ENV-2D02 ENERGY CONSERVATION

2004

Typical Examination Questions prior to 2000 in order of question type.

The Full Exam Paper of 1998 is presented as a complete paper as it appeared in the exam

INTRODUCTION

The following are examples of questions which either have been used in previous examination, papers, were used in the mock papers issued when the course ran the first time, or have been adapted from the original examination question to bring things up to date. You should note that the actual content of the course do change slightly from year to year as new developments take place, and some older topics are dropped. Consequently, some of the topics listed may not have been covered this year. Where a question is no longer valid (or part is not valid, this is indicated in the question).

The present course number ENV-2D02 dates from 2002. The previous course number was ENV-2B14 (from 1994), and prior to that, ENV 278. You should note that not all questions on previous papers can be attempted by you as content does change for year to year. Sometimes, part of a question is still relevant. Comments are made when questions like this appear. Prior to 1987, the course was part of ENV 217 Resources and Society, and prior to 1983 there was a whole unit Energy and Society. In previous years the lengths of questions have not always been the same as now. There have been 30 minute, 45 minute, and 1 hour questions. The detail expected of an answer clearly depends on the length that was given.

Prior to 1985, questions could be entirely numeric. Since that time there must be at least 30% descriptive to ensure adequate spread of marks.

Format of the Exam this Year

Please note that in the EXAM this year you will be required to answer THREE questions one from EACH SECTION, and that EACH question is to be answered in a separate book.

There will be **one section of 30 minute questions** which is entirely descriptive (you choose one question from three). **One section (30 minutes)** will have numeric questions with descriptive riders (choose 1 from 2). **The final section will have one hour questions.** At least one of these will be entirely descriptive, one will have a numeric component (60-70%), while the third may or may not have a limited numeric component, or alternative give figures which are intended to focus your argument rather than do much, if any, calculation. This format gives the option of doing a minimum of 17% numeric to a maximum of 51% numeric on the exam.

HALF HOUR DESCRIPTIVE QUESTIONS:-

1. It is often stated for British cities that the heat density requirement is too low to make large scale CHP viable. With reference to the relevant Energy Papers and your own experience critically comment on this statement.

   Briefly summarise the different technologies associated with combined heat and power giving key advantages and disadvantages of each.
   [ENV-278 Exam 1992 - Question 1]

3. Describe the likely effects of the implementation of a carbon tax on the pattern of energy use **[mostly covered in ENV-2D06 now - not relevant in 2002]. [ENV-278 Exam 1992 - Question 2]**

4. Briefly describe the main changes in the Building Regulations over the last 30 years in the way that they have affected the use of energy. To what extent have they been effective in promoting energy conservation? What further changes would you recommend to these regulations for the coming decade?
   [ENV-278 Exam 1992 - Question 3 - see similar questions in subsequent years].

5. Outline how you would carry out an Energy Analysis study.

   What difficulties and advantages are there in such analyses when compared to economic appraisals of energy projects?

6. What is meant by the terms:-

   i) Energy Efficiency, and ii) Energy Conservation.

   Explain why policies to promote Energy Conservation measures and Environmental issues in the UK could lead to an increase in the consumption of electricity.

7. What factors affect an individuals perception of thermal comfort. Indicate how the use of Fanger's Theory could be incorporated into energy management strategies.

8. Technical methods to achieve energy conservation are often not cost effective, and in some cases often fail by a considerable amount to achieve the saving which theoretically may be predicted. Explain with examples why this is the case. What effect might this have on future government policy towards energy conservation?

9. Explain the differences between BACK PRESSURE and ITOC (intermediate and condensing) turbines. What are the advantages and disadvantages of using these two types of turbines in combined heat and power schemes?

10. What scope is there for reducing total energy demand for road transport in the UK over the next 20 years?

    Your attention is drawn to the statistics in the Energy Data Sheet which you may wish to consult when answering this question. **[very much follows the practical done in Week 1 and Seminar in Week 4].**

11. In November 1993, Eastern Electricity launched a new tariff for Domestic Consumers called Economy 10. How does this differ from the established Economy 7 tariff. Comment critically on the Advertisement for Economy 10 indicating the benefits to the Consumer in both Economic and Energy Conservation terms. **[Not relevant as tariff is no longer in this format - however a derivative of this relating to deregulation might be relevant]**

12. Distinguish between the various meanings of the terms Energy Efficiency and Energy Conservation. Since 1973, the UK has had by far the lowest growth rate in Electricity consumption of any OECD Country despite the fact that the consumption per capita is below the average. This is often cited as an example of the reluctance of the UK to embrace Energy Conservation Technologies to the full. Explain this apparent contradiction giving examples of where increases in consumption will occur if the UK adopts these newer technologies. **[This question was valid until late 1980's, since then there has been a significant growth in electricity in the UK, and the question would be rephrased].**

13. Briefly summarise the power stations emissions which are thought to contribute to the 'enhanced greenhouse effect' and 'acid rain' issues. Comment on the technological requirements, environmental impact and feasibility of treating the effluent gases causing 'acid rain'. **[this is now part of the ENV-2D06 course]**

14. You are appointed as an energy manager for a university. What would be your most important priorities regarding the use of energy in your new post? Use your knowledge of the University of East Anglia to illustrate your answer.
    [a related question to this one appeared as a

15. Energy Analysis was a technique which was widely promoted in the 1970's. How does this differ from economic analysis? Discuss why the technique is little used nowadays.

HALF HOUR NUMERIC QUESTIONS

1. What information can be obtained from an Energy Balance Table?

   What difficulties are encountered when comparing the energy consumption in one country with that in another. What conventions are used to overcome these difficulties, and how does the use of these conventions distort the situation in some countries?

   From the Energy Balance Table provided, estimate the thermal efficiency of power stations. What proportion of electricity was generated from the different types of power station, and what proportion of electricity was imported?

   [this question was summarised in and used as an example the lectures - set in 1994]

Solution This question has at least four answers depending on assumptions made.

From final column, total input to electricity generators is 31379 million therms, and since the primary electricity is declared in terms of equivalence if generated in a thermal power station, this figure may be used directly with the figure of 10940 million therms (Electrical output) to give an overall thermal efficiency of:-

10940/31379 = 34.86%

Method 1: A simple approximation is to assume that all thermal power stations have the same efficiency

i.e. the amounts of electricity generated by each source are proportional to the inputs, and that the above factor can be used to determine the electricity generated by each type of power station.

Power Station	Fuel Input (million Therms)	Electricity Generated	Proportion
coal	19744	6882.8	62.9
gas	467	162.8	1.5
oil	3025	1054.5	9.6
nuclear	5932	2067.9	18.9
hydro	535	186.5	1.7
imports	1676	584.3	5.3

Method 2: However, a more correct solution is to recognise that CCGT stations are 40% more efficient than other fossil fuelled stations. To proceed we need to separate the fossil fuel component from nuclear

The total equivalent primary electricity input is 5932 + 535 + 1676 = 8143 million therms
So net input of fossil fuels = 31379 - 8143 = 23236 million therms

and this will produce 23236 *0.3486 = 8101 million therms

if ♒ is the efficiency of coal and oil fired power stations, then
(19744+3025) ♒ + 467 * 1.4 * ♒ = 8101

This gives an efficiency for coal and oil of 34.59% and revised table becomes:-

Power Station	Fuel Input (million Therms)	Electricity Generated	Proportion
coal	19744	6829.4	62.4
gas	467	226.0	2.1
oil	3025	1046.3	9.6
nuclear	5932	2067.9	18.9
Hydro	535	186.5	1.7
Imports	1676	584.3	5.3

Method 3: If it is recognised that because of the low load factor of oil fired stations, their efficiency is about 90% of the coal fired ones, then:-

19744 * ♒ +3025 * 0.9 * ♒ + 467 * 1.4 * ♒ = 8101

Efficiency of coal fired power stations now becomes 35.04%

Power Station	Fuel Input (million Therms)	Electricity Generated	Proportion
coal	19744	6918.3	63.2
gas	467	229.0	2.1
oil	3025	954.0	8.7
nuclear	5932	2067.9	18.9
hydro	535	186.5	1.7
imports	1676	584.3	5.3

Method 4: This is the same numerically as method 1, but explicitly discusses the fact that while the CCGT stations are 40% more efficient than oil or coal, the open circuit Gas Turbines are less efficient, and that at 1991, the proportion of electricity generated by CCGT was low and the consequential effect is for the improved efficiency of the CCGT's to be cancelled out by the OCGT's This situation will change rapidly over the next few years as the proportion of OCGT's will be low.

Marking scheme

Full marks on numeric part cannot be obtained by method 1. Recommended maximum marks for correct answer to numeric part ex 60:-

Method 1 --------- 45
Method 4 --------- 50
Method 2 --------- 55
Method 3 --------- 60

[A version of this was covered in the lectures]

2. An old cottage has walls made of stone 300 mm thick and single-glazed windows. The roof currently has a limited amount of insulation giving an effective U-value of 0.50 W m-2 °C-1.

The energy efficiency of the cottage is improved by increasing the loft insulation by 100 mm of fibre glass, replacing the windows with K-Glass double glazed units which also help to exclude draughts and reduce the air-exchange rate from 1.20 air changes per hour to 1.00 air changes per hour. The inside of the walls are lined with 50 mm of fibre glass and finished with 6 mm of plaster board. Estimate, using the data given in the Table 1, the percentage saving in energy which will arise following these conservation measures. Clearly state any assumption you make.

If resources were limited indicate the priority you would give to the different measures.

TABLE 1

material	conductivity (W m^{-3o}C^{-1})
stone	0.965
fibre glass	0.040
plasterboard	0.100

construction	area (m^{2})
walls	160
windows	20
roof/floor	80

component	U-Value (W m^{-2o}C^{-1})
floor	1.0
single glazing	5.7
K-Glass double glazing	1.8

volume of house	400 m^{3}
specific heat of air	1300 J m^{-3} ^{o}C^{-1}
internal surface resistance	0.123 m ^{o}C W^{-1}
external surface resistance	0.055 m ^{o}C W^{-1}

[this is relatively straight forward - but remember the trick shown on the field course to minimise amount of calculation]

Solution

First the existing and new U-values for the walls and roof must be computed

Internal and external surface resistances are 0.123 and 0.055 W m-2 ^{o}C -1 respectively.

Walls:
resitance before insulation = 0.123 +0.055 + 0.3/0.965 = 0.489 m2 oC W-1.
resistance after insulation = 0.123 +0.055 + 0.3/0.965 + 0.050/0.04 +0.006/0.10 = 1.799 m2 oC W-1.

Hence U-values are 2.045 W m-2 oC-1 and 0.556 W m-2 oC-1 respectively

Loft:

Existing U-value is 0.50 so new resistance = $\frac{1}{0.50} + \frac{0.1}{0.04} = 4.50$ m2 oC W-1.
and new U-value is 0.222 W m-2 oC-1.

The existing heat loss rate is

160 x 2.045 + 20 x 5.7 +80 x 1 + 80 x 0.50 +400 x 1.2 x 1300/3600 = 734.5 WoC-1

and new heat loss rate is

160 x 0.556 + 20 x 1.8 + 80 x 1 + 80 x 0.222 + 400 x 1 x 1300/3600 = 367.1 WoC-1

so saving is 367.1/734.5 = 49.98% i.e. 50.0%
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3. A secretary in the University spends most of her day seated in a draft free, north facing room. Her metabolic rate is 60 kcal hr-2m-2, and she wears clothing whose thermal resistance is 1.0 clo. The secretary regularly complains to you as Energy Manager that she is cold.

You note that the thermostat in her room is correctly adjusted to the air temperature at 19°C, and that the average mean radiant temperature is 18°C. In an identical south facing room the average mean radiant temperature is consistently 2°C higher. Through out the building the relative humidity is 50%.

What action would you take in response to these complaints?

[this was largely covered as an example in the lectures]

4. Data giving the mean daily consumption of electricity in a house in which gas appliances supply the space heating, water heating, and cooking are presented in Table 2. Refrigeration accounts for one-third of the non-lighting load. Lighting is required, on average, between sunset and midnight each evening, and also between 0700 and sunrise. The householder replaces all lamp bulbs with low energy fittings which consume only 25% of the energy of the original bulbs. In an attempt to conserve energy, the householder also purchases new refrigeration appliances which reduce the load by 20W, and encourages inhabitants to be careful in the use of energy.

Evaluate and critically review how effective the householder has been in reducing energy consumption.

TABLE 2.

Month	sunset	sunrise	Electricity Consumption	
	(GMT)	(GMT)	before conservation	after conservation
			(W)	(W)
June	2000	0400	410	370
May/July	1930	0430	416	371
April/August	1845	0515	426	373
March/September	1800	0600	435	375
February/October	1715	0645	444	377
January/November	1645	0730	460	380
December	1600	0800	473	383

[see lecture notes for solution - ENV-278 Exam 1992 - Question 4]

5. Briefly explain how a heat pump works, summarising the key advantages and disadvantages of the various sources of low temperature heat.

Two alternative heating systems are under consideration by a householder living in East Anglia. One possibility is for a gas boiler with an overall seasonal efficiency of 74.2%, the other is for an air to water heat pump. The latter has an isentropic efficiency of 50%, an evaporator which normally runs at 10°C below ambient temperature, and a condenser which operates 10°C above the heat delivery temperature of 50°C. The mean ambient temperatures are given in Table 3.

TABLE 3.

Month	Mean Temperature (°C)
January/February	3.0
March/April	5.0
May/June	12.0
July/August	14.0
September/October	11.9
November/December	5.0

Estimate the mean percentage saving in Primary Energy terms (based on the 30 year data) from using a heat pump as opposed to the gas boiler if the Primary Energy Ratio of the delivered energy is 2.96 for electricity and 1.06 for gas.

[ENV-278 exam 1992 Question 5]

Solution

Note you do not need to know the heat loss rate or the number of degree days - these cancel out.

Step 1:

work out the COP for each pair of months - remember that the evaporator T1 temperature is 10oC lower than heat source and condenser is 10OC higher thank heat supplied. Also remember to convert to degrees absolute by adding 273. Hence work out annual average COP as 2.72. [This is a simple average - a weighted avergae taking account of different number of days in each month also give 2.72.]

Temperature	effective evaporator temp (T2)	effective condenser temp (T1)	Theoretical COP	Actual COP
3	266	333	4.97	2.49
5	268	333	5.12	2.56
12	275	333	5.74	2.87
14	277	333	5.95	2.97
11.9	274.9	333	5.73	2.87
5	268	333	5.12	2.56
		Annual	Average	2.72

Let X be heat loss rate, and D be number of degree days

Then primary enenrgy requirement is

$$X . D .x \ 86400 / \ 2.72 \ * 2.96 = 1.088 * 86400 *XD$$

For gas primary enenrgy requirement is

$$X . D x \ 86000 / 0.742 * 1.06 \ = 1.429 * 86400 *XD$$

So percentage saving = (1.429 - 1.088)/1.429 *100 = 23.9% saving

6. One detached house, having a roof area of 50m2, has no loft insulation, while a second house is identical in all respects except it has 100 mm of fibre glass loft insulation.

Both houses have their roof insulation upgraded to 150mm at a cost of £20.00 per cubic metre of fibre glass. If the boiler is 75% efficient, and fuel costs £5.00 per GJ, examine the cost effectiveness of the schemes for the two houses.

Comment on your results, and in the light of previous Energy Conservation Grants, indicate how you might reformulate the regulations concerning such grants.

7. Briefly describe how a heat pump works.

A house in Arizona has a heat loss rate of 300 W oC-1 and incidental gains amounting to 1500 W. It is cooled by a normal vapour compression air-conditioner to ensure that the internal temperature in the house is kept at 25 oC during the summer months. The isentropic efficiency of the air-conditioner is 50%. Estimate the energy consumed during the cooling period. You may assume that all months have 30 days to simplify calculations. Data relating to external temperatures are given in Table 1. The evaporator operates at 10oC below the thermostat setting while the condenser operates 10 oC above the external temperature.

Table 1.

Month	Mean External Temperature (^{o}C)
January/December	12
February/November	16
March/October	20
April/September	24
May/August	32

June/July	37

SOLUTION

Free temperature rise from incidental gains = 1500 / 300 = 5 oC

- Thus add 5o C to all external temperatures to determine neutral/balance temperature
- All months in which temperature is above 25 oC require cooling - i.e. April - September
- Evaporator Temperature = 273 + (25 - 10) = 288 K
- Cooling requirement = Temp diff (ext - int) * 300 + 1500 (incidental gains)

Month	Mean External Temp (^{o}C)	Effective Internal Temp (^{o}C)	Mean external temp (K)	Effective condenser temp (K)	Carnot efficiency	actual efficiency	cooling required (kW)
January/December	12	17	no cooling required				
February/November	16	21	no cooling required				
March/October	20	25	no cooling required				
April/September	24	29	297	307	15.16	7.58	1200
May/August	32	37	305	315	10.67	5.33	3600
June/July	37	42	310	320	9.00	4.50	5100

COP (air con not heat pump) = $\frac{T_2}{T_1 - T_2}$ ....NOTE not T1 on numerator

Total energy required = $\sum \frac{\textbf{cooling requirement}}{\textbf{COP}} * \textbf{no of days} * \textbf{seconds in day}$

= (1200 / 7.58 + 3600 / 5.33 + 5100 / 4.5) * 30 * 2 * 86400 = **10.20 GJ**

[this is very similar to worked example in section 14.11 of handouts]

8. A house in Arizona has a heat loss rate of 300 Wm-2 oC-1, and a window area of 20 m-2. The internal temperature is kept at 25oC while the mean external temperature over the period from 1st June to 1st September is 38oC. The windows are replaced by double glazed units. Estimate the original energy consumption in primary energy terms and also the percentage saving given the following data:-

overall primary energy ratio of electricity:- 3.00

the effective inlet and outlet temperatures of the air-conditioning unit are 10oC below the internal, and 13oC above the external temperatures respectively.

Isentropic efficiency:- 50% : Continuous Fan Power for air-circulation 375 W.

What alternatives are there for cooling such a building?

The solution to this is somewhat similar to question 7

9. Describe ways in which the ventilation rate in a building may be determined. Why are ventilation rates not included in the current Building Regulations even though this is one of the most dominant aspects of heat loss from a building?

A room in a single storey building is 4m x 4m in plan and 2.4m high. It has one external wall with a single glazed window 1.6m2 in area. On a day when the external temperature is 0oC, the building is heated uniformally to 20oC. In an experiment the determine the intrinsic structural ventilation rate, the gaps at the edges of the windows and doors were sealed and supplementary heating of 1500 W was supplied to the room. After two hours the room temperature stabilised at 25oC. Estimate the intrinsic ventilation rate in air changes per hour if the specific heat of air is 1300 J m-3 oc-1. U-value data are given in Table 2.

U-Values (W m^{-2} $^oC^{-1}$)			
External Walls	1.0	Floor	1.0
Internal Walls	2.5	Window	5.0
Roof	0.2		

Continuity equation:-

supplementary heat - heat losses to outside + heat losses across internal walls = ventilation losses

The solution is best in tabular form

		Area (m^2)	U-value (W m^{-2} $^oc^{-1}$)	Temperature difference	heat lost (W)
internal heat transfers - 3 walls 4 x 2.4 m		28.8	2.5	5	360
external wall transfer		8.0	1.0	25	200
window transfer		1.6	5.0	25	200
roof transfer		16.0	0.2	25	80
floor transfer		16.0	1.0	25	400
Total conductive losses					**1240**

So ventilation losses = 1500-1240 = 260 W

but volume of room is 4 x 4 x 2.4 = (38.4 cum), and temperature difference = 25oC

so ventilation loss = 38.4 x 25 x 1306 / 3600 x ach = 260

$$38.4 \times 25 \times 1306 / \underbrace{3600}_{\text{seconds in an hour}} \times ach = 260$$

so number of air changes per hour = 0.75
=====

[an example of this was also given in lectures, and some people may also do this experimentally on the Field Course]

10. What is meant by the balance temperature of a house?

A house is electrically heated and has incidental gains amounting to 500 W and has its thermostat set at 20oC. The mean consumption of energy for the house is shown in Table 5. Energy conservation measures reduce the heat loss rate by 50 WoC-1. If the mean external temperature over the heating season of 240 days is 8oC, estimate the new total consumption over this period

Mean Weekly Temperature	**Mean Consumption**
^oC	**kW**
0	**8.75**
4	**6.75**
8	**4.75**
12	**2.75**
16	**1.00**
18	**1.05**
20	**0.95**

Table 5

11. The consumption of gas in a centrally heated house in East Anglia is show in Table 6. The internal temperature of the house is kept at 19.5oC. Conservation measures reduce the heat loss rate to 450WoC-1.

Estimate the new balance (neutral) temperature and the reduction in the typical annual consumption if the thermal efficiency of the boiler is 75%.

Mean Weekly Temperature	**Mean Consumption**
^{o}C	**kW**
2.0	**7.75**
5.0	**6.25**
8.0	**4.75**
11.0	**3.25**
14.0	**1.75**
17.0	**1.00**
20.0	**1.00**
23.0	**1.00**

12. The new generation of power stations are constructed using combined cycle gas turbines. How do these differ from conventional power stations?

A combined cycle gas turbine is designed as part of a combined heat and power system which will supply both electricity and heat to a small town. Data relating to the performance of the station is given in Table 2.

Estimate the overall efficiency of energy conversion and supply. In your answer you should include a flow diagram to account for all the losses.

Table 2.

Inlet temperature to gas turbine	1127 ^{o}C
Exhaust temperature from gas turbine	679 ^{o}C
Inlet temperature to steam turbine	547 ^{o}C
Condenser temperature	96 ^{o}C
Combustion losses	10.0%
Isentropic efficiency of both turbines	75.0%
Generator efficiencies	95.5%
Station use of electricity	5.3%
Distribution losses on heating mains	10.4%

First work out efficiencies of two turbines using formula:-

$$\textbf{efficiency} = \frac{T_1 - T_2}{T_1} * \textbf{isentropic efficiency}$$

gas turbine

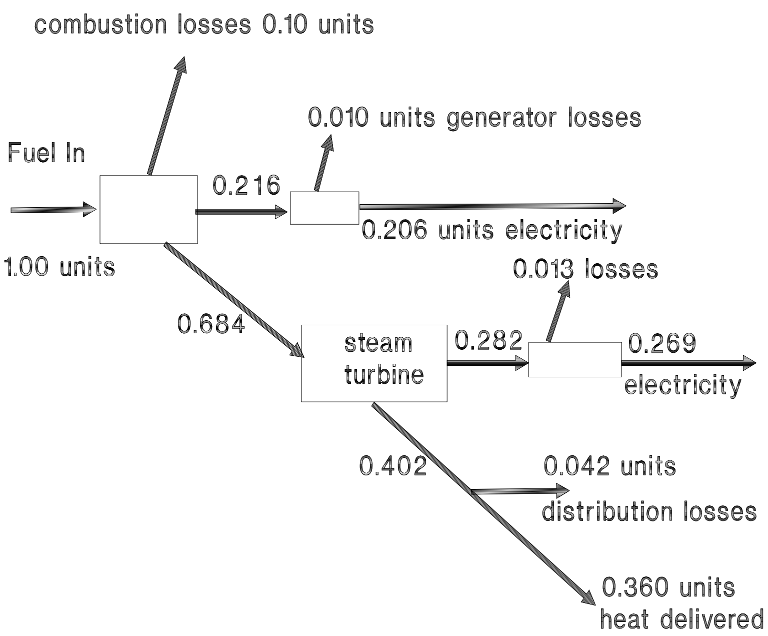
$$\frac{(1127 + 273) - (679 + 273)}{(1127 + 273)} * 0.75 = 0.24$$

steam turbine

$$\frac{(547 + 273) - (96 + 273)}{(547 + 273)} * 0.75 = 0.4125$$

Now consider gas turbine

1 unit of fuel in has 0.10 units lost in combustion and of the 0.9 remaining, 0.9 * 0.24 is converted to mechanical energy in the gas turbine = 0.216 units with 0.684 units rejected as waste heat to the waste heat boiler. Of the 0.216 units of mechanical energy, 0.206 produces electricity with 0.01 units lost in the generator. This position is summarised in the diagram below



- In the steam turbine, 0.684 * 0.4125 units of mechanical energy are produced = 0.282 units
- while 0.684 - 0.282 = 0.402 units of heat are rejected to the condenser.
- from the mechanical energy, 0.282 * 0.955 units of electricity are produced = 0.269 units with 0.013 units lost in the generator
- of the 0.402 units of heat available 0.402 * 0.896 = 0.360 units are available as useful heat energy after distribution losses.
- finally of the 0.269+ 0.206 = 0.475 units of electrical energy, 0.475 * 0.947 = 0.450 units are available to be sent out and 0.025 units are used on the station itself.
- overall conversion and supply efficiency = $\dfrac{\textbf{useful electricity + useful heat delivered}}{\textbf{fuel input}}$

= (0.450 + 0.360) * 100 = **81.0%**

There are other worked example shown in the lecture notes which is also typical of what might be set in an exam.

ONE HOUR QUESTIONS

Descriptive

1. Describe how a heat pump works. Compare the different types of heat pump giving the advantages and disadvantages of each type. Give examples of where the heat pump is a particularly effective form of heating.

   In new houses heat pumps are attractive if changes are made in the design of conventional heating systems in the domestic market. How would these improve the performance of heat pumps?

2. Describe the economic and institutional barriers to the implementation of energy efficiency measures in the UK.
   [ENV-278 Exam 1992 - Question 6]

3. Over the last 30 years the UK Government and Energy Supply Industries have attempted whenever possible to meet the demand for energy rather than introduce methods to control such demand. Discuss the advantages and disadvantages of this approach. Cite techniques which may be used to control demand.
   [ENV-278 Exam 1992 - Question 7]

4. Explain why energy conservation has never become a major component of UK energy policy.

5. Describe the differences between BACK-PRESSURE and PASS-OUT turbines. Indicate the advantages and disadvantages of using both types of turbine in combined heat and power stations.

   Critically review the main conclusions of Energy Papers 20 and 35 relating to Combined Heat and Power.

6. Formulate the basic aspects of an Energy Policy for the UK for the next 30 years.

7.

NOTE: This is largely a descriptive question. The figures are included to focus your recommendation on specifics rather than generalities. In the answer you may need to do simple calculations or plot graphs, but much of this is to deduce, for example what the extra 5 MW of steam is needed for in winter.

You have just been appointed as an Energy Manager at the headquarters of a manufacturing employing 1500 people in 10 locations across the UK, and have been asked to report to the Board within two weeks of starting outlining your strategies for Energy Conservation in the coming year.

The manufacturing processes is concentrated at the headquarters as are the central warehouses and offices. The 9 regional sites are staffed on average by 25 service/office personnel. Manufacturing continues on a three shift basis with 150 people employed between midnight and 0800, 450 between 0800 and 1600, and 300 between 1600 and midnight.

The manufacturing process requires steam at 120oC, and is supplied by an oil fired boiler which also provides steam at a similar temperature to the primary main for space heating. Demand for steam rises from about 5MW in summer to around 10MW in winter. The demand for electricity varies from an overnight low of 0.5 MW to around 1.5MW in the early afternoon and shows little seasonal variation.

Draft the report you will present to your Board.

8. Assess the feasibility of introducing conservation techniques and renewable energy technologies in the U.K. by the year 2020 and their respective impacts by that date.

Original question specified 2000. Date has been extended!.
[the issue of renewables is not relevant - and question set was when there was a single 40 credit course in Energy]

9. Explain the scientific principles on which one of the following energy conservation technologies is based.

EITHER Combined Heat and Power

OR Heat Pumps

Give specific examples of existing or potential applications of the technology and comment on the scope for, and likelihood of, its more widespread introduction in the UK.

use of internal EITHER/OR options are now discouraged

10. **EITHER**

a) Carefully assess the effectiveness of the Energy Efficiency Office in terms of its contribution to improving the efficiency of energy use in the UK.

we have only indirectly referred to EEO this year

OR

b) Examine why the discount rates to evaluate investments in the new energy supply and additional investments in energy conservation differ, and assess the implications for future UK energy policy.

this question was set some time ago, but we have alluded to some of the issues here. The wording of such a question now would be somewhat different perhaps on the lines [Discuss the advantages and disadvantages of using different discount rates when assessing energy related projects].

11. With the exception of the limited introduction of load management schemes to industry, the electricity supply industry has attempted to meet the full demand for electricity. What are the implications of such a policy? What are these load management schemes, and how do they help the industry to meet the short terms demands? What future developments do you foresee which will minimise further the effects of peak demand?

12. Until a few years ago the electricity supply industry in the developed countries attempted to meet the full demand for electricity. What are the technical economic, and environmental implications of such a policy? Recently load management schemes have been introduced on a limited scale. What are such schemes and how do they help the industry meet short term demands. What future developments do you foresee to minimise the adverse effects of peak demand?

13. Describe how a heat pump works. Summarise the advantages and disadvantages of the different types of heat pump. Give examples of where the heat pump has been or could be particularly effective in saving energy.

    In new houses heat pumps would become more attractive if changes are made in the design of conventional heating systems in the domestic market. How would these improve the performance of heat pumps?

14. What measures have been or could be taken in Norwich to control transport sector energy use? How could government initiatives help? What would be the resulting benefits to Norwich?
    [the year this was set the Transport seminar did focus on Norwich]

15. To what extent are the current (1994) UK Building Regulations an improvement over previous versions of the Regulations with regard to the conservation of energy. Indicate how implementation of these Regulations reduce energy consumption in the domestic sector? What improvements would you like to see in future versions of the Regulations?

16. What measures would you promote to conserve energy in the transport sector? How effective are these likely to be? In your answer you may wish to draw on information in the Energy Data Sheets to reinforce your proposals.

ONE HOUR NUMERIC QUESTIONS

1. Describe how an Energy Manager within a firm should undertake job to promote efficient use of Energy.

   A small industrial company which has a two shift work pattern (08:00 - 24:00) has electricity as its only supply of energy and uses 100 GJ of energy each quarter for appliances and process work . Two energy conservation strategies are to be implemented. The first involves the replacement of all light fittings with low energy light bulbs which should consume only 20% of that consumed by the old lights.

   The second is the installation of a Energy Management system which the manufacture claims should reduce heating demand by 10%. The schemes are implemented at the beginning of the 3rd and 4th quarters of the year respectively.

   Data relating to the consumption of energy in each quarter is given in Table 6. To what extent have the energy conservation measures lived up to expectation?

Quarter	Consumption (GJ)	Degree-Days	Lighting Hours
First Quarter	359.20	1100	500
Second Quarter	229.60	554	230
After Installation of Low Energy Lighting			
Third Quarter	124.71	100	240
After fitting Energy Management System			
Fourth Quarter	239.53	700	550

Table 6

[this is very similar to the example shown in lectures]

2. Describe at least one method to simulate the thermal performance of a building when the heating system is controlled by time switch.

A block of student residences is heated between the hours of 7am and 11pm by a heating system which has a maximum output of 1.2MW. The thermostat is set at 20oC while the ambient temperature remains constant at 0oC. If the heat loss rate of the building is 25 kW oC-1 and its thermal capacity is 2.88 GJoC-1,
estimate the time taken after the heating comes on for the building to reach the thermostat level. Estimate also the percentage saving in energy over a daily cycle. **[ENV-278 Exam 1992 - Question 8]**

[we covered a question similar to this in lectures - see also question on 1998 paper]

(Hint: use a time interval of 2 hours)

3. As an Energy Manager in a large firm in East Anglia, your salary is computed as follows. A basic £10,000 per annum (***this question was set in 1986***) plus 10% of the savings in energy costs arising from the schemes you implement. The period for assessment of the savings (climatically corrected) is to be taken as the period January 1st - March 31st each year with the starting year of 1984. Describe the type of records you would keep, and how you would present them to the Board of your company.

You decide that in the first year, there are two priorities to be tackled: first an awareness campaign, and secondly improvements to the roof insulation. You note that 75% of the fuel costs are spent on space heating. The roof has an area of 30000 m2, and the U-value is reduced from 2.0 to 0.5 Wm-2oC-1. In the control period in 1984 the fuel costs amount to £200000 at a mean cost of £5 per GJ.

Following a fuel price rise of 10% the fuel costs in the corresponding period in 1985 were £225000. Estimate what your salary would be in 1985, and determine the effectiveness of your awareness campaign.

4. A Gas Turbine Power Station has a rated maximum output of 110MW from two separate units which exhaust gas at 950oC. An overall efficiency of 23% has been achieved with both units. Consideration has been given to the conversion of one or both units to combined heat and power operation. Three possible conversion strategies are to be considered:-

[a numeric example similar to this was given in the lectures]

i) the addition of a waste heat boiler in the exhaust stream to heat district heating water. The boiler could recover up to 50% of the heat
ii) the addition of a waste heat boiler as in (i) to both raise steam for a back-pressure steam turbine and heat the district heating water. Reject heat from the condenser is also used in the district heating scheme.
iii) as (ii) but with an ITOC turbine substituted for the back-pressure turbine.

Outline how these three schemes might be incorporated into the power station and briefly describe the advantages and disadvantages of the different strategies.

From 1998 onwards- time does not permit is to cover the remaining part of the CHP/thermodynamics section relating to the temperature entropy charts and the enthalpy - entropy charts needed to answer the numeric part of this question as set below. A numeric question could follow the analysis actually given in the final lecture on CHP. e.g. Use say 600oC top steam temperature and 100oC condenser temperature with 70% in the exhaust gases available for raising steam.

Actual question set:

For option (ii), 19.4 kg of steam from the waste heat boiler is provided each second at 650^{o}C and 200 bar pressure. The steam is 98% dry when it is fully condensed at 1 bar pressure. This steam raising does not affect the energy extracted directly to the heat main.

Estimate the overall efficiency of the plant operating in both mode (i) and mode (ii).

Fig. 1 shows the demand for heat energy in the local area. Based on this information, which strategy of operation would appear the most logical to pursue.

5.. What are meant by the terms 'Energy Coefficient' and 'Energy Ratio'? How can they be used to predict future energy demands, and what are the main limitations of these forms of prediction?
The figures in Table 1 give the temperature corrected Energy Ratio (expressed in GJ per £1000 (1980 standardised prices)) for the years 1950-83. Comment on the trend of this ratio. To what extent have recent conservation measures reduced demand, and what (if any) is the magnitude of this saving when compared to 1973 if the GDP in 1983 was £206.5 x 109?

What refinements to the above energy forecasting are needed to improve the accuracy of prediction of future energy demands.

Table 1

Year	Energy ratio GJ/£1000	Year	Energy ratio GJ/£1000
1950	57.1	1970	48.5
1952	56.9	1972	47.0
1954	55.7	1974	43.9
1956	54.2	1976	42.0
1958	52.8	1978	41.0
1960	52.3	1980	39.8
1962	50.6	1981	38.6
1964	49.0	1982	37.4
1966	48.5	1983	36.5
1968	46.8		

[this question was set in 1985 - it is perhaps more relevant to ENV-2E02 now]

6. Explain the principles of a heat pump, and briefly discuss the advantages and disadvantages of the different forms of heat pump.

As an energy consultant you are asked to advise a householder on the choice of a new heating unit. A replacement oil boiler would cost £750 and deliver two-thirds of the energy contained in oil as useful heat. The alternative is an electrically driven air-water heat pump which would cost £1500 and for which the following performance data are available.

Mean external temperature ^{o}C	0^{o}	5^{o}	10^{o}	15^{o}
Coefficient of performance	2.39	2.75	3.11	3.47

The heating requirement for the house if 60GJ per annum, while the mean external temperature during the heating season is 8.5^{o}C. The heat pump would use both off-peak and peak electricity. Advise the householder as to which option he would choose assuming a discount rate of 10%. The following data will be required in your analysis:-

calorific value of oil	40MJ per litre
cost of oil	20p per litre (assumed constant)
mean cost of electricity	4.32p per kWhr (assumed constant)
life of oil boiler	10 years
life of heat pump	10 years

[questions similar to this have been set on two occasions - see also below- the question is also very similar to the practical relating to the UEA heat pump - in fact the COP data is identical]

7. Explain the principles of a heat pump, and briefly discuss the advantages and disadvantages of the different forms of heat pump.

As an energy consultant, you are asked to advise a householder on the choice of a new heating unit. A replacement oil boiler would cost £750 and deliver two-thirds of the energy contained in the oil as useful heat. The alternative is an electrically driven air-water heat pump which would cost £1500 and for which the manufacturer guarantees the following performance:-

Mean external temperature (^oC)	0	5	10	15
Coefficient of Performance	2.39	2.75	3.11	3.47

The heating requirement for the house is 72 GJ per annum, while the mean external temperature during the heating season is 8.5oC. The heat pump would use both off-peak and peak electricity. Advise the householder as to which option he should choose assuming a discount rate of 10%. The following data will required in your analysis

calorific value of oil	43.2 MJ per litre
cost of oil	20p per litre (assumed constant)
mean cost of electricity	4.5p per kWhr (assumed constant)
life of oil boiler	10 years
life of heat pump	10 years

8. Summarise the energy conservation measures which may be employed in the home.

A large detached house uses gas for hot water, space heating, and cooking. At present the gas boiler has an efficiency of 75%. Two energy conservation measures are to be installed:-

a) a condensing gas boiler with an efficiency of 90%
b) draft exclusion which will reduce the heat loss rate by 50 W ^oC-1.

Data from the house without the conservation measures are summarised in Table 3. Estimate:-

a) Which of the two conservation measures saves the most energy?,
b) If the total capital outlay for both schemes is £1200 how long will it be before this is repaid assuming a discount rate of 5%

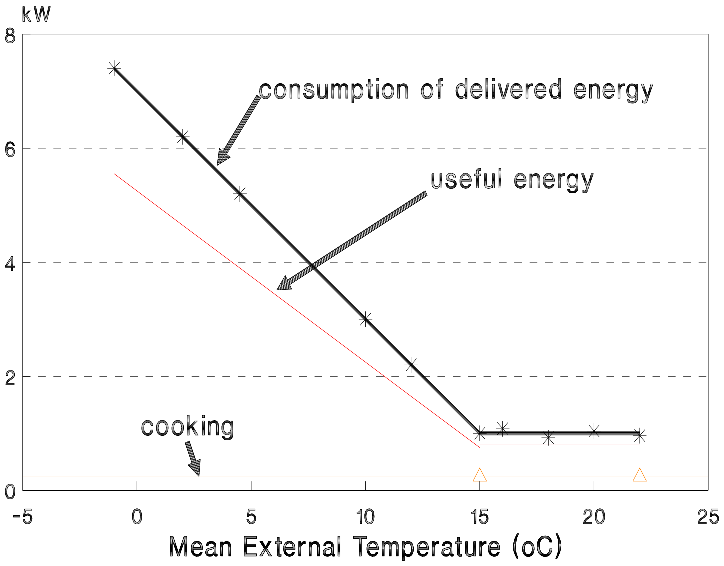
Table 3.

External Temperature (^oC)	Mean Consumption (kW)
-1.0	7.40
2.0	6.20
4.5	5.20
10.0	3.00
12.0	2.20
16.0	1.08
18.0	0.92
20.0	1.04
22.0	0.96

Incidental gains	1500 W
Mean cooking requirement	250 W
Price of gas	£4.40 per GJ
Degree - Days	2000

SOLUTION

First plot consumption vs temperature data



- Graph is in two parts, the heating dependant section which has a slope of 400 W^{o}C-1 and a horizontal section representing the steady hot water and cooking requirements (i.e. 1000 W). Also since boiler efficiency is 75%, net heat loss rate = 300 W^{o}C-1.
- Since cooking requirement is 250 W, 750 W is used for hot water which at an efficiency of 75% gives a net hot water requirement of 750 * 0.75 = 562.5 W.
- Current consumption for hot water and cooking = (250 + 750) * 365 * 86400 = **31.536 GJ**
- Balance Temperature - from graph = 15 oC, and free temperature rise = 1500 / 300 = 5oC
- so thermostat setting is 20oC.
- Degree day data is based on a balance temperature of 15.5oC, so corrected degree days is:-

2000 - (15.5 - 15.0) * 365 = 1817.5

$$\text{annual consumption} = (\underbrace{400}_{\text{heat loss rate}} * 1817.5) * \underbrace{86400}_{\text{seconds in day}} + 31.536 = \mathbf{94.349\ GJ}$$

Installing a condensing boiler will reduce hot water + cooking consumption to:-

(562.5 / 0.9 + 250) * 365 *86400 = 27.594 GJ

and total consumption to
(300 / 0.9 * 1817.5) * 86400 + 27.594 = **79.938 GJ**

i.e. a saving of 94.349 - 79.938 = 14.411 GJ

If draft exlusion reduces heat loss rate by 50 WoC-1 then free temperature rise will be 1500 / 250 = 6 degrees, and new balance temperature = 20 - 6 = 14oC.

New corrected degree days = 2000 - (15.5 - 14.0) * 365 = 1452.5

So reduced energy consumption arising sole from draft exclusion =

250 / 0.75 * 1452.5 * 86400 + 31.536 = **73.368 GJ**

and saving is 94.349 - 73.368 = **20.981 GJ**

i.e. installation of draft exclusion is more effective saving 20.981 GJ (cf 14.411 GJ).

If both strategies are adopted, new consumption is:-

250 / 0.9 *1452.5 * 86400 + 27.594 = 62.454 GJ

or a saving off 94.349 - 62.454 = 31.895 GJ

NOTE: savings are not cumulative

Annual saving is 31.895 * 4.4 = £140.34

Thus cumulative discount ratio must equal 1200 / 140.34 = 8.551 before payback occurs.

years	cumulative discount
11	8.307
12	8.864

From discount tables, pay back is between 11 and 12 years and by linear interpolation is

11 + (8.551 - 8.307) / (8.864 - 8.307) = **11.44 years**

45 Minute descriptive questions from earlier years

1. Explain how a heat pump works. Discuss the advantages and disadvantages of the different type of heat pump. Why are heat pumps not more popular in the residential market in the UK?

2. Write a book review of "Fuel's Paradise" (1975) by Peter Chapman.

3. Describe how the overall utility of a fuel may be improved by the use of combined heat and power cycles.

   Illustrate your answer with an example and explain the practical constraints that have limited its wider application.

4. Outline a design for a 'low energy' house. Explain the technological options available and justify your choice of design.

5. Give examples of two buildings having markedly different 'thermal inertias'. How is their energy consumption, suitability for their designed function, and comfort affected by the dynamic characteristics resulting from this thermal inertia? How can these dynamic characteristics be assessed and included as an integral part of a building design?

6. Consider why major advances in energy conservation are so difficult to achieve in western industrialised nations.

7. How does the source temperature of a heat pump working on a vapour compression cycle affect its power consumption and coefficient of performance? Explain the merits of different types of heat pump installation for home heating and the possible future directions for heat pump development.

8. Outline the principles used by Chapman and his 'school' in energy analysis.
   Describe the way in which the gross energy requirement of a particular material is established from mine to fully refined product at the point of use.

9. If you were given a budget of £500 million over the next five years to spend on energy conservation measures in the UK, how would you allocate it? Justify your answer.

10. Outline a reasoned strategy for energy supply for the UK over the next 50 years. In your answer take care to examine transitional periods and the relationship between energy supply and mobility, personal consumption and industry.

11. Describe how electrical components may be used to study the dynamic heating characteristics of a building. Describe the advantages and any limitations of the electrical model(s) you propose. Suggest how your model(s) may be improved.

Illustrate your answer graphically by sketching the boiler output and the internal temperature curves when the heating is switched off once a day between 2300 and 0700 for the following two cases:-

(a) steady external temperature
(b) sinusoidally varying external temperature with a maximum at 1500 hours.

(You may select any realistic internal and external temperatures for your sketches)

12. Debate the reasons for and against using 'energy analysis' as opposed to 'economic assessment' for evaluating energy production schemes.

45 minute Numeric Questions

1. The average daily temperature distribution in July in south-west United States is given in Table 1. A house having a space heating/cooling demand of 580 W ^{o}C-1 is cooled by a refrigerative type of air conditioner which rejects heat to the atmosphere at 7^{o}C above ambient. To maintain a mean internal temperature of 25o, the evaporator must be kept at 17^{o}C. Two fans, one external, one internal each consuming 0.3kW run whenever the air-conditional is operating.
Estimate the size of conditioner required (by specifying input electrical power) if 331/3% over capacity is provided to cope with dynamic effects. The device operates at 30% of the Carnot efficiency.

Estimate also the electrical energy consumed in a 24 hour period. Quote your answer in kilowatt hours.

Table 1

Time	Mean External Temperature ^{o}C
0300 - 0700	25
0700 - 1100	29
1100 - 1500	36
1500 - 1900	40
1900 - 2300	36
2300 - 0300	29

2. An electricity generating power station operating at 60% of Carnot efficiency has maximum and minimum cycle temperatures of 527^{o}C and 27^{o}C. The station is modified so that 50% of the steam is diverted through a pass-out valve before the final turbine stage at 127^{o}C. If this steam is used to serve a district heating scheme with an effective thermal efficiency of 80% what will be the overall primary energy conversion efficiency? How does this compare with that of the unmodified power station?

3. A detached house in East Anglia is 10m x 7m x 6m high has 36m2 of single-glazed windows (average 'U'-value of windows = 5.0 Wm-^{2} ^{o}C^{-1}). The 'U'-values of the floor, roof, and walls are 1.0 Wm-^{2} ^{o}C^{-1}, 0.5 Wm-^{2} ^{o}C^{-1}, and 1.0 Wm^{-2} ^{o}C^{-1}. Heating is provided by a fossil-fuel fired boiler. In Autumn 1978, double glazing was installed throughout the house (average 'U'-value of double-glazed windows = 2.5 Wm-^{2} ^{o}C^{-1}). From 1st January 1979 - 31st March 1979, a total of 91.0 GJ of energy were used as opposed to 87.6 GJ in the corresponding period in 1978.

If the neutral (balance) temperature (15.5^{o}C), ventilation rates, and boiler efficiency remain constant, estimate the total saving in energy arising from these conservation measures over a ten year period.

4. A tracer gas is released into a building of volume 400 m3 in which all doors and windows are closed. The concentration C of the tracer gas decreases through ventilation such that at any time t, it is given by:-

$$C = C_{o}e^{-xt/V}$$

where C_o is the initial concentration (at t=0)
V_o is the volume of the room
x is the quantity of air leaving the room in unit time.

The results are shown in Table 2. Estimate the air-change rate. After measures to reduce draughts, the experiment is repeated (Table 3). Estimate the annual saving in energy is there are 2400 degree-days in a year.

Table 2		Table 3	
Tracer Gas Concentration (ppm)	Time (mins)	Tracer Gas Concentration (ppm)	Time (mins)
80.00	10	60.00	15
57.32	20	41.24	30
41.07	30	28.34	45

this question we have not covered this year.

5. A second storey room in a three storey building (10m x 10m x 4m high) has two external walls, 75% of which are glazed. The mean activity of the occupants is 60 kcal hr-1 m-2, and the mean resistance of clothing is 0.75 clo. The relative humidity is maintained at 50%, and the air velocity is less than 0.1 m s-1. Show that the *average* mean radiant temperature is given by

$$\theta i \ - \ \frac{(\theta i \ - \ \theta o)}{8}$$

where θi and θo are the internal and external temperatures respectively. The overall resistance of the windows and walls are $0.18\ m^2\ {}^oC\ W^{-1}$ and $0.48\ m^2\ {}^oC\ W^{-1}$ respectively. The internal surface resistance should be taken as $0.12\ m^2\ {}^oC\ W^{-1}$.

The heating system for the room is designed to provide an internal air temperature of 22^oC. Show that when the external air temperature is at its mean seasonal value of 10^oC, approximately 9% of people will be dissatisfied with the thermal environment. Estimate the percentage of people who will be dissatisfied when the external temperature is -2^oC.

[this question was set in 1980 and it is not normal policy at the present time to expect a derivation like this]

6. A mid-storey room (10m x 10m x 3m high) in a multi-storey office block has two opposite external walls which are fully glazed. The internal temperature is 22^oC while the mean external temperature during the winter quarter is 6^oC. The mean radiant temperature at all points in the room may be taken as being 20^oC. Double glazing is installed to reduce conductive and ventilation losses.

Estimate the percentage saving in energy if the internal temperature is reduced to provide identical thermal comfort conditions, and the ventilation rate is reduced from 1.5 air-changes per hour to 1.0 air-changes per hour. The mean radiant temperature at all points in the room may now be taken as being approximately 1^oC below the room air-temperature.

(The mean clo-value of the occupants is 1.25 and their activity level is 50 kcal m-2 hr-1. The mean 'U'-values of single-glazed and double-glazed windows are $5.0\ Wm^{-2}\ {}^oC^{-1}$and $2.5\ Wm^{-2}\ {}^oC^{-1}$ respectively. It may be assumed that the relative humidity is kept constant at 50%, and that free convection conditions exist).

7. A detached house 7.5m x 7.5m x 6m high is constructed of 220mm thick brick walls having 15mm of light-weight plaster on the internal surfaces. 20% of the wall area is glazed. The 'U'-values of the windows, floor and roof are $5.0\ Wm^{-2}\ {}^oC^{-1}$, $0.6\ Wm^{-2}\ {}^oC^{-1}$, and $0.5\ Wm^{-2}\ {}^oC^{-1}$, respectively. Estimate the saving in energy per annum if a 3 mm polystyrene layer is bonded to the internal surface of each external wall. Climate records indicate that there are 4000 degree-days per year. If there are 2 air changes per hour, estimate the saving as a percentage of the total energy consumption before the polystyrene was attached.

8. A summary of the energy requirements for a house having an internal temperature of 20^oC are shown in Table 4. What is the heat loss rate (per degree Celsius) for the house? Comment on the relationship between mean weekly external temperature and the mean energy consumption.

Double glazing is fitted to 20m2 of window area in the house and this reduces the heat loss through the windows by $2.5\ Wm^{-2}\ {}^oC^{-1}$. If the incidental heat gains remain the same, estimate the new balance (neutral) temperature.

Hence, or otherwise, estimate the energy requirement for the double-glazed house when the external temperature is 5°C.

Table 4

Mean Weekly External Temperature (°C)	Mean Energy Consumption (kW)
2	7.75
6	5.75
9	4.25
13	2.25
17	1.00
19	1.05
21	0.95

===

Actual Paper as set in 1998

SECTION A (25%)

1. Critically review the procedures used in determining the Standard Assessment Procedure (SAP) Rating under the current Building Regulations.

2. How does a heat pump work? Using examples, discuss the advantages and disadvantages of the different types of heat pump.

3. Effective energy management requires the recording and analysis of data. Discuss which are the most important parameters to record, and how you would analyse the data obtained. You should illustrate your answer with typical graphs.

SECTION B (25%)

4. What is meant by the term "Degree Days", and how is it used to assess annual consumption of energy? What corrections are needed to values from standard tables before the data can be applied to a specific house?.

[20%]

A householder replaces his windows (total area 20 m2) with double glazing, replaces the existing boiler (75% efficiency) with a condensing boiler (90% efficiency) , and fits a boiler energy management system which the manufacturer claims will save around 10% in energy use. The original and new U-values of the windows are 5.3 W m^{-2} $^oC^{-1}$ and 2.8 W m^{-2} $^oC^{-1}$ respectively. Energy consumption data taken before and after installation are indicated in Table 1. If the thermostat setting remains unchanged and the incidental gains amount to 1500 W, critically examine the claim of the manufacturer. It may be assumed that cooking in the house is done using electricity

Table 1:

	Before conservation measures	After conservation measures
External temperature (^oC)	Consumption (kW)	Consumption (kW)
-2	7.800	4.833
2	6.200	3.833
6	4.600	2.833
10	3.000	1.833
14	1.400	0.833
18	1.000	0.833
22	1.000	0.833

[80%]

Solution

First plot up original data. Plot is in two parts, a temperature dependant part, and a temperature independent part. The intersection is at 15^{o}C and this is the balance or neutral temperature. The gradient of the temperature dependant part is 400 W^{o}C^{-1}, and since the boiler efficiency is 75%, the true heat loss rate is 300 W^{o}C^{-1}., Since the incidental gains are 1500, the thermostat temperature must be:

$$15 \quad + \quad 1500 / 300 \quad = \quad 20 \ ^oC$$

Installation of double glazing reduces heat loss rate by 20 x (5.3 - 2.8) = 50 W^{o}C^{-1}. i.e. to 250 W^{o}C^{-1}

So the new balance temperature will be 20 - 1500 / 250 = 14 ^{o}C.

The temperature independent part represents the demand for hot water, and allowing for boiler efficiency this is 1000 x 0.75 = 750 W, so after installation of a condensing boiler, the equivalent will be 750 / 0.9 = 833 W. This will represent the new consumption at all temperatures about the revised balance temperature, and this is indeed seen to be the case, so in this region, the boiler energy manager appear to have no effect at all.

Similarly the gross heat loss rate will be 250 / 0.9 = 277.77 W^{o}C^{-1}

Since the relationship is linear we need only define one point to highlight the new consumption curve. Selecting 0^{o}C as an example, the predicted consumption after double glazing and condensing boiler will be

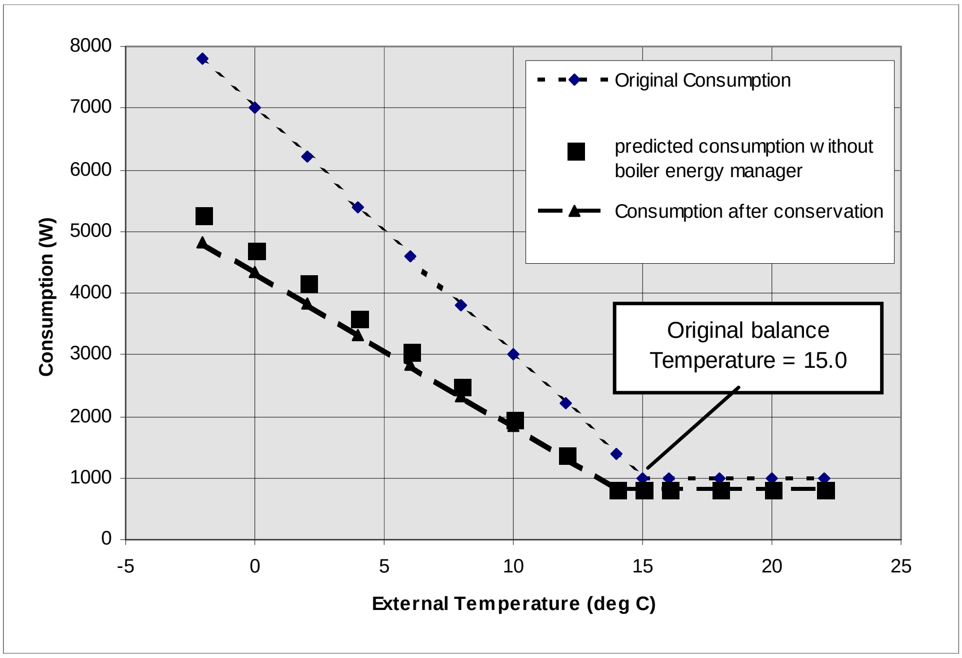
0.833 + (14 - -2) *277.77/1000 = 5.278 kW

Similar values can be determined, but this is not necessary as the diagram can be plotted directly. - shown dotted on graph. Actual values appear top be lower than this in temperature dependant part, so boiler energy manager does seem to be having an effect.

We note that at -2 ^{o}C, the new consumption is 4.833 kW - excluding the hot water requirement gives 4.000 kW. Similarly the predicted consumption at this temperature without the BEM and excluding the hot water is 5.278 - 0.833 = 4.444 kW.

The reduction from 4.444 to 4.000 represents a 10% reduction substantiating the claim, but this is only valid if hot water is excluded - which is realistic since the BEM only effects space heating, but the actual claim could be misleading.

Temp	before (kW)	predicted after no BEM (kW)	predicted after BEM only heating (kW)	predicted with BEM (kW)	actual new consumption (kW)
-2	7800	5278	4444	4000	4833
2	6200	4167	3333	3000	3833
6	4600	3056	2222	2000	2833
10	3000	1944	1111	1000	1833
14	1400	833			833
18	1000	833			833
22	1000	833			833



5. Describe ways in which the ventilation rate in a building may be determined. Why are ventilation rates not included in the current Building Regulations even though this is one of the most dominant aspects of heat loss from a building?

A room in a single storey building is 3m x 3m in plan and 2.4m high. It has one external wall with a single glazed window 1.8m2 in area. On a day when the external temperature is 0oC, the building is heated uniformly to 20oC. In an experiment the determine the intrinsic structural ventilation rate, the gaps at the edges of the windows and doors were sealed and supplementary heating of 998 W was supplied to the room. After two hours the room temperature stabilised at 25°C. Estimate the intrinsic ventilation rate in air changes per hour if the specific heat of air is 1306 J m^{-3} °C-1. U-value data are given in Table 2.

U-Values (W m^{-2} $^{o}C^{-1}$)			
External Walls	1.0	Floor	1.0
Internal Walls	2.5	Window	5.0
Roof	0.2		

SOLUTION

Continuity equation:-
supplementary heat - heat losses to outside + heat losses across internal walls = ventilation losses

The solution is best in tabular form

		Area (m^2)	U-value (W m^{-2} $^{o}c^{-1}$)	Temperature difference	heat lost (W)
internal heat transfers - 3 walls 3 x 2.4 m		21.6	2.5	5	270
external wall transfer		5.4	1.0	25	135
window transfer		1.8	5.0	25	225
roof transfer		9.0	0.2	25	45
floor transfer		9.0	1.0	25	225
Total conductive losses					**900**

So ventilation losses = 998 - 900 = 98 W

but volume of room is 3 x 3 x 2.4 = (21.6 cum), and temperature difference = 25oC

so ventilation loss = 21.6 x 25 x 1306 / 3600 x ach = 98
|
seconds in an hour

so number of air changes per hour = 0.500
=====

SECTION C (50%)

6. Critically review the changes that have taken place in the Energy Supply Industries in the last 15 years. Include in your answer a discussion of the changes which have, or will, take place in the Domestic Sector. To what extent have these helped or hindered energy conservation?

7. Discuss the advantages and problems from using Combined Heat and Power. (CHP) to save energy. Your answer review all the issues, but concentrate primarily on technical issues such as intermediate take-off and condensing (ITOC) turbines, combinations of CHP with combined cycle gas turbines (CCGT), and heat energy supply.

Co-generation in the UK has increase four-fold to 3000 MW since 1990, and is likely to double again by the ned of 2000 (OFFER, 1997). Why has there been this sudden increase in capacity despite several UK Energy Papers recommending such action in the previous two decades?

8. Describe ways in which the dynamic thermal performance of a building may be assessed clearly indicating any limitations of the methods described.

Waveney Terrace has a heat loss rate of 45 kW°C^{-1} and a thermal capacity of 4 GJ °C^{-1}. The heating is timed to go off at midnight and on again at 6 am. Estimate the time at which the internal temperature reaches the thermostat level on a cloudy day, and also the saving in energy achieved by time switching. The following data are relevant:

Internal thermostat setting	20^{o}C	Number of students	700
External temperature	0^{o}C	body heat	80W per student
Rating of heat supply	1500 kW	incidental gains	44 kW

[numeric part 70%]

Solution

The total heat lost from building immediately after heating is turned off at midnight
= heat lost rate x temperature difference = 45000 x (20 - 0) = 900 kW
Choosing a time interval of 1 hour = 3600 seconds, this means that the total heat lost from building in an hour is
900 x 3600 = 3.24 GJ
Similarly, heat gained from body heat and incidental gains = ((700 x 80) + 44000) * 3600 = 0.36 GJ
So net loss in first hour is 3.24 - 0.26 = 2.88 GJ.
Since the thermal capacity of the building is 4GJ, this will mean a fall in temperature of 0.72 oC over the hour.
i.e. the temperature at the start of the second hour is 20 - 0.72 = 19.28^{o}C.

The best way to solve the problem is using a table - as shown.

Successive hours proceed in exactly the same way until 6 am when heating comes on at rate of 2000kW, so in this hour the net gain/loss will be the loss as calculated above + the heat input of 2000 x 3600 = 7.2 GJ giving a net gain of 4.95 GJ. This time of course the temperature will see a rise.

Successive hours follow same procedure until the computed temperature rises above 20^{o}C. this occurs between 9 am and 10 am.

It remains to estimate the proportion of an hour = (20 - 19.66) / 1.09 = 0.31 hrs = 19 minutes
actual rise **computed rise**

So building will be up to temperature at 09:19

time	Internal Temp	heat input	heat lost	heat gained	net gain/loss	Temp change
		kW	GJ	GJ	GJ	^{o}C
0000	20.00	0	3.24	0.36	-2.88	-0.72
0100	19.28	0	3.12	0.36	-2.76	-0.69
0200	18.59	0	3.01	0.36	-2.65	-0.66
0300	17.93	0	2.90	0.36	-2.54	-0.64
0400	17.29	0	2.80	0.36	-2.44	-0.61
0500	16.68	0	2.70	0.36	-2.34	-0.59
0600	16.09	2000	2.61	0.36	4.95	1.24
0700	17.33	2000	2.81	0.36	4.75	1.19
0800	18.52	2000	3.00	0.36	4.56	1.14
0900	19.66	2000	3.19	0.36	4.37	1.09
0100	20.00	800	3.24	0.36	2.88	0.72

Using a time interval of 2 hours gives the same result (to nearest minute), as does a time interval of 30 minutes.

The total energy consumed in warm up period = 3.31 x 2000 *3600/1000000 = 22.536 GJ

Energy which would have been consumed over same period without time switching =

= 9.31 x 800 *3600/1000000 = 26.813 GJ

so saving is **4.277 GJ or 15.9%**

[Maximum mark to be gained using 2 hour interval - 63/70 as it is often too coarse, but will involve less time, and so students may opt for this.
Comments on time interval selected should be given in descriptive part.