonium-239**. The process leading to Pu-239 starts when a neutron interacts with a U-238 nucleus, producing unstable U-239. Beta emission by U-239 leads to another beta-emitting nucleus [*Np-239*] and thus finally to Pu-239.

Total for 5(c) *correct identification and brief explanation* .... **2 marks**

Total for Question 5 ....**2 + 2 + 2 = 6 marks**

Question 6

You are considering the relative merits of installing either solar thermal panels or PV modules on your south-facing roof.

The solar panels are expected to supply about 1500 kWh of heat per year. This is about half your annual demand for hot water, which is at present supplied by a natural gas boiler with an overall efficiency of 60%.

The PV system is expected to generate about 1500 kWh of electricity per year. This is about one third of your annual electricity consumption, which is at present supplied from the grid.

(a) Using the data below, compare the two systems in terms of the resulting overall reduction in carbon dioxide emissions, assuming that in each case the annual output is fully used.

CARBON DIOXIDE EMISSIONS

The combustion of natural gas releases 0.19 kg of CO_2 per kWh of heat.

The UK grid releases an average of 0.50 kg of CO_2 per kWh of electricity.

(3 marks)

(b) Briefly discuss the factors that could affect whether or not the annual output of each system would in practice be fully used.

(3 marks)

Q.6 Marking notes

Sources *Part (a) needs only arithmetic. For (b), pp.31–2 in Chapter 2, Solar Thermal Energy, in Book 2, and pp.85–7 in Chapter 3, Solar Photovoltaics, have relevant points.*

Answers and marks

(a) Comparison of CO_2 emissions

The solar panels replace 1500 kWh of heat from the gas boiler

At 60% efficiency, the reduction in gas input = 1500 × 100 / 60 = 2500 kWh

CO_2 reduction = 2500 × 0.19 = **475 kg**

Correct method and result.. *1.5 marks*

The PV panels replace 1500 kWh of mains electricity

CO_2 reduction = 1500 × 0.5 = **750 kg**

Correct method and result.. *1.5 marks*

Total for 6(a) *[including comment that 750 > 475?]* .... ***3 marks***

(b) Full use of output

Factors that might be mentioned include...

- the daily and annual miss-match between **solar thermal** input and demand for heat...
- ...but the system needs to meet only half the annual gas demand
- ...and hot water is needed throughout the year

For any reasonable discussion of solar thermal .... *1.5 marks*

- the daily and annual miss-match between **PV** input and demand for electricity
- ...but the system needs to meet only one third of the annual electricity demand
- ...and the miss-match could be reduced or possibly eliminated by a grid connected system

For any reasonable discussion of PV .... *1.5 marks*

Total for 6(b) .... ***1.5 + 1.5 = 3 marks***

Total for Question 6 .... **3 + 3 = 6 marks**

Question 7

The electrical power output (P) in watts from a hydroelectric plant is given by the following equation.

$P = 1000 \times \eta \times g \times Q \times H$

(a) Identify the quantities represented by the four symbols on the right-hand side of the above equation.

(2 marks)

(b) A mini-hydro system provides power for a remote house, making use of a mountain lake which can supply water at an effective head of 40 metres. Calculate the water flow rate needed to provide 3.0 kW of power if the plant runs at an overall efficiency of 75%.

You may use the approximation $g = 10\ \cancel{\mathrm{N\,kg^{-1}}}$. $\mathrm{m\,s^{-2}}$

(2 marks)

(c) In an average day, the household uses 15 kilowatt-hours (kWh) of electricity. Show that this could be maintained for 10 days during a dry period if the lake held 1800 cubic metres of water at the start of the period.

(2 marks)

Q.7 Marking notes

Sources *The equation in (a) is on p.156 in Chapter 5, Hydroelectricity, in Book 2 (but worth noting that part (b) effectively gives almost all the answers!)*

Answers and marks

(a) The symbols

η is the [*overall*] plant efficiency

g is the acceleration due to gravity

Q is the volume flow rate of the water OR the water flow rate in cubic metres per second

H is the effective head of water for the system [*allowing for energy losses – drag, turbulence, etc.*]

For correct identification .... *0.5 mark each*

Total for 7(a) .... ***4 × 0.5 = 2 marks***

(b) Water flow rate

Note*: In (b) and (c) it seems reasonable to deduct only 0.5 mark for an arithmetical error – with no further reduction for errors carried forward.*

The power in watts is given by $P = 1000 \times \eta \times g \times Q \times H$

so the power in kilowatts $P(\mathrm{kW}) = \eta \times g \times Q \times H$

and the flow rate is $Q = \dfrac{P(kW)}{\eta \times g \times H} = \dfrac{3.0}{0.75 \times 10 \times 40} = \mathbf{0.010\ m^3\ s^{-1}}$

Total for 7(b) *as above or equivalent* .... **2 marks**

(c) The dry period

15 kWh is effectively 3.0 kW for 5 hours, which is 5 × 60 × 60 = 18,000 seconds.

From (b), the water flow rate needed for 3.0 kW is 0.010 cubic metres per second.

So the volume flow per day = 0.010 × 18,000 = 180 cubic metres

... and the 1800 cubic metres stored will last for **10 days**.

Total for 7(c) *for any valid route to the required answer* .... **2 marks**

Total for Question 7 .... **2 + 2+ 2 = 6 marks**

Question 8

(a) A combined cycle gas turbine (CCGT) plant and a very large off-shore wind farm both have the same rated output power of 200 MW. However, their average annual *capacity factors* are very different, at 80% for the CCGT plant but only 40% for the wind farm.

Calculate the annual output from each plant, expressing your answers in millions of kilowatt-hours.

(2 marks)

(b) Table 3 shows a breakdown of the annual costs of the two plants, in millions of pounds per year..

Determine the total annual cost of each plant and use this together with your results from part (a) to calculate the unit cost of electricity from each plant, in pence per kWh of output

Table 3 Annual costs of CCGT and off-shore wind plants

plant	annual capital repayment	annual O&M costs	annual fuel cost
CCGT	8.0	6.0	36.0
Off-shore wind	30.0	6.0	nil

All cost data are in millions of pounds (£M) per year.

(2 marks)

(c) Table 3 shows a much greater annual capital repayment for the wind farm than for the CCGT plant. Suggest any TWO possible reasons for this.

(2 marks)

Q.8 Marking notes

Sources *Capacity factor is defined on p.353 of Book 1 and in Box 5.2 on p.152 of Book 2. Costing is treated in Chapter 12 of Book 1 and Appendix 1 of Book 2 – but this is needed only in (c), as (a) and (b) are already in annual quantities throughout.*

Answers and marks

(a) Annual output

Annual output in MWh = capacity factor × rated output (MW) × 8760 (hours per year)

CCGT annual output = 0.80 × 200 × 8760 = 1,401,600 MWh = **1402 million kWh** (1401.6)

Wind farm, annual output = 0.40 × 200 × 8760 = 700,800 MWh = **701 million kWh** (700.8)

Total for 8(a) *method and correctly expressed results*.. **2 marks**

(b) Table 3A Annual costs of CCGT and off-shore wind plants

plant	annual capital repayment	annual O&M costs	annual fuel cost	total annual cost £M	(a) annual output million kWh	unit cost p/kWh
CCGT	8.0	6.0	36.0	**50.0**	1402	**3.57**
Off-shore wind	30.0	6.0	nil	**36.0**	701	**5.14**

Total for 8(b) *annual totals and unit costs*.. **2 marks**

(c) Capital repayments

Possibilities include greater initial **capital cost** of the wind farm, shorter anticipated **lifetime**, and perhaps a higher interest rate in view of **uncertainties** associated with new technology.

Total for 8(c) *for any TWO valid suggestions* .... **2 marks**

Total for Question 8.. **2 + 2 + 2 = 6 marks**