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Elective 3 Energy and Use of Energy

3.1 Electricity at home

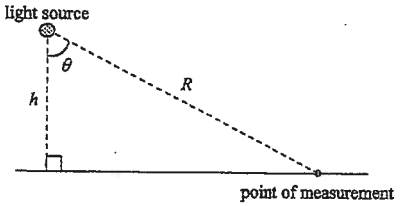
The following list of formulae may be found useful :

Illuminance $E = \frac{\Phi}{A}$

Part A :

The following questions marked with {SP} are the Sample Paper questions of the new DSE Examination.

M1. {SP} In the figure, a light source is a perpendicular distance h above a horizontal surface. The amount of illuminance (unit : lux) of a point on the surface at a distance R from the source is directly proportional to



A. $\cos^2\theta / R^2$
B. $\cos^2\theta / h^2$
C. $\cos^3\theta / h^2$
D. $\cos^3\theta / R^2$

M2. {SP} The Coefficient of Performance (COP) of a heat pump is

A. the ratio of energy absorbed from the cold reservoir to the energy rejected to the hot reservoir.
B. the heat energy rejected to the hot reservoir per unit work done.
C. the ratio between the total energy input to the useful work done.
D. the ratio between the extra work input to the total energy input.

Part B :

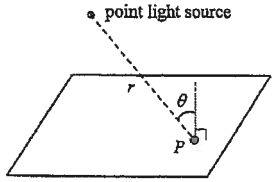
The following questions marked with {PP} are the Practice Paper questions of the new DSE Examination.

M3. {PP} A 100 W filament light bulb and a 22 W compact fluorescent lamp both produce a luminous flux of 1600 lm. Which of the following statements about the two light sources is/are correct ?

(1) Both light sources give out the same amount of energy in the form of electromagnetic waves in 1 s.
(2) 78 J of electrical energy is converted to heat in the filament light bulb in 1 s.
(3) Both light sources have the same brightness to the human eye when observed from the same distance.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M4. {PP} A point light source with luminous flux F is illuminating a point P on a table surface as shown in the figure below. The illumination at point P is



A. $\frac{F\cos\theta}{4\pi r^2}$
B. $\frac{F\cos^2\theta}{4\pi r^2}$
C. $\frac{F\cos(90°-\theta)}{4\pi r^2}$
D. $\frac{F\cos^2(90°-\theta)}{4\pi r^2}$

M5. {PP} Which of the following statements about an electric hotplate and an induction cooker is/are correct ?

(1) Both cookers make use of the heating effect of a current.
(2) Only metal cooking pots can be used for both cookers.
(3) In general, an induction cooker has a higher energy efficiency than an electric hotplate.

A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

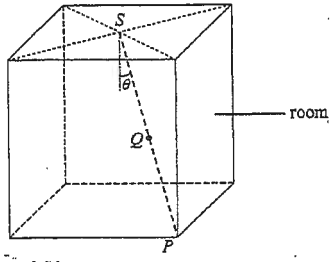
Part C :

The following questions marked with { } are the past DSE questions. The number inside the brackets represents the year of the examination.

M6. {12} Which of the following lamps has the greatest end-use energy efficiency ?

	luminous flux	power rating
A.	750 lm	15 W
B.	900 lm	30 W
C.	750 lm	60 W
D.	600 lm	90 W

M7. {12} Below is a diagram of a room, the illuminance at corner P is E under the illumination of a point light source S as shown. Neglect the reflections from the room surfaces.



The illuminance at point Q midway between P and S is

A. $\frac{\sqrt{2}E}{\cos\theta}$
B. $2E\cos\theta$
C. $4E$.
D. $8E$.

M8. {12} Estimate the time required to cool an insulated room of interior volume 29.0 m^3 from 37°C to 24°C by an air conditioner of cooling capacity 2.2 kW.

Given : density of air = 1.2 kg m^{-3} ; specific heat capacity of air = 1000 J kg^{-1} K^{-1}

A. 171 s
B. 206 s
C. 380 s
D. 586 s

Part D :

The following questions are designed to give supplemental exercise for this chapter.

M9. Which of the following form of energy given out by a vacuum cleaner is useful ?

(1) kinetic energy

(2) sound energy

(3) heat

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M10. Which of the following form of energy may be given out by a TV set ?

(1) light energy

(2) sound energy

(3) heat energy

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M11. Which of the following concerning electrical appliances at home is/are correct ?

(1) All electrical appliances would give out heat during operation.

(2) All electrical appliances would give out sound during operation.

(3) The heat given out by all electrical appliances is useless.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M12. The end-use energy efficiency of a lamp is 35%. If the power rating of the lamp is 60 W, how much useful energy is given out in 8 hours ?

A. 575 kJ
B. 605 kJ
C. 792 kJ
D. 848 kJ

M13. Which of the following is/are the advantages of incandescent lamp, compared with the compact fluorescent lamp ?

(1) Incandescent lamp is cheaper.

(2) Incandescent lamp has longer life.

(3) Incandescent lamp has higher end-use energy efficiency.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

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M14. A filament lamp has a resistance of 960 Ω. An a.c. voltage of r.m.s. value 220 V is applied to it for 12 hours. If the end-use energy efficiency is 8%, how much heat is released to the surroundings during the time of operation ?

A. 1.5 MJ
B. 2.0 MJ
C. 2.5 MJ
D. 3.0 MJ

M15. Which of the following concerning a CFL is NOT correct ?

A. The tube inside contains mercury.
B. The phosphor coating converts ultra-violet radiation to visible light.
C. During its operation, no heat is produced.
D. Radiation is emitted by mercury atoms after they are excited.

M16. Which of the following is/are the disadvantages of CFL, compared with the conventional incandescent lamp ?

(1) CFL is more expensive.

(2) CFL has shorter life.

(3) Improper disposal of CFL would cause the pollution of environment.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M17. Which of the following concerning a LED is/are correct ?

(1) LED consists of two layers of semiconductor.

(2) LED can be operated by d.c. or a.c. supply.

(3) LED is usually installed in electronic circuit due to its small size.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M18. To which wavelength does the human eye response most sensitively ?

A. 500 nm
B. 550 nm
C. 600 nm
D. 650 nm

M19. Which of the following affect the cost effectiveness of a lamp ?

(1) price of the lamp

(2) end-use energy efficiency of the lamp

(3) size of the lamp

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M20. A CFL has a power rating of 18 W. It gives out light at a rate of 61 lm/W. What is the luminous flux that can be emitted by this CFL in normal working condition ?

A. 1000 lm
B. 1100 lm
C. 1200 lm
D. 1300 lm

M21. Which of the following lamps can give out the greatest brightness in normal condition ?

A. a lamp of power rating 20 W with 62 lm/W
B. a lamp of power rating 40 W with 36 lm/W
C. a lamp of power rating 80 W with 25 lm/W
D. a lamp of power rating 100 W with 12 lm/W

M22. A small light bulb gives out light steadily in all directions. If the illuminance at a point 4 m from the lamp is 12 lx, what is the illuminance at a point 6 m from the lamp ?

A. 5.3 lx
B. 5.6 lx
C. 5.9 lx
D. 6.2 lx

M23. The power rating of a lamp is 60 W. It emits light at 18 lm/W. If the lamp is installed at a height of 2.5 m above the desk, what is the illuminance at the desk ?

A. 10 lx
B. 12 lx
C. 14 lx
D. 16 lx

M24. The illuminance at a point 1.6 m from a lamp is 25 lx. If the lamp emits light at 45 lm/W, what is the power rating of the lamp ?

A. 12 W
B. 18 W
C. 24 W
D. 36 W

M25. A small light source emits visible light in all directions. Which of the following would NOT affect the illuminance on a certain surface ?

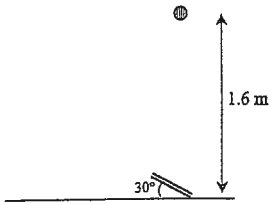
A. power of the light source
B. orientation of the surface
C. area of the surface
D. distance of the surface from the light source

M26. The illuminance at a point in a room due to a small lamp can be found the Inverse square law and the Lambert's cosine law. However, the actual illuminance is usually higher than the calculated value. Which of the following may be a factor to account for this deviation ?

(1) The lamp is not a point source.
(2) There is reflection of light by the surrounding walls.
(3) The light is not emitted evenly in all directions.

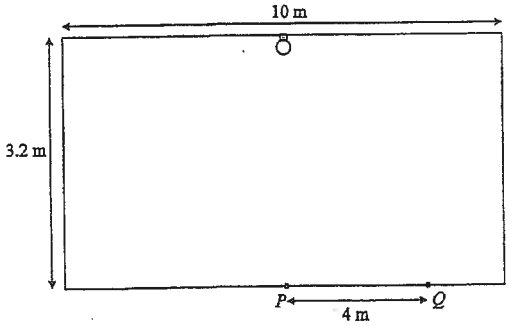
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M27. A small book is placed vertically below a lamp as shown in the figure. If the illuminance on the book is 26.5 lx, what is the luminous flux emitted by the lamp ?



A. 679 lm
B. 725 lm
C. 846 lm
D. 984 lm

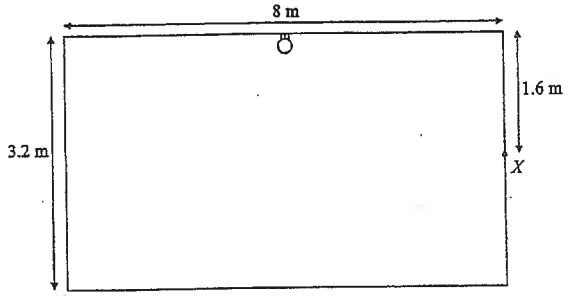
M28.



In the above figure, P is a point vertically below the lamp at the ceiling. If the luminous flux given out by the lamp is 1800 lm, what is the illuminance at the point Q ?

A. 2.8 lx
B. 3.4 lx
C. 4.2 lx
D. 5.6 lx

M29.



In the above figure, a small lamp given out a total luminous flux of 1350 lm is installed at the middle of the ceiling. What is the illuminance at the point X ?

A. 5.37 lx
B. 6.25 lx
C. 7.35 lx
D. 7.95 lx

M30. The end-use energy efficiency of an induction cooker is 78%. If the cost of electricity is $0.95 per kWh, what is the expenditure to heat 1.5 kg of water from the room temperature of 25°C to boiling. Given that the specific heat capacity of water is 4200 J kg^{-1} $°C^{-1}$.

A. $0.12
B. $0.14
C. $0.16
D. $0.18

M31. Which of the following concerning the operation of an induction cooker is/are correct ?

(1) Magnetic field is produced by the high voltage of d.c. supply.
(2) The change of magnetic field induces eddy current at the cover of the cooker.
(3) Only cookware with ferrous metal can be used on an induction cooker.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M32. Which of the following can account for the reason that a gas cooker is much lower efficient than an induction cooker ?

(1) Large amount of heat is lost to the surroundings with a gas cooker.
(2) The material of the induction cooker would not get hot during cooking.
(3) All the electrical energy supplied to an induction cooker would convert to the internal energy of the food.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M33. The end-use energy efficiency of a gas cooker is 42%. If the cost of gas is $0.25 per MJ, find the expenditure to heat 1.2 kg of water from the room temperature of 25°C to boiling. Given that the specific heat capacity of water is 4200 J kg^{-1} $°C^{-1}$.

A. $0.225
B. $0.250
C. $0.275
D. $0.300

M34. Which of the following is NOT an advantage of an induction cooker for cooking food, compared with a gas cooker ?

A. An induction cooker does not produce naked flame that may catch fire.
B. An induction cooker would not burn off the oxygen in the room.
C. A cookware made of metal should be used for an induction cooker.
D. The end-use energy efficiency of an induction cooker is high.

M35. Which of the following correctly compare(s) the cooking by conventional ovens and by microwave ovens ?

(1) Conventional ovens cook food by infrared radiation but microwave ovens cook food by microwave radiation.
(2) Conventional ovens can cook food with a crispy surface but microwave ovens cannot.
(3) Conventional ovens cook food by transferring heat from surface to the interior but microwave ovens cook food by transferring heat from the interior to the surface.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M36. Suppose 1.2 kg of water is heated from 20°C to 90°C by an electric hotplate of power rating 1600 W in 7.5 minutes. Specific heat capacity of water is known to be 4200 J kg^{-1} $°C^{-1}$. What is the end-use energy efficiency of the cooker ?

A. 37%
B. 49%
C. 56%
D. 62%

M37. The Coefficient of Performance (COP) of a refrigerator is

A. the ratio of energy absorbed from the cold reservoir to the energy rejected to the hot reservoir.
B. the ratio between the total energy input to the useful work done.
C. the ratio between the extra work input to the total energy input.
D. The heat energy absorbed from the cold reservoir per unit work done.

M38. A heat pump can extract a heat of 2500 J from a cold reservoir and deliver a heat of 3000 J to a hot reservoir in 1 minute. What is its coefficient of performance ?

A. 4
B. 5
C. 6
D. 8

M39. An air-conditioner of rating power of 1500 W is installed inside a room. If the coefficient of performance is 2.86, what is the cooling capacity of the air-conditioner ?

A. 524 W
B. 1050 W
C. 2145 W
D. 4290 W

M40. An air-conditioner of power 850 W is installed inside a room of size 5 m × 4 m × 2.8 m. Density of air is 1.2 kg m^{-3} and the specific heat capacity of air is 1006 J kg^{-1} $°C^{-1}$. If the time taken to cause the temperature of the room to drop from 32°C to 25°C is 4 minutes after switching on the air-conditioner, what is the coefficient of performance of the air-conditioner ?

A. 2.3
B. 2.6
C. 2.9
D. 3.2

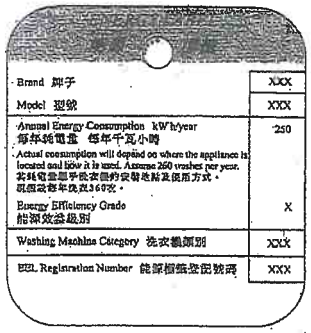
M41. Which of the following concerning an air-conditioning system is correct ?

A. Conservation of energy cannot be applied.
B. The flow of heat is from high temperature region to low temperature region.
C. The heat rejected to the hot reservoir must be greater than the heat absorbed from the cold reservoir.
D. Work done on the system is equal to the heat absorbed from the cold reservoir.

M42. Which of the following concerning the grading types of EELS is correct ?

A. The more efficient an electrical appliance, the more expensive is the appliance.
B. The label does not include the data of the power rating of the electrical appliance.
C. The Annual energy consumption assumes the continuous use of the electrical appliance in one year.
D. All electrical appliances are under the scheme of EELS.

M43.



The figure shows the energy label of a washing machine. If the average working time per wash is 1.8 hours, estimate the average electric power consumed by the machine.

A. 450 W
B. 534 W
C. 962 W
D. 1731 W

M44. Which of the following would cause a waste of energy at home ?

(1) Leave the home without switching off the lights.
(2) Use incandescent light instead of CFL.
(3) Set the indoor temperature to 20°C in using the air-conditioner.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M45. Which of the following would save energy at home ?

(1) Use fans instead of air-conditioners.
(2) Don't use the washing machine until a full load of clothes has been accumulated.
(3) Leave the entertainment equipments in standby mode.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M46. Why should we save energy ?

(1) To reduce the use of fossil fuels which have limited supply.
(2) To reduce the release of carbon dioxide which is one of the greenhouse gases that cause global warming.
(3) To protect the Earth and our environment.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

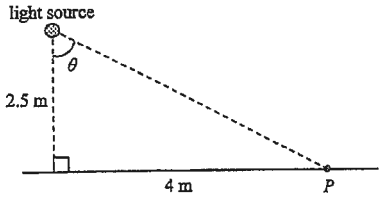
M47. Suppose a heat pump can deliver a heat energy of 8500 J to the hot reservoir by absorbing 6500 J of heat energy from the cold reservoir, what is its coefficient of performance ?

A. 1.31
B. 2.25
C. 3.25
D. 4.25

M48. A 100 W filament light bulb and a 22 W compact fluorescent lamp can produce the same luminous flux in normal use. The price of a filament light bulb is $10 and its duration life is 6 months. The price of a compact fluorescent lamp is $32 and its duration life is 3 years. Calculate the money saved in 3 years if the filament light bulb is replaced by the compact fluorescent lamp, assuming the lamp is used continuously in 3 years without switching off, and the cost of electricity is $1 per kWh.

A. $ 2 022
B. $ 2 050
C. $ 2 078
D. $ 2 628

M49.



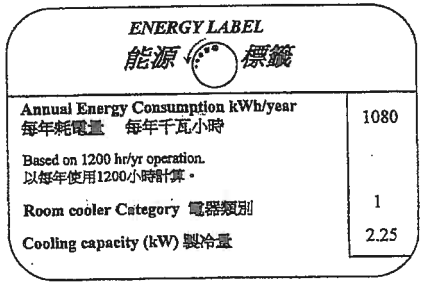
A point light source gives out a steady luminous flux of 2400 lm in all directions. Calculate the illuminance at the point *P* as shown in the above figure.

A. 4.55 lux
B. 6.33 lux
C. 7.28 lux
D. 16.2 lux

M50. Which of the following statements concerning an induction cooker is correct ?

A. An induction cooker makes use of the heating effect of the eddy current to give out heat.
B. No heat is lost to the surroundings by the induction cooker during cooking.
C. During operation, eddy current is induced in the cooker to generate heat.
D. It is dangerous to touch the surface of the cooker as eddy current may be induced in our body.

M51.



The above figure shows the energy label of an air-conditioner. Which of the following statements is/are correct ?

(1) The average power rating of the air-conditioner is 900 W.
(2) The amount of heat that can be removed from the room by the air-conditioner in 1 hour is 2.25 kWh.
(3) The coefficient of performance of the air-conditioner is 2.5

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

Answers

1. C	11. A	21. C	31. B	41. C	51. D
2. B	12. B	22. A	32. C	42. B	
3. B	13. A	23. C	33. A	43. B	
4. A	14. B	24. B	34. C	44. D	
5. C	15. C	25. C	35. A	45. A	
6. A	16. B	26. D	36. B	46. D	
7. C	17. B	27. D	37. D	47. D	
8. B	18. B	28. B	38. C	48. C	
9. A	19. A	29. A	39. D	49. A	
10. D	20. B	30. C	40. A	50. A	

Solution

1. C

Assume that it is a point light source with luminous flux of Φ.

Illuminance at the point :

$$E = \frac{\Phi}{4\pi R^2}\cos\theta = \frac{\Phi\cos\theta}{4\pi(h/\cos\theta)^2} = \frac{\Phi\cos^3\theta}{4\pi h^2} \propto \frac{\cos^3\theta}{h^2}$$

2. B

The function of a heat pump is to supply as much heat as possible to the hot body.

Coefficient of a heat pump is defined as :

$$\text{COP} = \frac{Q_H}{W}$$

Thus, COP is the heat energy rejected to the hot reservoir per unit work done.

3. B

× (1) Although both light sources give the same amount of visible light,
they also give out infra red radiation that is also electromagnetic wave.
As the amount of infra-red radiation are not the same,
they give out different amount of energy in the form of electromagnetic waves in 1 s.

× (2) Since the compact fluorescent lamp would also give out heat,
thus the electrical energy converted to light is less than 22 J in 1 s.
For the filament light bulb, the electrical energy converted to light is also less than 22 J in 1 s,
thus the electrical energy converted to heat should be more than 78 J in 1 s.

✓ (3) Since the luminous flux of the two light sources is the same, they give the same brightness.

4. A

Illumination at point P :

$$E = E_0\cos\theta$$

$$= \frac{F}{4\pi r^2}\cos\theta$$

5. C

✓ (1) Electric hotplate makes use of the heating effect of the current through the resistive element.
Induction cooker makes use of the heating effect of the eddy current induced in the cookware.

× (2) Every type of cooking pots can be used for electric hotplate, such as glass or ceramic pots.
Only metal cooking pots or cooking pots containing metal can be used for induction cooker.

✓ (3) Since the induction cooker itself is not heated to high temperature, less heat is wasted,
thus induction cooker is more energy efficient.

6. A

Considering the efficacy of each lamp :

A. 750 / 15 = 50 lm / W

B. 900 / 30 = 30 lm / W

C. 750 / 60 = 12.5 lm / W

D. 600 / 90 = 6.67 lm / W

Since the efficacy of lamp A is the greatest, lamp A has the greatest end-use energy efficiency.

7. C

Illuminance obeys inverse-square law :

$$\therefore E \propto \frac{1}{r^2}$$

$$\therefore r \to \frac{r}{2} \Rightarrow E \to 4E$$

8. B

Total mass of air inside the room $= 1.2 \times 29.0 = 34.8$ kg

Heat need to be extracted from the room $= mc\Delta T = (34.8)(1000)(37-24) = 452400$ J

By $E = Pt$

$\therefore (452400) = (2.2 \times 10^3)t$

$\therefore t = 206$ s

9. A

✓ (1) The kinetic energy of the motor can help to produce vacuum effect to draw the dirt.

× (2) The sound energy output gives the unnecessary noise.

× (3) The heat produced causes the decrease of efficiency.

10. D

✓ (1) TV set gives out light on the screen.

✓ (2) TV set gives out sound in the loudspeakers.

✓ (3) Heat energy must be produced when current flows, but the heat generated is useless.

11. A

✓ (1) All electrical appliances would give out heat as current has heating effect when flowing through resistor.

× (2) Some electrical appliance would not give out sound, e.g. lamps.

× (3) The heat given out by heaters is useful.

12. B

$P_{out} = 60 \times 35\% = 21$ W

$E_{out} = 21 \times 8 \times 60 \times 60 = 604800 \approx 605$ kJ

13. A

✓ (1) Incandescent lamp is the cheaper than CFL.

× (2) Incandescent lamp has short life, due to the evaporation of the filament at high temperature.

× (3) The end-use energy efficiency of incandescent lamp is lower than CFL.

14. B

$P_{in} = \frac{V^2}{R} = \frac{(220)^2}{(960)} = 50.4$ W

$P_{loss} = 50.4 \times (1 - 8\%) = 46.4$ W

$E_{loss} = 46.4 \times 12 \times 3600 = 2.0$ MJ

15. C

Some heat is still produced in CFL.

16. B

✓ (1) CFL is more expensive than incandescent lamp.

× (2) CFL has longer life.

✓ (3) CFL contains mercury, thus improper disposal would pollute the environment.

17. B

✓ (1) LED consists of a p-type semiconductor and a n-type semiconductor.

× (2) LED can only be operated by d.c. supply.

✓ (3) LED has very small size, convenient to be used in electronic cirucits.

18. B

Human eye is most sensitive towards the electromagnetic wave of wavelength 550 nm

19. A

✓ (1) The lower the price, the higher the cost effectiveness.

✓ (2) The higher the end-use energy efficiency, the higher the cost effectiveness.

× (3) The size of the lamp has no relation with the cost effectiveness.

20. B

Luminous flux $= 61 \times 18 = 1100$ lm

21. C

A. luminous flux $= 20 \times 62 = 1240$ lm

B. luminous flux $= 40 \times 36 = 1440$ lm

C. luminous flux $= 60 \times 25 = 1500$ lm : brightest

D. luminous flux $= 100 \times 12 = 1200$ lm

22. A

By inverse square law,

$E \propto \frac{1}{r^2}$ $\therefore \frac{E_2}{E_1} = (\frac{r_1}{r_2})^2$ $\therefore E_2 = 12 \times (\frac{4}{6})^2 = 5.3$ lx

23. C

Total luminous flux $= 60 \times 18 = 1080$ lm

Illuminance $= \frac{\Phi}{4\pi r^2} = \frac{1080}{4\pi (2.5)^2} = 14$ lx

24. B

Luminous flux $= E \times 4\pi r^2 = 25 \times 4\pi (1.6)^2 = 804$ lm

$\therefore 804 = 45 \times P$ $\therefore P = 18$ W

25. C

Illuminance does not depend on the area of the surface.

26. D

✓ (1) The inverse square law assumes that the light is emitted from a point.

✓ (2) Reflection (diffuse reflection) of light from walls would increase the illuminance.

✓ (3) The inverse square law assumes light is emitted evenly in all directions.

27. D

$E = \frac{\Phi}{4\pi r^2} \cos\theta$ $\therefore (26.5) = \frac{\Phi}{4\pi (1.6)^2} \cos 30°$ $\therefore \Phi = 984$ lm

28. B

$r = \sqrt{(3.2)^2+(4)^2} = 5.12$ m

$\tan\theta = \frac{4}{3.2} \quad \therefore \theta = 51.3°$

$E = \frac{\Phi}{4\pi r^2}\cos\theta = \frac{(1800)}{4\pi(5.12)^2}\cos 51.3° = 3.4$ lx

29. A

$r = \sqrt{(4)^2+(1.6)^2} = 4.31$ m

$\tan\theta = \frac{1.6}{4} \quad \therefore \theta = 21.8°$

$E = \frac{\Phi}{4\pi r^2}\cos\theta = \frac{(1350)}{4\pi(4.31)^2}\cos 21.8° = 5.37$ lx

30. C

$E_{out} = mc\Delta T = (1.5)(4200)(100-25) = 472500$ J

$E_{in} = \frac{472500}{78\%} = 605769$ J

cost $= \frac{605769}{3600000} \times \$0.95 = \$0.16$

31. B

× (1) Magnetic field should be produced by the high voltage of a.c. supply.

× (2) The cover of the induction cooker is not made of metal, and thus no current can be induced.

✓ (3) Ferrous metal (iron) is a good magnetic material,
magnetic field can easily penetrate through the metal to induce eddy currents there.

32. C

✓ (1) The naked flame would lose much heat to the surrounding air.

✓ (2) Since eddy current is induced in the cookware but not in the cooker, the cooker does not get hot.

× (3) There is still heat lost to the surrounding air and heat lost to heat up the cooker material.

33. A

$E_{out} = mc\Delta T = (1.2)(4200)(100-25) = 378\,000$ J

$E_{in} = \frac{378000}{42\%} = 900\,000$ J

cost $= \frac{900000}{1\times10^6} \times \$0.25 = \$0.225$

34. C

Only cookware made of metal can be used is the disadvantage of an induction cooker.

35. A

✓ (1) Conventional cookers cook food by heat radiation.

✓ (2) Since the outside of the food is cooked first, a crispy surface can form for conventional cookers.

× (3) Microwaves would penetrate evenly to the food,
thus the interior and the exterior can be cooked at the same time.

36. B

$E_{out} = mc\Delta T = (1.2)(4200)(90-20) = 352800$ J

$E_{in} = Pt = (1600)(7.5\times60) = 720000$ J

$\eta = \frac{352800}{720000}\times100\% = 49\%$

37. D

A refrigerator tries to absorb heat from the cold reservoir as much as possible,
thus the COP is defined as the heat absorbed from the cold reservoir per unit work done

38. C

$W = 3000-2500 = 500$ J

$\text{COP} = \frac{Q_H}{W} = \frac{3000}{500} = 6$

39. D

Cooling capacity $= 1500\times2.85 = 4290$ W

40. A

$Q_C = mc\Delta T = (5\times4\times2.8\times1.2)(1006)(32-25) = 473000$ J

$W = Pt = 850\times4\times60 = 204000$ J

$\text{COP} = \frac{Q_C}{W} = \frac{473000}{204000} = 2.3$

41. C

The heat rejected to the hot reservoir is the sum of heat absorbed from the cold reservoir and the work done input,
i.e. $Q_H = Q_C + W \quad \therefore Q_H > Q_C$

42. B

The power rating and the voltage rating are not put on the label of the EELS.

43. B

No. of washes per year = 260

Average time per wash = 1.8 hours $\quad \therefore$ Total operating time $= 260\times1.8 = 468$ hours

By $E = Pt \quad \therefore$ (250 kWh) $= P$ (468 h) $\quad \therefore P = 0.534$ kW $= 534$ W

44. D

✓ (1) The lights are still on but without usage.

✓ (2) Incandescent lamps give out much useless heat when operating.

✓ (3) The setting temperature is too low, thus waste much energy of the air-conditioner.

45. A

✓ (1) The power rating of fans is much lower than air-conditioners.

✓ (2) If the clothes are washed one by one by the machine, then the machine would operate many times and thus much energy is used.

× (3) Equipments in standby mode still uses energy, thus energy is wasted.

46. D

✓ (1) Electrical energy are generated by using fossil fuels.

✓ (2) Burning fossil fuels would give out carbon dioxide.

✓ (3) Save energy can reduce global warming, thus protect the Earth.

47. D

$$\text{COP of a heat pump} = \frac{Q_H}{W} = \frac{Q_H}{Q_H - Q_C} = \frac{8500}{8500 - 6500} = 4.25$$

48. C

$$\text{Money saved} = (100 - 22) \times \frac{1}{1000}\text{kW} \times 3 \times 365 \times 24\text{ h} \times \$1/\text{kWh} + (\$10 \times 6 - \$32) = \$2\,078$$

49. A

$$\text{Distance between light source and } P: r = \sqrt{(2.5)^2 + (4)^2} = 4.717\text{ m}$$

$$\tan\theta = \frac{4}{2.5} \quad \therefore \quad \theta = 58°$$

$$\text{Illuminance at } P: E = \frac{\Phi}{4\pi r^2}\cos\theta = \frac{2400}{4\pi(4.717)^2}\cos 58° = 4.55\text{ lux}$$

50. A

✓ A. In an induction cooker, high frequency alternating magnetic field induces eddy current in the cookware, the eddy current then gives out heat by the heating effect of current.

× B. Since the cookware would become hot, there is still some heat lost to the surroundings.

× C. Eddy current is induced in the cookware, not in the cooker.

× D. Since our body is not made of metal, no eddy current can be induced in our body.

51. D

✓ (1) By $E = Pt$ $\therefore$ (1080 kWh) = P (1200 h) $\therefore$ P = 0.9 kW = 900 W

✓ (2) Cooling capacity = 2.25 kW $\therefore$ Heat removed in 1 hour = 2.25 kW × 1 h = 2.25 kWh

✓ (3) Q_C = 2.25 kW × 1200 h = 2700 kWh $\therefore$ COP = Q_C / W = 2700 / 1080 = 2.5

The following list of formulae may be found useful :

Illuminance $E = \frac{\Phi}{A}$

Part A :

The following questions marked with {SP} are the Sample Paper questions of the new DSE Examination.

Q1. {SP} (a) Gas cookers and induction cookers are common domestic cooking devices. Their typical conversion efficiencies and costs are tabulated below :

Cooking device	Conversion efficiency	Cost
Gas cooker	40%	\$0.25 per MJ
Induction cooker	75%	\$0.90 per kW h

(i) Explain how an induction cooker generates heat in a cooking vessel placed on it. (2 marks)

(ii) Give a reason why the conversion efficiency of gas cookers is much lower than that of induction cookers. (1 mark)

(iii) If a gas cooker and an induction cooker are used to heat up 1 kg of water at room temperature of 25°C to boiling. Calculate the cost of doing this for each cooker. (4 marks)
Given : specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$.

(b) The European Commission is preparing to replace incandescent light bulbs across most of Europe by compact fluorescent bulbs (CFLs) or light emitting diodes (LEDs). State TWO advantages and TWO disadvantages of such a move. (3 marks)

Part B :

The following questions are designed to give supplemental exercise for this chapter.

Q2. The rating values of an electric boiler are '220 V, 1.8 kW'.

(a) If the end-use energy efficiency of the boiler is 72%, how long will it take to heat 1.5 kg of water from 25°C to the boiling point ? (Specific heat capacity of water = 4200 $J\ kg^{-1}\ °C^{-1}$) (3 marks)

(b) Give two reasons why the efficiency of the boiler is not 100%. (2 marks)

(c) If the cost of electricity is $1.05 per kWh, how much does this heating process cost ? (2 marks)

Q3. A CFL has rating power of 12 W and its duration life-time is 3 years. It gives the same light output as a 60 W incandescent light bulb, which can last for 6 months for continuous use. The price of the CFL is $28 while that of the incandescent light bulb is $8. Current cost of electricity is $1.04.

(a) Find the total cost of using CFL in 3 years continuously without switching off. (2 marks)

(b) Find the total cost of using incandescent light bulbs in 3 years continuously without switching off. (2 marks)

(c) Hence compare the total cost in using these two types of lamps in 3 years. (2 marks)

Q4.

ENERGY LABEL
能源 標籤

Brand 牌子	AAA
Model 型號	456
Annual Energy Consumption kWh/year **每年耗電量 每年千瓦小時** Based on 1200 hr/yr operation. 以每年使用1200小時計算。	1260
Energy Efficiency Grade **能源效益級別**	1
Room cooler Category 電器類別	1
Cooling capacity (kW) 製冷量	3.2
EEL Registration Number 能源標籤登記號碼	XXX

The above label is found on a certain brand of an air-conditioner.

(a) Calculate the average power rating of the air-conditioner. (2 marks)

(b) Calculate the coefficient of performance of the air-conditioner. (2 marks)

(c) If the current cost of electrical energy is $1.05 per kWh, what is the expenditure for using the air-conditioner in 1 month, operating 10 hours per day in summer ? (Assume a 30 day month.) (2 marks)

Q1. (a) (i) The induction cooker's coil produces a high frequency alternating magnetic field. [1]

The field penetrates the metal of ferrous cooking vessels and induces eddy currents to circulate in the metal for heat generation. [1]

(ii) A considerable amount of energy is lost to the surroundings with a gas cooker as the temperature difference between the heating source and the environment is very high. [1]

(iii) $E = mc\Delta T = (1)(4200)(100-25) = 3.15 \times 10^5$ J [1]

For the gas cooker :

$$\text{cost} = \$0.25 \times \frac{3.15\times10^5}{40\%} \times \frac{1}{1\times10^6} \quad [1]$$

$$= \$0.197 \quad [1]$$

For the induction cooker :

$$\text{cost} = \$0.90 \times \frac{3.15\times10^5}{75\%} \times \frac{1}{1000\times3600}$$

$$= \$0.105 \quad [1]$$

(b) Advantages (any TWO) : < 1 mark for one correct; 1.5 mark for two correct >

- CFLs and LEDs are energy efficient than incandescent light bulbs
- To reduce the emission of green-house gases from power plants
- To save fossil fuels, which are non-renewable.

Disadvantages (any TWO) : < 1 mark for one correct; 1.5 mark for two correct >

- High initial capital for replacement of incandescent light bulbs by CFLs and LEDs
- Improper disposal of CFLs can cause pollution due to the mercury inside them.
- Improper disposal of CFLs and LEDs poses the problem of electronic waste

< Accept other reasonable answers >

Q2. (a) $E_{out} = mc\Delta T = (1.5)(4200)(100-25) = 472500$ J [1]

$$E_{in} = \frac{472500}{72\%} = 656250 \text{ J} \quad [1]$$

By $E = Pt$ $\therefore (656250) = (1800)t$ $\therefore t = 365$ s < accept 364 s > [1]

(b) Some heat is lost to the surrounding air. [1]

Some heat is lost to raise the temperature of the boiler. [1]

(c) $$\text{cost} = 1.8 \times \frac{365}{3600} \times 1.05 \quad [1]$$

= \$ 0.192 < accept \$ 0.191 > [1]

Q3. (a) $$E = \frac{12}{1000} \text{ kW} \times 3 \times 365 \times 24 \text{ h} = 315 \text{ kWh} \quad [1]$$

Total cost = $315 \times \$1.04 + \$28 = \$\,356$ [1]

(b) $$E = \frac{60}{1000} \text{ kW} \times 3 \times 365 \times 24 \text{ h} = 1577 \text{ kWh} \quad [1]$$

Total cost = $1577 \times \$1.04 + \$8 \times 6 = \$\,1688$ [1]

(c) Difference in total cost = 1688 − 356 = \$1332 [1]

Using CFL can save a total money of \$ 1332 in three years. [1]

Q4. (a) By $E = Pt$

$\therefore$ (1260 kW h) = P (1200 h) [1]

$\therefore P = 1.05$ kW (1050 W) [1]

(b) Total heat absorbed in 1200 hours = 3.2 kW × 1200 h = 3840 kW h [1]

$$\text{COP} = \frac{Q_c}{W} = \frac{3840}{1250} = 3.07 \quad [1]$$

(c) $E = Pt = (1.05 \text{ kW})(10 \text{ h} \times 30) = 315$ kW h [1]

Cost = $315 \times 1.05 = \$\,331$ [1]

3.2 Energy efficiency in building

The following list of formulae may be found useful :

Rate of energy transfer by conduction $\frac{Q}{t} = k\frac{A(T_H - T_C)}{d}$

Thermal transmittance U-value $U = \frac{k}{d}$

Part A :

The following question marked with {SP} is the Sample Paper question of the new DSE Examination.

M1. {SP} Which of these actions reduces the heat gained in the summer by buildings in Hong Kong ?

A. Increase the OTTV values of the building envelop.
B. Apply solar films on windows to reduce solar heat gain.
C. Minimize internal heat gain from indoor activities.
D. Improve the air-tightness of the building envelope.

Part B :

The following question marked with {PP} is the Sample Paper question of the new DSE Examination.

M2. {PP} The table below shows the data of a house. Calculate the Overall Thermal Transfer Value of the house.

	Windows	Walls	Roof
Rate of heat transfer / W	6200	4400	8600
Total area / m^2	20	480	140

A. 30 W m^{-2}
B. 127 W m^{-2}
C. 310 W m^{-2}
D. 381 W m^{-2}

Part C :

The following question marked with { } is the past DSE question. The number inside the bracket represents the year of the examination.

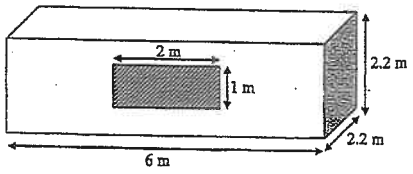
M3. {12} A container is modified into an office as shown. A window of 1 m × 2 m is installed on the front side of the container. Apart from the bottom, assume that all the five surfaces of the container are under sunlight. On all the five surfaces, the equivalent temperature difference between the interior and the exterior of the container is 7°C.

Given :

U-value of metallic material of the container = 26.2 W m^{-2} K^{-1}
U-value of glass of the window = 1.8 W m^{-2} K^{-1}

Estimate the Overall Thermal Transfer value (OTTV) in W m^{-2} of the container office.

A. 25.2
B. 26.2
C. 176.5
D. 183.4



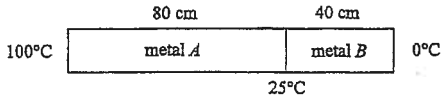
Part D :

The following questions are designed to give supplemental exercise for this chapter.

M4. The SI unit for thermal conductivity is

A. W m^{-1} K^{-1}
B. W m^{-2} K^{-1}
C. J m^{-2} K^{-1}
D. J kg^{-1} K^{-1}

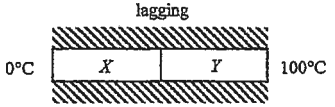
M5.



Two metal rods, *A* and *B*, have lengths 80 cm and 40 cm, identical cross-sectional areas and are joined end-to-end as shown in the above figure. One end of metal *A* is maintained at 100°C and the opposite end of metal *B* is kept in melting ice. When steady conditions have been reached with the bars well lagged, the temperature of the junction is found to be 25°C. The ratio of the thermal conductivity of metal *A* to that of metal *B* is

A. 1 : 6
B. 2 : 3
C. 3 : 2
D. 6 : 1

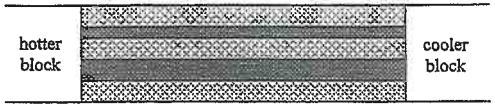
M6.



The above figure shows two rods of the same size made of two different materials *X* and *Y* placed end-to-end in thermal contact and heavily lagged at their sides. The outer ends of *X* and *Y* are kept at 0°C and 100°C, respectively. The conductivity of *X* is four times that of *Y*. The steady state temperature of the interface is

A. 20°C
B. 25°C
C. 50°C
D. 75°C

M7.



Two thermally conducting blocks are maintained at temperatures which differ by 20 K and are joined by two cylindrical bars of length 0.40 m and of thermal conductivity 25 W m^{-1} K^{-1}. The cross-sectional areas of the bars are 1 cm^2 and 4 cm^2 respectively. The remainder of the space between the blocks is filled with insulating materials as shown in the below figure.

The rate of heat flow between the two blocks is

A. 0.13 W
B. 0.25 W
C. 0.31 W
D. 0.63 W

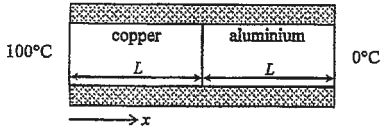
M8. The ends of a well-lagged cylindrical rod of a metal are maintained at temperatures T_1 and T_2, where $T_1 > T_2$. The rate of flow of heat across unit cross-sectional area of the rod at different points along the rod is

A. the same at all points.
B. proportional to the temperature at that point.
C. inversely proportional to the temperature at that point.
D. proportional to the distance of that point prom the hotter end.

M9. An unlagged cubic tank containing hot water loses heat to its surroundings at a rate of 900 W. This loss is reduced to 60 W if all the faces of the tank are covered with a layer of lagging. What will be the rate of loss of heat if one face is left unlagged ? (The temperatures of the water and surroundings are unaltered. You may assume that heat is lost only from the faces and that the rate of loss of heat from a face is unaffected by whether it is vertical or horizontal, top or bottom.)

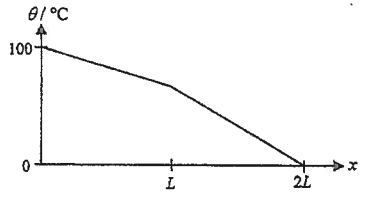
A. 210 W
B. 200 W
C. 190 W
D. 160 W

M10. A composite rod of uniform cross-section has copper and aluminium sections of the same length in good thermal contact. The ends of the rod, which is well-lagged, are maintained at 100°C and at 0°C as shown in the diagram below.

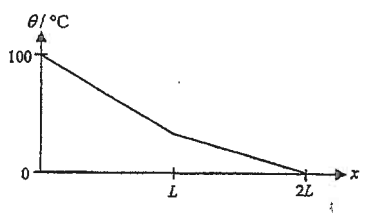


The thermal conductivity of copper is twice that of aluminium. Which one of the following graphs represents the variation of temperature θ with distance x along the rod in the steady state ?

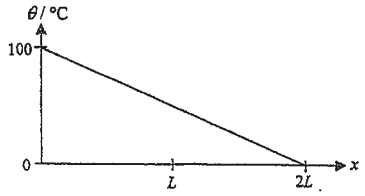
A.



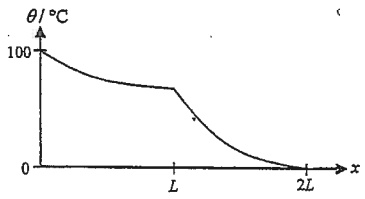
B.



C.



D.



M11. The SI unit for thermal transmittance is

A. $W\,m^{-1}\,K^{-1}$
B. $W\,m^{-2}\,K^{-1}$
C. $J\,m^{-2}\,K^{-1}$
D. $J\,kg^{-1}\,K^{-1}$

M12. Which of the following factors would affect the U-value of a building material ?

(1) the area of the building material
(2) the thickness of the building material
(3) the thermal conductivity of the building material

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M13. Which of the following factors would affect the rate of heat conduction through a building material ?

(1) the temperature difference across the building material
(2) the area of the building material
(3) the U-value of the building material

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M14. Which of the following factors would affect the thermal conductivity of a wall ?

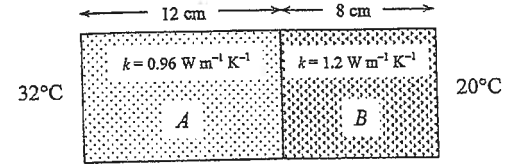
(1) the thickness of the wall
(2) the area of the wall
(3) the building material of the wall

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M15. A wall is made of a building material that has the thermal conductivity of 0.25 $W\,m^{-1}\,K^{-1}$. The area of the wall is 18 m^2 and the thickness of the wall is 16 cm. The outdoor temperature is 32°C. If the rate of heat transfer by conduction through the wall is 338 W, what is the indoor temperature ?

A. 18°C
B. 20°C
C. 22°C
D. 24°C

M16. A composite wall of cross-sectional area of 25 m^2 consists of two different materials A and B as shown below.



Calculate the rate of heat conduction through the wall.

A. 1280 W
B. 1560 W
C. 1640 W
D. 1920 W

M17. A wall of size 5 m × 6 m conducts heat at a rate of 380 W. The temperature across the wall is 7.5°C. What is the U-value of the wall ?

A. 1.1 $W\,m^{-2}\,K^{-1}$
B. 1.3 $W\,m^{-2}\,K^{-1}$
C. 1.5 $W\,m^{-2}\,K^{-1}$
D. 1.7 $W\,m^{-2}\,K^{-1}$

M18. If the U-value of a building material is 2.5 $W\,m^{-2}\,K^{-1}$ and the thickness of the material is 8 cm, find its thermal conductivity.

A. 0.2 $W\,m^{-1}\,K^{-1}$
B. 0.4 $W\,m^{-1}\,K^{-1}$
C. 0.6 $W\,m^{-1}\,K^{-1}$
D. 0.8 $W\,m^{-1}\,K^{-1}$

M19. Which of the following can lower the OTTV of a building envelop ?

A. Use a higher efficiency air-conditioning system.
B. Replace the incandescent lamps by fluorescent lamps.
C. Use an automatic control system to switch off the facilities if no one is there.
D. Install a sun shade to block the direct sunlight shining into the building.

M20. Which of the following would NOT affect the OTTV of a building ?

A. change the orientation of the building
B. increase the total area of windows
C. use building material with lower U-value
D. use heat pump to supply warm water

M21. In a certain building, the total area of walls is 5400 m^2 and the total area of windows is 800 m^2. If the average rate of heat transfer into the building through the walls is 18 $W\,m^{-2}$ and the average rate of heat transfer into the building through the windows is 86 $W\,m^{-2}$, calculate the OTTV of the building envelop.

A. 27 $W\,m^{-2}$
B. 30 $W\,m^{-2}$
C. 33 $W\,m^{-2}$
D. 36 $W\,m^{-2}$

M22. Which of the following windows can transmit the most visible light but block most infrared radiation ?

A. double glazing clear window
B. double glazing reflective window
C. double glazing low-e window
D. double glazing low-e reflective window

M23. In summer with outdoor temperature of 37°C, a wall of size 5 m × 3 m with thickness 30 cm conducts heat at a rate of 270 W when the indoor temperature is 25°C. Find the thermal transmittance U-value of the wall.

A. 0.45 $W\,m^{-2}\,K^{-1}$
B. 1.5 $W\,m^{-2}\,K^{-1}$
C. 3.0 $W\,m^{-2}\,K^{-1}$
D. 5.0 $W\,m^{-2}\,K^{-1}$

Answers

1. B	6. A	11. B	16. B	21. A
2. A	7. D	12. D	17. D	22. C
3. C	8. A	13. D	18. A	23. B
4. A	9. B	14. B	19. D	
5. B	10. A	15. B	20. D	

Solution

1. B

× A. Increase the OTTV values of the building envelop would increase the heat gained by the building.
✓ B. By applying solar films on windows, some infrared radiation would be blocked, thus the heat gained is reduced.
× C. The heat gained by buildings should be from the outside environment, not by inside activities.
× D. The air-tightness has no relation with the heat gained by buildings.

2. A

$$\text{OTTV} = \frac{Q/t}{A} = \frac{6200+4400+8600}{20+480+140} = 30\ W\,m^{-2}$$

3. C

Total area of the metallic material $= 6\times2.2\times3 + 2.2\times2.2\times2 - 2\times1 = 47.28\ m^2$

Rate of heat transfer through the metallic material $= UA(T_h - T_c) = (26.2)(47.28)(7) = 8671$ W

Area of the window $= 2\times1 = 2$ m

Rate of heat transfer through the window $= UA(T_h - T_c) = (1.8)(2)(7) = 25.2$ W

$$\text{OTTV} = \frac{Q/t}{A} = \frac{8671+25.2}{47.28+2} = 176.5\ W\,m^{-2}$$

4. A

$$\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$$

$\therefore$ unit of k : $W\,m^{-1}\,K^{-1}$

5. B

Since the heat flow by conduction through the two metals must be the same,

$$\text{As } \frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d} \quad \therefore\ k\frac{(T_{hot} - T_{cold})}{d} = \text{constant}$$

$$\therefore\ k_A\frac{(100-25)}{(80)} = k_B\frac{(25-0)}{(40)} \quad \therefore\ k_A : k_B = 2:3$$

6. A

Since the heat flow by conduction through the two metals must be the same,

by $\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$,

$k(T_{hot} - T_{cold})$ = constant ; since A and d are the same.

$\therefore$ $(4)(T_i - 0) = (1)(100 - T_i)$

$\therefore$ $T_i = 20°C$

7. D

$$\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$$

$$= (25)\frac{(1+4)\times10^{-4}(20)}{(0.40)} = 0.625\ W \approx 0.63\ W$$

8. A

Since the rod is well lagged, all the heat must flow along the rod,

thus the rate of heat flow across every point is the same.

9. B

The tank has 6 faces.

Rate of heat loss through each face = $(900 - 60)/6 = 140$ W

Rate of heat loss if one face is left unlagged = $140 + 60 = 200$ W

10. A

By $\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$

since copper has greater thermal conductivity,

thus the temperature difference across the copper is smaller.

11. B

$$\frac{Q}{t} = UA(T_{hot} - T_{cold})$$

the unit for U is $W\ m^{-2}\ K^{-1}$.

12. D

$$U = \frac{k}{d}$$

U-value should depend on

① thermal conductivity k (3) is correct

② thickness of the building material d (2) is correct

13. D

$$\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$$

The rate of heat conduction Q/t depends on :

① the U-value U

② the area A

③ the temperature difference across the material $(T_{hot} - T_{cold})$

14. B

Thermal conductivity of a wall depends on the building material only.

It is not affected by the thickness and area of the wall.

15. B

$$\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$$

$$\therefore (338) = (0.25)\times\frac{(18)(32 - T_{cold})}{(0.16)}$$

$\therefore$ $T_{cold} = 20°C$

16. B

Let the temperature of the interface be θ.

By $\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d}$ $\therefore$ $k\frac{(T_{hot} - T_{cold})}{d}$ = constant

$$\therefore (0.96)\frac{(32-\theta)}{(12)} = (1.2)\frac{(\theta - 20)}{(8)} \quad \therefore \theta = 24.2°C$$

$$\frac{Q}{t} = k\frac{A(T_{hot} - T_{cold})}{d} = (0.96)\frac{(25)(32 - 24.2)}{(0.12)} = 1560\ W$$

17. D

$$\frac{Q}{t} = UA(T_{hot} - T_{cold})$$

$$\therefore (380) = U(5\times6)(7.5)$$

$\therefore$ $U = 1.7\ W\ m^{-2}\ K^{-1}$

18. A

$$U = \frac{k}{d}$$

$$\therefore (2.5) = \frac{k}{0.08}$$

$\therefore$ $k = 0.2\ W\ m^{-1}\ K^{-1}$

19. D

Install a sun shade to block the direct sunlight can reduce the heat gained by the building, thus lower the OTTV.

20. D

✓ A. Change the orientation of the building would affect the amount of sunlight entering the building.

✓ B. Increase the total area of windows would increase the heat entering the building by radiation.

✓ C. Use building material with lower U-value can reduce the heat entering the building by conduction.

× D. The use heat pump inside a building does not affect the heat entering the building.

21. A

Average rate of transfer through the walls $= 18 \times 5400 = 97200$ W

Average rate of transfer through the windows $= 86 \times 800 = 68800$ W

$$\text{OTTV} = \frac{97200 + 68800}{5400 + 800} = 26.8 \text{ W m}^{-2} \approx 27 \text{ W m}^{-2}$$

22. C

× A. This type of window transmits both visible light and infrared radiation well.

× B. This type of window reflects and thus blocks both visible light and infrared radiation.

✓ C. This type of window selectively transmits visible light well and blocks infrared radiation well.

× D. This type of window blocks both visible light and infrared radiation.

23. B

$Q/t = UA(T_h - T_c)$

$\therefore (270) = U(5 \times 3)(37 - 25)$

$\therefore U = 1.5 \text{ W m}^{-2} \text{ K}^{-1}$

The following list of formulae may be found useful :

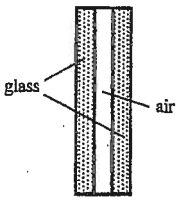
Rate of energy transfer by conduction $\quad \frac{Q}{t} = k\frac{A(T_H - T_C)}{d}$

Thermal transmittance U-value $\quad U = \frac{k}{d}$

Part A :

The following question marked with {PP} is the Practice Paper question of the new DSE Examination.

Q1. {PP} (a) The heat transfer through a window can be reduced by using double-glazed glass. The table below shows some information of two types of windows, both made from the same type of glass.

		
Type	Single layer	Double-glazed
Thickness	0.01 m	0.03 m (0.01 m for each layer)
Thermal transmittance U-value	5.7 W m^{-2} K^{-1}	2.8 W m^{-2} K^{-1}

(i) Suggest two reasons why the thermal transmittance of the double-glazed window is smaller than that of the single layer window. (2 marks)

(ii) On a hot sunny afternoon, the temperatures outside and inside a room are 36°C and 24°C respectively.

(1) If the double-glazed window is used in the room and the area of the window is 2 m^2, estimate the rate of heat transfer due to conduction through this window. (1 mark)

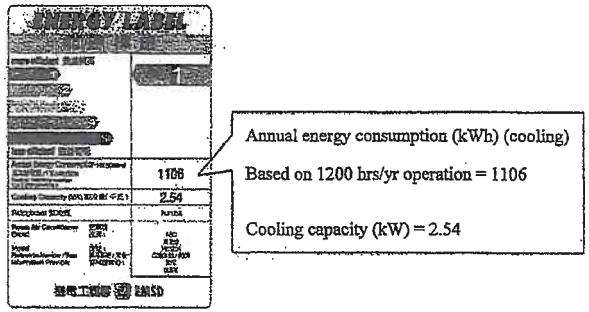
(2) Briefly explain whether the actual rate of heat transfer will be higher or lower than your answer in part (1) ? (2 marks)

(iii) Other than using double-glazed windows, suggest one method to reduce the heat flow through windows. (1 mark)

Q1. (b) An air-conditioner is installed in a room to keep the room cool.

(i) Briefly explain how the refrigerant in an air-conditioner absorbs heat from the room. (2 marks)

(ii) The energy label of the air-conditioner is shown in the Figure below.



Annual energy consumption (kWh) (cooling)

Based on 1200 hrs/yr operation = 1106

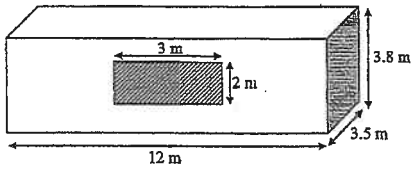
Cooling capacity (kW) = 2.54

Estimate the amount of heat that can be removed from the room by the air-conditioner in 5 minutes. (2 marks)

Part B :

The following questions are designed to give supplemental exercise for this chapter.

Q2.



The above figure shows the simplified sketch of a house. A window of 3 m × 2 m is installed on the front side of the house. Apart from the bottom, assume that all the five surfaces of the house are under sunlight. The temperature inside is kept at a constant value of 25°C. The outside temperature of the environment has an average value of 34°C.

Given :

U-value of building material of the house = 1.5 $W m^{-2} K^{-1}$

U-value of glass of the window = 4.2 $W m^{-2} K^{-1}$

Q2. (a) Calculate the rate of heat transfer through the walls of the building. (2 marks)

(b) Calculate the rate of heat transfer through the window. (2 marks)

(c) If the average thickness of the walls is 0.36 m, find the thermal conductivity of the walls. (2 marks)

(d) Hence, determine the overall thermal transfer value of the house. (2 marks)

(e) Suggest TWO methods to reduce the OTTV value of the house. (2 marks)

Q3. (a) Explain what is meant by thermal transmittance of a building material. (2 marks)

(b) State TWO factors that affect the thermal transmittance of a building material. (2 marks)

Q1. (a) (i) ① The air in the double-glazed glass has a much lower thermal transmittance than glass. [1]

OR

The air in the double-glazed glass is a poor conductor. [1]

② The double glazed glass is thicker than the single layer window. [1]

(ii) (1) $\frac{Q}{t} = UA(T_H - T_C)$

$= (2.8)(2)(36-24) = 67.2\ W$ [1]

(2) The actual rate of heat transfer is higher [1]

since heat can also be transferred by radiation through the window. [1]

(iii) Any ONE of the followings : [1]

* Use solar control window film
* Use reflective windows
* Use low-e windows
* Use drawing blinds

(b) (i) The refrigerant evaporates [1]

and absorbs latent heat of vaporization from the room. [1]

(ii) Heat that can be removed $= (2.54 \times 10^3) \times (5 \times 60)$ [1]

$= 7.62 \times 10^5\ J$ [1]

Q2. (a) Total area of the 4 walls and the roof :

$A = 12 \times 3.8 \times 2 + 12 \times 3.5 + 3.8 \times 3.5 \times 2 - 3 \times 2 = 153.8\ m^2$ [1]

$\frac{Q}{t} = UA(T_H - T_C)$

$= (1.5)(153.8)(34-25)$

$= 2076\ W$ <accept 2080 W> [1]

(b) $\frac{Q}{t} = UA(T_H - T_C)$

$= (4.2)(2 \times 3)(34-25)$ [1]

$= 227\ W$ <accept 226.8 W> [1]

(c) $U = \frac{k}{d}$

$\therefore (1.5) = \frac{k}{(0.36)}$ [1]

$\therefore k = 0.54\ W\ m^{-1}\ K^{-1}$ [1]

Q2. (d) OTTV $= \frac{Q/t}{A} = \frac{2076+227}{153.8+6}$ [1]

$= 14.4\ W\ m^{-2}$ [1]

(e) ① Any ONE of the followings : (accept other reasonable answers) [1]

* Decrease the U-value of the building material of the wall.
* Increase the thickness of the walls.

② Any ONE of the followings : (accept other reasonable answers) [1]

* Decrease the U-value of the windows
* Use double-glazed windows.
* Install solar control window film to the windows.
* Use reflective windows.
* Use low-e windows.

Q3. (a) Thermal transmittance is the rate of heat conduction through a unit cross-sectional area [1]

per unit temperature difference across the building material. [1]

(b) The thickness of the building material. [1]

The thermal conductivity of the building material. [1]

3.3 Energy efficiency in transport

Part A :

The following question marked with {SP} is the Sample Paper question of the new DSE Examination.

M1. Which of these is NOT an advantage of Battery Electric Vehicle ?

{SP} A. zero emission

B. low energy cost per kilometer covered

C. long mileage range

D. energy security by diversifying energy sources

Part B :

The following question marked with { } is the past DSE question. The number inside the bracket represents the year of the examination.

M2. Which sequence best describes the energy conversion in an electric vehicle's regenerative braking system during braking ?

{12} A. kinetic energy → electrical energy

B. kinetic energy → chemical energy

C. kinetic energy → chemical energy → electrical energy

D. kinetic energy → electrical energy → chemical energy

Part C :

The following questions are designed to give supplemental exercise for this chapter.

M3. Which of the following is/are the main components of the power system of an electric vehicle ?

(1) electric motor

(2) rechargeable battery pack

(3) combustion engine

A. (3) only
B. (1) & (2) only
C. (1) & (3) only
D. (1), (2) & (3)

M4. Which of the following is/are correct concerning an electric vehicle ?

(1) An electric vehicle is quieter in operation.

(2) An electric vehicle usually takes a long time for recharging of the battery pack.

(3) The motor of an electric vehicle can give much more power than a petrol engine.

A. (3) only
B. (1) & (2) only
C. (1) & (3) only
D. (1), (2) & (3)

M5. An electric vehicle uses Lithium-ion batteries that consumes about 2.25 MJ per each kilometre. If the range of the vehicle is 120 km for each full charging of batteries, and the cost of electricity is $1.05 per kWh, calculate the cost of electricity for each charging process.

A. $ 71
B. $ 75
C. $ 79
D. $ 84

M6. Which of the following are included on an Energy Label for petrol passenger cars ?

(1) urban fuel consumption

(2) highway fuel consumption

(3) estimated annual fuel consumption

A. (3) only
B. (1) & (2) only
C. (1) & (3) only
D. (1), (2) & (3)

M7. Which of the following concerning an electric-petrol hybrid car is/are correct ?

(1) The car has to go to the charging station regularly for charging of the battery inside the car.

(2) The regenerative brake converts part of the kinetic energy of the car into electrical energy by the generator.

(3) During acceleration, the engine and the motor work together to provide a large propulsion force.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M8. Which of the following are emissions produced by diesel vehicles ?

(1) carbon dioxide

(2) nitrogen oxides

(3) carbon monoxide

(4) hydrocarbons

(5) water vapour

(6) particulates

A. (1) & (5) only
B. (1), (5) & (6) only
C. (1), (2) & (6) only
D. All of the above

M9. What does LPG stands for ?

A liquid petrol gas
B. liquefied petroleum gasoline
C. liquid petroleum gas
D. liquefied petroleum gas

M10. A train travelling at a constant speed of 72 km per hour is carrying 200 passengers each with an average mass of 60 kg. What is the total kinetic energy of all the passengers ?

A. 240 kJ
B. 864 kJ
C. 4.8 MJ
D. 2.4 MJ

M11. Which of the following concerning MagLev is/are correct ?

(1) A MagLev train has zero emission in travelling.

(2) A MagLev train does not have to do work against air resistance.

(3) A MagLev train is one of the mass transportation system.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M12. Which of the following about a vehicle diesel engine is generally true ?

A. The burning of diesel inside the engine produces only carbon dioxide and water vapour.

B. Spark ignition is usually used.

C. Air is compressed to high temperature in the engine to ignite the diesel.

D. Diesel is burned to heat water to produce steam to drive the engine.

M13. What is the increase in gravitational potential energy for a bus of mass 15000 kg and carrying 50 people each with an average mass of 60 kg to climb up a hill of height 40 metres ? (Take the acceleration due to gravity to be 10 $m\ s^{-2}$.)

A. 18 MJ

B. 1800 MJ

C. 7.2 MJ

D. 7200 MJ

M14. What is currently the main fuel for taxis in Hong Kong ?

A. Petrol
B. Natural gas
C. LPG
D. Diesel

M15. Which of the following can promote mass transportation ?

(1) Set up the Bus-bus Interchange Scheme at some specific places.

(2) Set up the Park-and-ride Scheme at some specific railway stations.

(3) Give free ticket to passengers who have used the mass transportation for a certain number of times.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M16. Why should the mass transportation be promoted ?

(1) To improve the air quality of the city.

(2) To reduce the consumption of fossil fuels as they have limited supply.

(3) To reduce the traffic jam in the urban areas.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M17. Which of the following are true about diesel and petrol engines ?

(1) Diesel engine generally emits more particulates than petrol engine.

(2) Diesel engine generally uses compression ignition while petrol engine generally uses spark ignition.

(3) In Hong Kong, private cars mainly use petrol engines while lorries and buses mainly use diesel engines.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M18. Which of the following can help improve the energy efficiency of vehicles in Hong Kong ?

(1) Reduce congestion on roads.

(2) People using more mass transportation and less small scale transportation.

(3) People driving to work instead of using railway.

A. (2) only
B. (1) & (2) only
C. (1) & (3) only
D. (1), (2) & (3)

M19. Which of the following about a vehicle petrol engine is generally true ?

A. A spark plug is usually used for ignition.

B. The burning of petrol inside the engine produces only carbon dioxide and water vapour.

C. The petrol engine is a steam engine that uses petrol as fuel.

D. Compression ignition is usually used.

Answers

1. C	6. D	11. B	16. D
2. D	7. C	12. C	17. D
3. B	8. D	13. C	18. B
4. B	9. D	14. C	19. A
5. C	10. D	15. D	

Solution

1. C

✓	A.	Battery Electric vehicle does not emit gas pollutant.
✓	B.	The cost per kilometre is lower by using electricity from the power plant.
×	C.	Battery Electric Vehicle can only travel short range of distance before the next charging process.
✓	D.	By using the energy supply from the power plants that use different energy sources, energy sources can be diversified.

2. D

kinetic energy of the vehicle → electrical energy produced by the generator → chemical energy of the battery

3. B

An electric vehicle contains electric motor and rechargeable battery pack, but no combustion engine

4. B

✓	(1)	Since an electric vehicle does not contain combustion engine, it does not produce large noise.
✓	(2)	The battery pack takes a long time for each charging process.
×	(3)	Petrol engine is usually more powerful.

5. C

Total energy consumes for each charging $= 2.25 \times 10^6 \times 120 = 2.7 \times 10^8$ J

Cost of electricity $= \frac{2.7 \times 10^8}{3600 \times 1000} \times 1.05 = \$78.75 \approx \$79$

6. D

All the three information are included in the Label.

7. C

×	(1)	A hybrid car is charged by the generator inside the car and no need to go to the charging station.
✓	(2)	During braking, part of the kinetic energy of the car would drive the generator to charge the battery.
✓	(3)	When large force is required, the motor and the engine would work together.

8. D

A diesel combustion engine would produce all of the emissions from (1) to (6).

9. D

LPG is the short form of liquefied petroleum gas.

10. D

$KE = \frac{1}{2} m v^2 = \frac{1}{2} (200 \times 60) (72 \times \frac{1000}{3600})^2 = 2\,400\,000$ J $= 2.4$ MJ

11. B

✓	(1)	A MagLev train uses electricity and does not have emission in travelling.
×	(2)	As the train travels with high speed, large air resistance acts on the train, and work is done against it.
✓	(3)	A MagLev train can carry large number of passengers.

12. C

Diesel engine is also known as compression engine that uses compression to ignite the diesel.

13. C

$PE = m g h = (15000 + 50 \times 60) (10) (40) = 7\,200\,000$ J $= 7.2$ MJ

14. C

Nearly all taxis in Hong Kong are now using LPG for the fuel.

15. D

✓	(1)	People are more convenient to reach their destination by interchanging suitable route at the station.
✓	(2)	It is cheaper by using this scheme.
✓	(3)	It encourages people to use more mass transportation.

16. D

✓	(1)	By using mass transportation and reducing the use of private cars, less pollutant is emitted and thus the air quality can be improved.
✓	(2)	As less private cars are used, less fuel is consumed.
✓	(3)	As less private cars are on the road, traffic jam can be reduced.

17. D

✓	(1)	Diesel contains more pollutants.
✓	(2)	These are the ignition method of the two engines.
✓	(3)	Diesel engines are mainly used in commercial vehicles such as lorries and buses.

18. B

✓ (1) Congestion of roads would cause many vehicles to waste much energy in waiting.

✓ (2) Mass transportation is more energy efficient.

× (3) Driving to work consumes much fuel and thus not energy efficient.

19. A

Petrol engine uses spark ignition.

3.4 Non-renewable energy sources

Use the following data wherever necessary :

Avogadro constant	$N_A = 6.02 \times 10^{23}\ mol^{-1}$	
Speed of light in vacuum	$c = 3 \times 10^{8}\ m\ s^{-1}$	
Charge of an electron	$e = 1.60 \times 10^{-19}\ C$	
Electron rest mass	$m_e = 9.11 \times 10^{-31}\ kg$	
Atomic mass unit	$u = 1.661 \times 10^{-27}\ kg$	(1 u is equivalent to 931 MeV)

Part A :

The following question marked with {SP} is the Sample Paper question of the new DSE Examination.

M1. {SP} If each fission of uranium-235 liberates 200 MeV of energy, how much uranium-235 must undergo fission per second to generate a power of 1000 MW ?

A. 2.0×10^{-24} kg
B. 2.2×10^{-10} kg
C. 5.0×10^{-8} kg
D. 1.2×10^{-5} kg

Part B :

The following questions marked with {PP} are the Practice Paper questions of the new DSE Examination.

M2. {PP} The difference in mass between a uranium-238 nucleus and its constituent nucleons is 1.88482 u. Determine the binding energy per nucleon of a uranium-238 nucleus.

A. 2.08 MeV
B. 7.37 MeV
C. 448.59 MeV
D. 1754.77 MeV

M3. {PP} Which of the following is the function of the control rods in a fission reactor ?

A. They slow down neutrons.
B. They absorb neutrons.
C. They absorb heat from the reactor.
D. They transfer heat to the generator.

Part C :

The following question marked with { } is the past DSE question. The number inside the bracket represents the year of the examination.

M4. {12} What would happen if the moderator of a nuclear fission reactor fails to function ?

A. The chain reaction might stop eventually.
B. Neutrons cannot be absorbed by the moderator.
C. Heat cannot be transferred to the steam generator.
D. The fuel rods might melt down.

Part D :

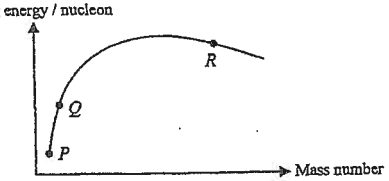
The following questions marked with [ ] are the past HKAL questions. The number inside the brackets represents the year of the examination.

M5. [81] Given : the mass of a proton is 1.6733×10^{-27} kg
the mass of a neutron is 1.6744×10^{-27} kg
the mass of an alpha particle is 6.6443×10^{-27} kg
the electronic charge e is -1.6×10^{-19} C
the speed of light in vacuum is $3.00 \times 10^{8}\ m\ s^{-1}$

The binding energy per nucleon in a helium nucleus is

A. 1.15×10^{-12} J
B. 2.30×10^{-12} J
C. 4.60×10^{-12} J
D. 1.44×10^{7} eV

M6. [83] The binding energy per nucleon varies with mass number as shown below:



If nuclear energy were to be generated by the fusion of the nuclei of an element X, which of the points P, Q and R would represent possible positions of X on the graph ?

(1) P
(2) Q
(3) R

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M7. [84] ^{3}He is an isotope of helium. Given that the masses of a proton, a neutron and a ^{3}He nucleus are 938.3 MeV/c^2, 939.6 MeV/c^2 and 2808.5 MeV/c^2 respectively, the binding energy of ^{3}He is

A. zero.
B. 7.7 MeV.
C. 9.0 MeV.
D. 930.6 MeV.

M8. [84] In a controlled thermal fission reactor, the function of the moderator is to reduce

A. the speed of the neutrons released on fission.
B. the rate of production of the neutrons.
C. the energy generated in the nuclear reactor.
D. the amount of radioactive radiation produced in the nuclear reactor.

M9. When fission occurs in a heavy nucleus, the two nuclei produced

[86] (1) are stable.

(2) contain more protons than neutrons.

(3) have more binding energy per nucleon than the original nucleus.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M10. In a controlled thermal fission reactor, the use of the control rods will NOT affect

[88] A. the speed of the neutrons released on fission.

B. the rate of production of the neutrons.

C. the energy generated in the nuclear reactor.

D. the amount of radioactive radiation produced in the nuclear reactor.

M11. A helium atom, a hydrogen atom and a neutron have masses of 4.003 u, 1.008 u and 1.009 u respectively. Assuming that
[89] hydrogen atoms and neutrons can fuse to form helium, the binding energy of a helium nucleus is

A. 0.0031 u.
B. 0.031 u.
C. 1.017 u.
D. 2.014 u.

M12. Which of the following statements concerning a moderator in a nuclear fission reactor is/are correct ?

[91] (1) It is used to slow down the neutrons released during fission.

(2) It is used to absorb excess neutrons.

(3) Boron steel is a suitable material.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M13. The main reason why a chain reaction can occur in a nuclear reactor using uranium is that

[92] A. a large quantity of energy is evolved in each fission.

B. the products of nuclear fission are highly radioactive.

C. plutonium is produced and it undergoes further fission.

D. neutrons are produced when a nucleus undergoes fission.

M14. Given : mass of proton = 1.0073 u
[94] mass of neutron = 1.0087 u
mass of $^{206}_{82}Pb$ = 205.969 u
1 u corresponds to 931 MeV

Find the binding energy per nucleon for a $^{206}_{82}Pb$ nucleus.

A. 7.46 MeV
B. 7.72 MeV
C. 12.39 MeV
D. 12.83 MeV

M15. Given : mass of proton = 1.0073 u
[96] mass of neutron = 1.0087 u
binding energy of an alpha particle = 28.396 MeV
1 u is equivalent to 931 MeV

The mass of an alpha particle is

A. 3.9100 u.
B. 4.0015 u.
C. 4.0320 u.
D. 4.0625 u.

M16. Which of the following statements about a typical nuclear reactor in a power plant are correct ?

[97] (1) The percentage of ^{235}U isotope in fuel rods is higher than that in natural uranium.

(2) Boron-coated steel rods are used to control the rate of neutron production.

(3) Pressurised water is used as coolant inside the reactor core.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M17. When several neutrons and protons come together to form a stable nucleus, which of the following statements is/are correct ?

[98] (1) Energy is released.

(2) The mass of the nucleus is smaller than the sum of the mass of the individual nucleons.

(3) In the nucleus, the electrostatic repulsion between two protons is overcome by the nuclear force between them.

A. (3) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

M18. In a nuclear reactor, the $^{235}_{92}U$ nucleus is fissioned by a neutron into two nuclei and a few neutrons are produced. Which of
[98] the following statements about this process is/are correct ?

(1) High energy neutrons are most likely to produce nuclear fission than low energy neutrons.
(2) Graphite can be used to absorb excess neutrons.
(3) The two nuclei produced have smaller neutron-to-proton ratios than that of the uranium nucleus.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

M19. Given : mass of proton = 1.0078 u
[01] mass of neutron = 1.0087 u
mass of deuteron $^{2}_{1}H$ = 2.0146 u
1 u is equivalent to 931 MeV

Calculate the binding energy per nucleon, in MeV, of a deuteron.

A. 9.5×10^{-4}
B. 1.9×10^{-3}
C. 8.8×10^{-1}
D. 9.4×10^{2}

M20. The following nuclear reaction represents the two deuterons, $^{2}_{1}H$, which combine to form a helium isotope, $^{3}_{2}He$, with the
[04] release of energy.

$$2\,^{2}_{1}H \rightarrow {}^{3}_{2}He + X + \text{energy}$$

Which of the following statements are correct ?

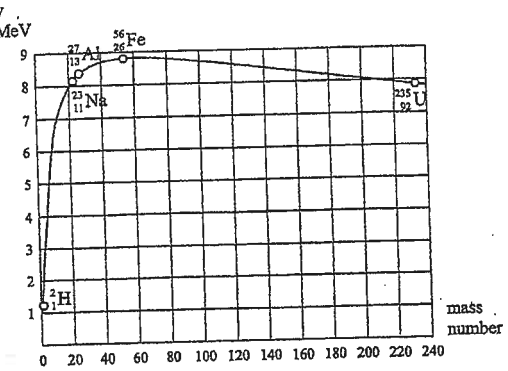
(1) This is an example of nuclear fusion.

(2) The total mass of $^{3}_{2}He$ and X is greater than that of the two $^{2}_{1}H$.

(3) X is a neutron.

A. (1) & (3) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

M21.
[08]



The diagram is a plot of binding energy per nucleon for a number of naturally occurring nuclides against their mass number.
Which of the following statements are correct ?

(1) Of the five nuclides plotted, $^{56}_{26}Fe$ is the most unstable.

(2) Comparing to $^{23}_{11}Na$, it takes more energy to split $^{27}_{13}Al$ into its individual nucleons.

(3) Energy is released if $^{235}_{92}U$ is spilt into two nuclei of comparable masses.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M22. A nucleus has mass number A, atomic number Z and binding energy of magnitude B (i.e. B is positive).
[08] Let m_n = mass of a neutron
m_p = mass of a proton
c = speed of light in vacuum
Which of the following expressions correctly gives the mass of the nucleus ?

A. $A\,m_n + Z\,m_p + \dfrac{B}{c^2}$

B. $A\,m_n + Z\,m_p - \dfrac{B}{c^2}$

C. $(A-Z)\,m_n + Z\,m_p + \dfrac{B}{c^2}$

D. $(A-Z)\,m_n + Z\,m_p - \dfrac{B}{c^2}$

M23. In a nuclear reaction, deuterium, $^{2}_{1}H$, fuses with tritium, $^{3}_{1}H$, to form a helium nucleus, $^{4}_{2}He$. Which statements are correct ?
[11] (1) $^{2}_{1}H$ and $^{3}_{1}H$ should possess high enough kinetic energy in order to overcome their repulsion and undergo fusion.

(2) A neutron is released in the reaction.

(3) The magnitude of the binding energy per nucleon of $^{4}_{2}He$ is greater than that of $^{2}_{1}H$ or $^{3}_{1}H$.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

Part E :

The following questions are designed to give supplemental exercise for this chapter.

M24. Which of the following is the advantage of nuclear power using uranium ?
A. The energy source is renewable.
B. It does not emit any greenhouse gas.
C. It has unlimited supply.
D. It does not cause adverse environmental impact.

M25. Which of the following about nuclear power generation is correct ?
A. It uses renewable energy source for electricity generation.
B. It does not cause any adverse impact to the environment.
C. Nuclear power stations do not have to be refuelled.
D. It does not require the burning of fossil fuels.

M26. The Guangdong Nuclear Power Station uses the fission of which nuclide as the energy source ?
A. polonium-210
B. uranium-235
C. uranium-238
D. plutonium-239

M27. Town gas contains which of the following ?
A. carbon particulates, hydrogen peroxide, propane, butane
B. carbon monoxide, nitrogen oxide, water vapour, methanol
C. carbon dioxide, nitrogen dioxide, sulphur dioxide, ethanol
D. carbon monoxide, hydrogen, methane, carbon dioxide

M28. Which of the following fraction of petroleum is used in Hong Kong to produce town gas ?
A. kerosene
B. diesel
C. naphtha
D. petrol

M29. Which of the following are true about fossil fuels ?
(1) They came from organisms living millions of years ago.
(2) They are non-renewable.
(3) Their consumption by humans causes pollution.
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M30. The common sources of energy used for domestic cooking in Hong Kong includes :
A. landfill gas, natural gas, town gas
B. natural gas, coal, kerosene
C. town gas, electricity, LPG
D. landfill gas, charcoal, hydrogen gas

M31. The 2002, the total amount of energy used by end-users in Hong Kong is about 283 922 terajoules. How many megajoule is a terajoule ?
A. 10 MJ
B. 1 billion MJ
C. 1000 MJ
D. 1 million MJ

M32. What happens inside the reactor core of a nuclear power plant for the release of energy ?
A. Uranium fuel rods and hydrogen are burnt inside the reactor core to release energy.
B. Hydrogen nuclei in the water combine to form heavier nucleus releasing energy.
C. Hydrogen is burnt inside the reactor core to release energy.
D. Uranium nucleus absorbs a neutron and split into two lighter nuclei with the emission of 2 or 3 neutrons and the release of energy.

M33. Which of the following is/are the disadvantage(s) of nuclear power ?
(1) If an accident happens in a nuclear power station, the consequences can be potentially very serious.
(2) The spent fuel is highly radioactive and needed to be handled with great care.
(3) Apart from spent fuel, nuclear power stations also produce low-level radioactive waste.
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M34. The electricity consumed in Hong Kong comes from which of the following sources ?
A. coal, natural gas, uranium
B. coal, hydrogen gas, LPG
C. town gas, landfill gas, uranium
D. naphtha, petrol, natural gas

M35. The common sources of energy used for land transportation in Hong Kong includes :
A. hydrogen gas, electricity, kerosene, natural gas
B. petrol, town gas, LPG, landfill gas
C. petrol, diesel, LPG, electricity
D. petrol, diesel, kerosene, natural gas

M36. The process for separating petroleum into different fractions is called :
A. fermentation
B. hydrogenation
C. fractional distillation
D. pasteurization

M37. Which of the following are all coming from fossil fuel ?
A. landfill gas, petrol, kerosene
B. coal, uranium, natural gas
C. town gas, natural gas, diesel
D. landfill gas, LPG, hydrogen gas

M38. What is the main energy source for electricity generation in Hong Kong ?
A. natural gas
B. uranium
C. coal
D. fuel oil

M39. If each fission of uranium-235 liberates 200 MeV of energy, how much uranium-235 must undergo fission per second to generate a power of 5000 MW ?
A. 1.0×10^{-23} kg
B. 1.1×10^{-9} kg
C. 2.6×10^{-7} kg
D. 6.1×10^{-5} kg

M40. Which of the following air pollutant(s) is/are emitted in a coal-fired power plant for generation of electricity ?
(1) carbon dioxide
(2) sulphur dioxide
(3) nitrogen oxides
A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

Answers

1. D	11. B	21. C	31. D
2. B	12. A	22. D	32. D
3. B	13. D	23. D	33. D
4. A	14. B	24. B	34. A
5. A	15. B	25. D	35. C
6. C	16. D	26. B	36. C
7. B	17. D	27. D	37. C
8. A	18. B	28. C	38. C
9. B	19. C	29. D	39. D
10. A	20. A	30. C	40. D

Solution

1. D

In 1 s, the energy generated is 1000 MJ.

Number of fission required $= \dfrac{1000\times10^{6}}{200\times10^{6}\times1.6\times10^{-19}} = 3.125\times10^{19}$

Number of mole of uranium-235 required $= \dfrac{3.125\times10^{19}}{6.02\times10^{23}} = 5.19\times10^{-5}$ mol

Mass of uranium-235 required $= 5.19\times10^{-5}\times235\times10^{-3} = 1.2\times10^{-5}$ kg

2. B

Binding energy $= 1.88482\times931 = 1754.77$ MeV

Binding energy per nucleon $= \dfrac{1754.77}{238} = 7.37$ MeV

3. B

Control rods are used to absorb neutrons,

thus control the rate of nuclear fission reaction.

4. A

The moderator is used to slow down the fast fission neutrons to increase the chance of capture by the U-235 nuclei.

If the moderator fails to function, the fast fission neutrons cannot be captured by the U-235 nuclei,

and thus chain reaction might stop eventually.

5. A

$(1.6733\times10^{-27})\times2 + (1.6744\times10^{-27})\times2 = 6.6443\times10^{-27}$ + mass defect

$\therefore$ Mass defect $= 5.11\times10^{-29}$ kg

$\therefore$ Binding energy = energy equivalent of mass defect $= mc^2 = (5.11\times10^{-29})\times(3\times10^{8})^2 = 4.599\times10^{-12}$ J

$\therefore$ Binding energy per nucleon $= \dfrac{4.599\times10^{-12}}{4} = 1.15\times10^{-12}$ J

$= \dfrac{1.15\times10^{-12}}{1.6\times10^{-19}}$ eV $= 7.19\times10^{6}$ eV

6. C

For fusion to be possible, energy must be released after the fusion.

Thus, the binding energy per nucleon of the element must increase after the fusion reaction

Moreover, after fusion, the mass number must increase.

From the graph, P and Q are possible but R is impossible.

7. B

$938.3\times2 + 939.6\times1 = 2808.5$ + mass defect

$\therefore$ mass defect $= 7.7$ MeV/c^2

Binding energy = energy equivalent of the mass defect $= mc^2 = (7.7\ \text{MeV}/c^2)(c^2) = 7.7$ MeV

8. A

Slow neutrons increase the chance of capture by the U-235 nuclei for fission to occur

9. B

× (1) The nuclei produced are not stable as they would then undergo radioactive decay.

× (2) For all nuclei except hydrogen H-1 or helium He-3, $n \geq p$.

✓ (3) Fission : energy is released ⇒ more stable ⇒ the product must have more binding energy per nucleon

10. A

Speed of fission neutrons is controlled by moderator.

Control rods would absorb the neutrons but cannot slow down the neutrons.

11. B

Mass defect of a helium atom $= 1.008\ \text{u}\times2 + 1.009\ \text{u}\times2 - 4.003 = 0.031$ u

Mass equivalent of the binding energy $= 0.031$ u

12. A

✓ (1) Properties of moderator

× (2) Properties of control rod

× (3) Moderator : made of graphite (Boron steel is used as control rods)

13. D

Neutrons can trigger the further fissions of the remaining U-235 nuclei, thus maintain the chain reaction

14. B

$1.0073 \times 82 + 1.0087 \times (206 - 82) = 205.969 + \text{mass defect}$ $\therefore$ mass defect $= 1.7084$ u

Binding energy per nucleon $= \dfrac{1.7084 \times 931}{206} = 7.72$ MeV

15. B

Mass equivalence $= \dfrac{28.396}{931} = 0.0305$ u

$1.0073 \times 2 + 1.0087 \times 2 = m_\alpha + 0.0305$

$\therefore\ m_\alpha = 4.0015$ u

16. D

✓ (1) The fuel rod has to be enriched with U-235 so that chain reaction can occur.

✓ (2) Boron steel rod : control rod $\Rightarrow$ control the number of fission neutrons

✓ (3) Water can carry large amount of heat when it is used as coolant

17. D

✓ (1) Forming a stable nucleus $\Rightarrow$ energy content decreases $\Rightarrow$ energy is released

✓ (2) Energy released $\Rightarrow$ mass decreases $\Rightarrow$ mass defect

✓ (3) There exists strong nuclear force between proton and proton inside the nucleus, which is much greater than the electrostatic repulsive force between two protons

18. B

× (1) High energy neutrons have too high speed and thus they are less likely to be captured by U-235. They need moderator to slow them down to increase the chance of capture.

× (2) Control rod, made of boron steel, is used to absorb excess neutrons. Graphite is used as moderator to slow down the neutrons

✓ (3) After fission, fission neutrons (may be 2 or 3) are emitted, thus the percentage of total number of neutrons in the two nuclei of the product is smaller than the percentage of neutrons in the U-235 nucleus.

19. C

Mass defect of a deuteron $= 1.0078 + 1.0087 - 2.0146 = 0.0019$ u

Energy equivalent of the mass defect = binding energy $= 0.0019 \times 931 = 1.7689$ MeV

Binding energy per nucleon of the deuteron $= 1.7689 / 2 = 0.88$ MeV

20. A.

✓ (1) Small nuclei ${}^{2}_{1}\mathrm{H}$ combining to form large nuclei ${}^{3}_{2}\mathrm{He}$ is a fusion process.

× (2) Since energy is released, there must be mass defect. Thus the total mass of the product should be smaller.

✓ (3) $2\ {}^{2}_{1}\mathrm{H} \rightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{X}$ $\therefore$ X is a neutron.

21. C

× (1) Since Fe-56 has the greatest binding energy per nucleon, it is the most stable.

✓ (2) Since Al-27 has greater binding energy per nucleon, it needs greater energy to split into the nucleons.

✓ (3) Energy is released in nuclear fission when U-235 is split.

22. D

Number of neutrons $= A - Z$ Number of protons $= Z$ mass equivalent of binding energy $= \dfrac{B}{c^2}$

Nucleus + binding energy $\rightarrow$ neutrons + protons

$\therefore$ Mass of nucleus $= (A-Z)\,m_n + Z\,m_p - \dfrac{B}{c^2}$

23. D

✓ (1) Due to their electrostatic repulsion, their speed or KE must be high enough for them to fuse.

✓ (2) ${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n}$

✓ (3) After fusion, energy is released and the product becomes more stable, thus the binding energy per nucleon is greater.

24. B

× A. Uranium has limited supply, not renewable.

✓ B. The use of uranium fuel for fission would not produce any greenhouse gas such as CO_2.

× C. Uranium would be used up eventually.

× D. To the environment, the public would worry about the leakage of radiation. The disposal of radioactive waste is also a problem.

25. D

By using nuclear source for power generation, there is no burning of fossil fuel.

26. B

Uranium-235 is used as the fuel source for fission to release energy for generation of electricity.

27. D

Town gas consists of hydrogen, methane, carbon dioxide and carbon monoxide, in descending order of proportion.

28. C

Naphtha is used to produce town gas.

29. D

✓ (1) Fossil fuels are the remains of plants or small animals living millions of years ago.

✓ (2) Fossil fuels have limited supply, they are not renewable.

✓ (3) The burning of fossil fuels give out many air pollutants.

30. C

Landfill gas (沼氣) is not used in domestic cooking in HK.

Natural gas is only used for generation of electricity, but not used in domestic cooking in HK.

Charcoal is not a common source, though some houses may still use it for cooking.

31. D

mega : $M = 10^6$

tera : $T = 10^{12}$

$1\ TJ = 10^6\ MJ$ = 1 million MJ

32. D

Nuclear power plant makes use of the fission of uranium for the release of energy to generate electricity.

33. D

✓ (1) Accident involving nuclear power plant is usually very serious, due to the widespread of radioactive substance to the environment.

✓ (2) The spent fuel is still highly radioactive, and has to be treated with great care.

✓ (3) The product produced in a nuclear plant include high level and low level radioactive wastes.

34. A

The power plants in HK use mainly coal.

Some systems use natural gas.

Part of the electricity used in HK is bought from the Daya Nuclear power plant which uses uranium as fuel.

35. C

Most private cars use petrol.

Lorries and buses use diesel.

Taxis and mini-buses use LPG.

MTR and KCR use electricity.

36. C

Fractional distillation can separate the crude oil into different fractions due to their different boiling points.

37. C

Town gas is made from naphtha, which is a fraction of petroleum, and petroleum is one of the fossil fuels.

Natural gas is one of the fossil fuel.

Diesel is one of the fraction of petroleum.

38. C

Most power plants in HK use coal as the fuel for power generation.

39. D

In 1 second, 5000 MJ of energy is generated.

Each U-235 nuclei can give out 200 MeV of energy.

Number of U-235 nuclei needed in 1 s $= \dfrac{5000\times10^6}{200\times10^6\times1.6\times10^{-19}} = 1.5625\times10^{20}$

Molar mass of U-235 is 235 g or 0.235 kg.

Mass of U-235 needed in 1 s $= \dfrac{1.5625\times10^{20}}{6.02\times10^{23}}\times 0.235 = 6.1\times10^{-5}$ kg

OR

Mass of one U-235 nuclei is about 235 u, and 1 u is equal to 1.661×10^{-27} kg

Mass of U-235 needed in 1 s $= 1.5625\times10^{20}\times235\times1.661\times10^{-27} = 6.1\times10^{-5}$ kg

40. D

By burning coal, the three pollutants would all be emitted.

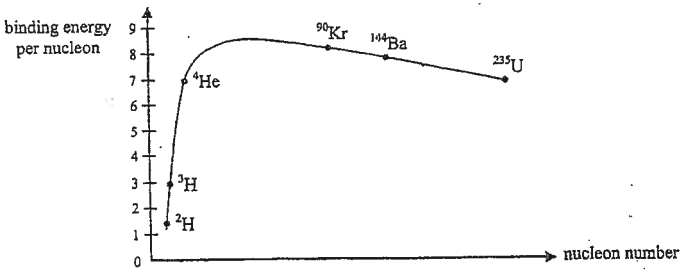
Use the following data wherever necessary :

Avogadro constant	$N_A = 6.02 \times 10^{23}\ mol^{-1}$	
Speed of light in vacuum	$c = 3 \times 10^{8}\ m\ s^{-1}$	
Charge of an electron	$e = 1.60 \times 10^{-19}\ C$	
Electron rest mass	$m_e = 9.11 \times 10^{-31}\ kg$	
Atomic mass unit	$u = 1.661 \times 10^{-27}\ kg$	(1 u is equivalent to 931 MeV)

Part A:

The following questions marked with [ ] are the past HKAL questions. The number inside the brackets represents the year of the examination.

Q1.
[90]



The figure above shows the variation of the average binding energy per nucleon with nucleon number.

(a) Consider the following 2 nuclear reactions :

Fission reaction : $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{144}_{56}Ba + {}^{90}_{36}Kr + 2\,{}^{1}_{0}n$

Fusion reaction : $^{2}_{1}H + {}^{2}_{1}H \longrightarrow {}^{3}_{2}He + {}^{1}_{0}n$

Explain, with reference to the Figure above, why these two reactions are possible. (2 marks)

(b) What is the significance of the two neutrons produced in the fission reaction ? (2 marks)

(c) Make a rough estimate of the energy (in MeV) released in the fission of a uranium-235 nucleus.

Given : Binding energy of $^{235}_{92}U$ = 7.50 MeV/nucleon

Binding energy of $^{144}_{56}Ba$ = 8.30 MeV/nucleon

Binding energy of $^{90}_{36}Kr$ = 8.65 MeV/nucleon (2 marks)

Q2. (a) The following equation represents a possible nuclear reaction in a fission reactor :

[93] $^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{91}_{36}Kr + {}^{142}_{56}Ba + 3\,{}^{1}_{0}n$

Given : the mass of one nucleus of $^{235}_{92}U$ = 235.0439 u,

$^{1}_{0}n$ = 1.0087 u,

$^{91}_{36}Kr$ = 90.9234 u,

$^{142}_{56}Ba$ = 141.9164 u,

(i) According to the above equation, what is the mass defect between the reactants and products when one $^{235}_{92}U$ nucleus undergoes fission ? (2 marks)

(ii) If 4.00×10^{-5} kg of $^{235}_{92}U$ splits per second, calculate the rate of energy production. (3 marks)

(b) Explain how energy can be extracted from the core of a fission reactor for producing electricity. (3 marks)

Q3. A reaction which takes place in the core of a nuclear reactor is described by the following equation :

[98] $^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{142}_{56}Ba + {}^{91}_{36}Kr + 3\,{}^{1}_{0}n + 174.4\ MeV$

Mass of one nuclide of $^{235}_{92}U$ = 235.0439 u

Mass of one nuclide of $^{142}_{56}Ba$ = 141.9164 u

Mass of one nuclide of $^{91}_{36}Kr$ = 90.9234 u

(a) The fuel rods in the reactor contain 1.0×10^{4} kg of U-235 isotope. Calculate the total energy released from the complete fission of all the U-235 nuclei in the fuel rods. (3 marks)

Q3. (b) If the mean power output of the reactor is 500 MW and the efficiency of conversion of nuclear energy to electrical energy is 40%, estimate the time for which the fuel rods can be used. (2 marks)

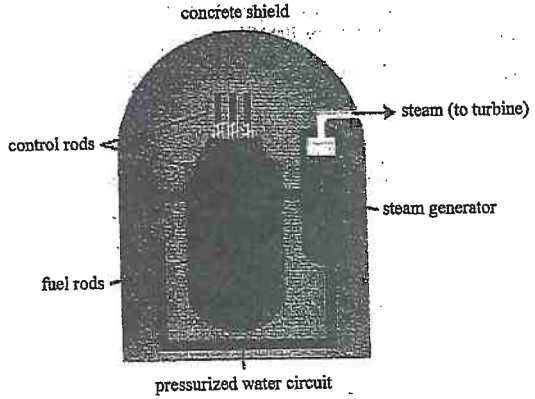
(c) Explain why the fuel rods are usually replaced well before the time estimated in (b) has elapsed. (2 marks)

(d) In an emergency, explain how the reactor can be shut down immediately. (2 marks)

Part B :

The following question is designed to give supplemental exercise for this chapter.

Q4. The figure below shows a fission reactor used to generate electrical energy by fission of uranium-235.



(a) (i) State the meaning of the binding energy of a nucleus. (1 mark)

Q4. (a) (ii) The binding energy of the nucleus $^{235}_{92}U$ is found to be 7.391 MeV/nucleon. Calculate the mass of one nucleus of $^{235}_{92}U$, in atomic mass unit. Give your answer to three decimal places. (2 marks)

Given : mass of a proton = 1.00728 u ; mass of a neutron = 1.00867 u

(b) One of the possible fission reaction of U-235 is given by the following equation :

$$^{235}_{92}U + {}^{1}_{0}n \longrightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3\,{}^{1}_{0}n$$

Given : Mass of one nucleus of $^{141}_{56}Ba$ = 140.917 u ; mass of one nucleus of $^{92}_{36}Kr$ = 91.923 u.

(i) There are three fission neutrons released in each fission of U-235 nuclide. What is the importance of these fission neutrons ? (1 mark)

(ii) Calculate the energy release in the fission of one U-235 nucleus, express your answer in joule. (2 marks)

(iii) Hence calculate the total energy that can be released from the complete fission of 1 kg of pure U-235 fuel rod. (2 marks)

(c) In the above fission reactor, the total mass of pure U-235 in the fuel rods is 1200 kg. The fuel rods have to be replaced once a year. The mean power output of the reactor is 700 MW.

(i) What is the efficiency of conversion of nuclear energy to electrical energy ? (2 marks)

(ii) Moderator has to be put into the reactor in practice. What is the function of the moderator ? (1 mark)

(iii) In case of emergency, what action should be taken to shut down the reactor ? (1 mark)

(d) Do you support the development of nuclear energy ? Give TWO reasons for your answer. (2 marks)

Q1. (a) The two reactions produce nuclides with more binding energy per nucleon than the original ones. [1]
Energy is released during the process and the resulting nuclides are more stable. [1]

(b) The fission neutrons are significant to cause further fission of the other U-235 nuclei [1]
so that the 'chain reaction' can continue. [1]

(c) Energy released = $(8.30 \times 144 + 8.65 \times 90 - 7.50 \times 235)$ [1]
= 211.2 MeV [1]

Q2. (a) (i) Mass defect = $(235.0439\text{ u} + 1.0087\text{ u}) - (90.9234\text{ u} + 141.9164\text{ u} + 3 \times 1.0087\text{ u})$ [1]
= 0.1867 u [1]

(ii) Number of U-235 nuclei split per second = $\dfrac{4.00\times10^{-5}}{235.0439\times1.661\times10^{-27}} = 1.0246 \times 10^{20}$ [1]

Rate of energy production = $[0.1867 \times 1.661 \times 10^{-27} \times (3 \times 10^8)^2] \times (1.0246 \times 10^{20})$ [1]
= 2.86×10^9 W [1]

OR

Rate of energy production = $[0.1867 \times 931 \times 10^6 \times 1.6 \times 10^{-19}] \times (1.0246 \times 10^{20})$ [1]
= 2.85×10^9 W [1]

(b) The gas coolant absorbs heat as it flows around the reactor core, and [1]
the thermal energy is transferred to the water which is then converted to steam. [1]
The turbine is then driven by steam to rotate and drive the generator to produce electricity. [1]

Q3. (a) Number of U-235 nuclei = $\dfrac{1.0\times10^4}{235.0439\times1.661\times10^{-27}} = 2.561\times10^{28}$ [1]

Energy released = $2.561 \times 10^{28} \times 174.4$ MeV [1]
= 4.47×10^{30} MeV <OR 7.15×10^{17} J> [1]

(b) Time = $\dfrac{4.47\times10^{30}\times10^6\times1.6\times10^{-19}\times0.4}{500\times10^6}$ [1]
= 5.72×10^8 s <OR 1.59×10^5 hours or 6620 days or 18.1 years> [1]

(c) The percentage of U-235 in the fuel rods will decrease as time goes on. [1]
Chain reaction cannot be maintained when the concentration of U-235 is below a certain level. [1]

(b) Insert all the control rods into the reactor core [1]
so as to absorb all the fission neutrons. [1]

Q4. (a) (i) Binding energy of a nucleus is the energy required to completely separate all the nucleons in the nucleus. [1]

(ii) Mass defect in forming a nucleus of $^{235}_{92}U$ = $7.391 \times 235 \times \dfrac{1}{931} = 1.8656$ u [1]

Mass of one nucleus of $^{235}_{92}U$ = $(235 - 92) \times 1.00867 + 92 \times 1.00728 - 1.8656 = 235.044$ u [1]

(b) (i) The fission neutrons ensure that the chain reaction can be sustained. [1]

(ii) Mass defect : $\Delta m = 235.044 - 140.917 - 91.923 - 2 \times 1.00867 = 0.18666$ u [1]

Energy released : $E = 0.18666 \times 931 \times 10^6 \times 1.6 \times 10^{-19} = 2.78 \times 10^{-11}$ J [1]

OR

Energy released : $E = 0.18666 \times 1.661 \times 10^{-27} \times (3 \times 10^8)^2 = 2.79 \times 10^{-11}$ J [1]

(iii) Number of U-235 nuclei = $\dfrac{1}{235.050\times1.661\times10^{-27}} = 2.5614 \times 10^{24}$ [1]

Total energy released = $2.5614 \times 10^{24} \times 2.78 \times 10^{-11} = 7.12 \times 10^{13}$ J <accept 7.15×10^{13} J> [1]

(c) (i) Total nuclear energy that can be released = $1200 \times 7.12 \times 10^{13} = 8.54 \times 10^{16}$ J <accept 8.58×10^{16} J>

Total electrical energy generated = $700 \times 10^6 \times 1 \times 365 \times 24 \times 3600 = 2.21 \times 10^{16}$ J [1]

Efficiency = $\dfrac{2.21}{8.54} \times 100\% = 25.9\%$ <accept 25.5% to 26.1%> [1]

(ii) Moderator is used to slow down the fission neutrons
so as to increase the probability of neutron capture by the U-235 nuclei. [1]

(iii) All the control rods would be inserted into the reactor
to absorb all the fission neutrons and stop all the reactions. [1]

(d) I support with reasons : (any TWO) [1 + 1]

* Nuclear energy does not produce air pollution, thus cause less harm to our environment.
* Nuclear energy provides an alternative source of energy since fossil fuel has limited supply.
* Nuclear energy does not release greenhouse gases, thus reduce the global warming of the earth.
* The running cost of a nuclear power plant is lower, thus nuclear energy is cheaper.

OR

I do not support with reasons : (any TWO) [1 + 1]

* Once accident occurs in nuclear power plant, it would be very serious.
* The capital investment of nuclear power plant is very high.
* The disposal of radioactive waste causes a serious problem.
* There are still other sources of renewable energy that can be developed.

3.5 Renewable energy source

Use the following data wherever necessary :

Speed of light in vacuum $c = 3 \times 10^8 \text{ m s}^{-1}$

Acceleration due to gravity $g = 9.81 \text{ m s}^{-2}$

The following list of formulae may be found useful :

Maximum power by wind turbine $P = \frac{1}{2}\rho A v^2$

Part A :

The following questions marked with {SP} are the Sample Paper questions of the new DSE Examination.

M1. {SP} The solar constant is 1367 W m^{-2} (power per unit area from the Sun reaching the outer atmosphere) and the Earth-Sun distance is 1.50×10^{11} m (i.e. 1 AU), estimate the total radiation power of the Sun.

A. 3.9×10^{26} W
B. 3.2×10^{25} W
C. 2.3×10^{25} W
D. 7.7×10^{24} W

M2. {SP} In estimating the maximum power available from a wind turbine, what is assumed to be true ?

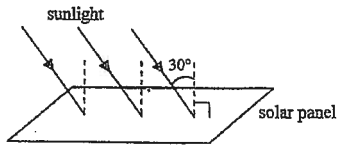
(1) The density of air is constant.
(2) The direction of wind relative to the orientation of the turbine is unchanged.
(3) The area swept by the turbine is constant.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

Part B :

The following questions marked with {PP} are the Practice Paper questions of the new DSE Examination.

M3. {PP} Estimate the electrical power output of a 20 m^2 solar panel when it is illuminated with sunlight of intensity 1 kW m^{-2} at an angle of 30° to the vertical. Given : efficiency of the solar panel = 12%



A. 1200 W
B. 1386 W
C. 2078 W
D. 2400 W

M4. {PP} A wind turbine has an overall efficiency of 30% and its output power is 360 kW when the wind blows normally at the turbine with a constant velocity of 10 m s^{-1}. Find the length of the blades of the wind turbine. Given : density of air = 1.2 kg m^{-3}

A. 4.1 m
B. 7.6 m
C. 13.8 m
D. 25.2 m

Part C :

The following question marked with { } is the past DSE question. The number inside the bracket represents the year of the examination.

M5. {12} The blades of a wind turbine are 5 m long, which are set to rotate when wind blows normally at 12 m s^{-1}. The overall efficiency of the wind turbine is 25%. Estimate the number of wind turbines required to generate an electrical power output of 1 MW.
Given : density of air = 1.2 kg m^{-3}.

A. 12
B. 49
C. 122
D. 196

M6. {12} The difference in water levels of a hydroelectric power plant is 50 m. Water passes through the turbine of the power plant at the lower water level at a rate of 3000 kg s^{-1}. Estimate the efficiency of the turbine if its output power is 1 MW.

A. 32%
B. 60%
C. 68%
D. 75%

Part D :

The following question marked with [ ] is the past HKAL question. The number inside the bracket represents the year of the examination.

M7. [06] The intensity of the solar radiation falling normally on the earth's surface due to the overhead sun is about 500 W m^{-2}. It is known that about $\frac{2}{3}$ of the solar radiation reaching the earth is absorbed by the atmosphere. Estimate the total power output of the sun. (Given : earth - sun separation = 1.5×10^8 km)

A. 1×10^{20} W
B. 4×10^{20} W
C. 1×10^{26} W
D. 4×10^{26} W

Part E :

The following questions are designed to give supplemental exercise for this chapter.

M8. Which of the following can be classified as renewable energy ?

(1) tidal energy
(2) wind energy
(3) nuclear energy

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M9. Which of the following energy sources is/are due to the origin of solar radiation ?

(1) wind energy
(2) hydroelectric energy
(3) tidal energy

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M10. Which of the following would affect the amount of solar radiation falling on the surface of the Earth's surface ?

(1) the latitude of the place
(2) the altitude of the place
(3) weather of the day

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M11. Which of the following areas are the solar cells being used in Hong Kong ?

(1) street lamp systems
(2) weather stations
(3) artificial satellites

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M12. What facilities are installed to increase the solar radiation absorbed by a solar cell panel ?

(1) A tracking system rotates the solar panel to face the Sun.
(2) Lenses are used to concentrate direct sunlight to the effective area of the solar cells.
(3) There is an anti-reflection coating on the top of the solar cell.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M13. Which of the following statements concerning a solar cell is NOT correct ?

A. The electric field in the p-n junction of the solar cell directs from the p-type to the n-type.
B. When light is incident on the p-n junction of the solar cell, pairs of electrons and holes are created.
C. The holes act as positive charges and move in the direction of the electric field.
D. The free electrons move in the opposite direction of the electric field.

M14. In a hydroelectric power plant, water falls for 120 m at a rate of 240 kg per second pass the turbine generator, what is the electrical power generated by the generator. Assume an overall energy conversion efficiency of 84%.

A. 148 kW
B. 237 kW
C. 368 kW
D. 584 kW

M15. Which of the following concerning the flat-plate collector of a solar heater is/are correct ?

(1) Large number of flow tubes is used to increase the thermal contact with the absorber plate.
(2) The absorber plate has white colour to reduce the emission of radiation.
(3) The heat insulating box can reduce heat loss to the surroundings by conduction and by convection.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M16. A solar furnace consists of thousands of mirrors to track the sunlight and produces a very high temperature to heat water into steam, which then used to drive turbine generators to give out electricity. What is/are the disadvantage(s) of using solar furnace for generation of electricity ?

(1) The output is not steady.
(2) The furnace requires a very large land area to place the thousands of mirrors.
(3) The capital cost of building the furnace is very high.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M17. Which of the following concerning the concentrating collector of a solar heater is/are correct ?

(1) The concave reflectors can reflect sunlight to the receiver.
(2) The receiver is placed at the focal line of the reflectors.
(3) The collector is controlled by a tracking system to follow the direct sunlight..

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M18. Which of the following can increase the efficiency of a solar cooker ?

(1) The reflector is covered with aluminium foil to increase the reflection of solar radiation.
(2) The metal container is painted black to increase the absorption of solar radiation.
(3) The container is placed inside a sealed glass bottle to reduce heat loss by conduction and convection.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M19. Which of the following is/are the advantage(s) of using hydroelectric power ?

(1) It has unlimited supply.
(2) It would not cause global warming.
(3) It would not have any adverse impact on the environment.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M20. Take the solar constant as 1360 W m^{-2}, and assuming that on average this is reduced to 42% due to the absorption in the atmosphere, calculate the total solar energy arriving at the land of Hong Kong in an hour at the noon, if the total land area of Hong Kong is about 1100 km.

A. 2.3×10^{15} J
B. 3.6×10^{15} J
C. 4.6×10^{15} J
D. 6.2×10^{15} J

M21. Which of the following is NOT the advantage of promoting solar cookers in development countries ?

A. Solar cooking produces no smoke and no pollution.
B. Plenty trees can be saved by using solar cookers.
C. Solar cookers can cook food faster than induction cookers.
D. By using solar cooking, children can be relieved from the infections of respiratory sickness.

M22. Which of the following is NOT the application of solar heating ?

A. To heat water.
B. To warm buildings.
C. To cook food.
D. To generate electricity.

M23. A wind turbine gives out an electrical power of 200 W for a certain wind speed. What would be the power output if the speed of wind is doubled ?

A. 400 W
B. 600 W
C. 800 W
D. 1600 W

M24. The blades of a wind turbine have lengths of 20 m each. The overall efficiency of the wind turbine is 35%. Density of air is 1.3 kg m^{-3}. What is the electrical power output when wind blows normally at an average speed of 12 m s^{-1} ?

A. 268 kW
B. 494 kW
C. 682 kW
D. 857 kW

M25. What is the approximate efficiency of commercial photovoltaic cells currently ?

A. around 1%
B. around 20%
C. around 50%
D. nearly 100%

M26. Which of the following is/are the adverse effect of mining to extract fossil fuels from underground ?

(1) Mining may involve deforestation.
(2) Mining may emit greenhouse gases.
(3) Mining may affect the habitat for wildlife.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M27. Which of the following consequence may result due to global warming ?

(1) The icebergs at North Pole would melt.
(2) The sea level would rise.
(3) The magnetic field of the Earth may change.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M28. Which of the following way can reduce the global greenhouse effect ?

(1) Save electricity.
(2) Use mass transportation instead of driving.
(3) Plant more trees.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M29. Solar water heater with parabolic reflector can heat water to a higher temperature than solar water heater with flat plate collector because

A. energy coming from the sun can be focused by the parabolic reflector.
B. the parabolic reflector eliminates heat lost from the heated water.
C. the parabolic reflector reflects all the infrared radiation emitted from the heated water back to the water.
D. the parabolic reflector focuses the infrared radiation from the sun while letting the visible light to pass through.

M30. Which of the following about current photovoltaic cells is/are true ?

(1) Photovoltaic cells can convert infrared radiation into electrical energy.
(2) Photovoltaic cells can convert visible light into electrical energy.
(3) Photovoltaic cells can convert ultraviolet radiation into electrical energy.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M31. Which of the following about application of solar electricity in Hong Kong is / are true ?

(1) Hong Kong does not have any solar panels.
(2) The Hong Kong Observatory uses solar panels to provide electricity for weather stations.
(3) Solar panels are installed in government and as well as private buildings in Hong Kong.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

M32. A windmill is used to raise water from a well. The depth of the well is 12 m. The windmill raises 270 kg of water every day. What is the useful power extracted from the wind ?

A. 0.368 W
B. 0.938 W
C. 9.375 W
D. 135 W

Answers

1. A	6. C	11. D	16. D	21. C	26. B	31. C
2. D	7. D	12. D	17. D	22. D	27. A	32. A
3. C	8. A	13. A	18. D	23. D	28. D	
4. D	9. A	14. B	19. A	24. B	29. A	
5. B	10. D	15. B	20. A	25. B	30. D	

Solution

1. A

Total radiation power of the Sun $= 1367 \times 4\pi \times (1.5 \times 10^{11})^2 = 3.9 \times 10^{26}$ W

2. D

✓ (1) The density of air ρ is assumed constant to give the constant maximum power.

✓ (2) The direction of wind is assumed constant, otherwise, the maximum power would change.

✓ (3) The area swept by the turbine A is assumed constant to give the constant maximum power.

3. C

$P = 1 \times 10^3 \times \cos 30° \times 20 \times 12\% = 2078$ W

4. D

$P = \frac{1}{2} \rho A v^3 \times 30\%$

$(360 \times 10^3) = \frac{1}{2} (1.2) (\pi r^2) (10)^3 \times 30\%$

$r = 25.2$ m

5. B

$P = \frac{1}{2} \rho A v^3 \times 25\% \times n$

$(1 \times 10^6) = \frac{1}{2} (1.2) \times \pi (5)^2 \times (12)^3 \times 25\% \times n$

$n = 49.2 \approx 49$

6. C

$P_{in} = \frac{m}{t} g h = (3000) (9.81) (50) = 1.47 \times 10^6$ W

Efficiency : $\eta = \frac{P_{out}}{P_{in}} = \frac{1 \times 10^6}{1.47 \times 10^6} \times 100\% = 68\%$

7. D

Intensity of solar radiation reaching the top of atmosphere $= 500 \times 3 = 1500$ W m^{-2}

Total power output of the sun $= 1500 \times 4\pi \times (1.5 \times 10^{11})^2 = 4.24 \times 10^{26}$ W $\approx 4 \times 10^{26}$ W

8. A

Tidal energy and wind energy are renewable.

Nuclear energy is not renewable.

9. A

✓ (1) The sun heats the air, warm air rises up, the convection of air then gives the wind.

✓ (2) The sun evaporates the water in oceans to form clouds, the clouds give rain, and the rain water at high level runs down to give hydroelectric energy.

× (3) Tidal energy is due to the gravitational attraction force of the Moon and the self-rotation of the Earth.

10. D

✓ (1) Different latitude would receive different sunlight, the latitude closer to the equator would receive more.

✓ (2) Places at different altitude absorb different amount of sunlight.

✓ (3) Weather of the day would affect the sunlight, as cloudy days have little sunlight.

11. D

✓ (1) Some street lamp systems use solar cells to absorb sunlight to give out electricity, which then stored in batteries and to be used at night.

✓ (2) The weather stations at some remote places where electricity is not available, solar cells are used.

✓ (3) Artificial satellites use solar cells for its operation in space.

12. D

✓ (1) The tracking system helps to absorb direct sunlight.

✓ (2) Lenses can converge and concentrate sunlight to the effective area of the solar cells.

✓ (3) The anti-reflecting coating can increase the absorption of the solar radiation.

13. A

× A. The electric field in the p-n junction of the semiconductor should direct from n-type to p-type.

✓ B. Light gives energy to create the pairs of electrons and holes.

✓ C. The holes are treated as positive charges and movable along the direction of the electric field.

✓ D. The free electrons are negatively charged, thus move in the opposite direction of the electric field.

14. B

$\frac{m}{t} = 240$ kg s^{-1}

$P_{out} = \frac{m g h}{t} \times \eta = (240) \times (9.81) (120) \times 84\% = 237$ kW

15. B

✓ (1) Large number of flow tubes can increase the thermal contact areas.

× (2) The absorber plate should be dark in colour to absorb more radiation as black colour is a good absorber.

✓ (3) The box can reduce heat lost to the surroundings when the water is heated up to a higher temperature.

16. D

✓ (1) When there is no sunlight in cloudy or rainy days, the furnace cannot operate.

✓ (2) Large area is needed to place thousands of mirrors for collecting sunlight.

✓ (3) The building of equipments is expensive.

17. D

✓ (1) The reflectors are concave in shape for collecting and reflecting sunlight.

✓ (2) The sunlight would be reflected to the focus at the focal plane, thus the receiver is placed there.

✓ (3) The tracking system can absorb more direct sunlight to increase its power output.

18. D

✓ (1) Aluminium has silvery surface to increase the reflection of solar radiation.

✓ (2) Black colour body is good absorber.

✓ (3) The sealed bottle can reduce heat lost to the surroundings.

19. A

✓ (1) Hydroelectric power is a renewable energy source that has unlimited supply.

✓ (2) The use of hydroelectric power would not give out greenhouse gases to cause global warming.

× (3) The building of dam causes many environmental problems.

20. A

Intensity of solar radiation on the Earth's surface $= 1360 \times 42\% = 571.2\ \text{W m}^{-2}$

Total solar energy arriving at the Hong Kong land in 1 s $= 571.2 \times 1100 \times 10^6 = 6.28 \times 10^{11}\ \text{W}$

Total solar energy arriving at the Hong Kong land in 1 hour $= 6.28 \times 10^{11} \times 3600 = 2.3 \times 10^{15}\ \text{J}$

21. C

✓ A. Solar cooking does not use fossil fuels, thus no smoke and polluted air are emitted.

✓ B. If solar cookers are used instead of burning trees or charcoals, plenty trees can be saved.

× C. Solar cookers cook food much slower, as it takes a long time to accumulate the energy of the sunlight.

✓ D. Burning woods give out smoke and poisonous gases that infects the respiratory system of children.

22. D

Generation of electricity is by solar cells.

23. D

By $P = \frac{1}{2}\rho A v^3 \times \eta$

$\therefore P \propto v^3$

$\therefore P = 200 \times 2^3 = 1600\ \text{W}$

24. B

$P = \frac{1}{2}\rho A v^3 \times \eta = \frac{1}{2}(1.3)(\pi \times 20^2)(12)^3 \times 35\% = 4.94 \times 10^5\ \text{W} = 494\ \text{kW}$

25. B

Photovoltaic cells have efficiency of about 10% to 20%.

26. B

✓ (1) The extraction of fuels from underground has to remove the trees for the installation of large machines..

× (2) The mining process does not emit greenhouse gases.

✓ (3) The mining process may disturb the wildlife habitat.

27. A

✓ (1) When the temperature of the Earth increase, more ice at the North pole would melt.

✓ (2) Due to the melting of ice into water, the sea level would rise.

× (3) Global warming does not affect the magnetic field of the Earth.

28. D

✓ (1) By saving electricity, less fossil fuels are used, thus less greenhouse gases are produced.

✓ (2) Use mass transportation can save energy, thus save fossil fuels.

✓ (3) Plant more trees can help to absorb and reduce carbon dioxide which is a greenhouse gas.

29. A

More sunlight can be focused to the receiver, thus the temperature can be higher.

30. D

Infrared radiation, visible light and ultraviolet radiation can all be converted into electrical energy by solar cells.

31. C

× (1) Many solar panels have been used in Hong Kong buildings.

✓ (2) The weather stations in remote areas where no electricity can reach use solar cells to provide electricity.

✓ (3) More and more buildings are designed to make use of solar panels to save electricity.

32. A

$P = \frac{m}{t} g h = (\frac{270}{1 \times 24 \times 3600})(9.81)(12) = 0.368\ \text{W}$

Use the following data wherever necessary :

Speed of light in vacuum	$c = 3 \times 10^8$ m s^{-1}
Acceleration due to gravity	$g = 9.81$ m s^{-2}

The following list of formulae may be found useful :

Maximum power by wind turbine $P = \frac{1}{2}\rho A v^2$

Part A :

The following question marked with { } is the past DSE question. The number inside the bracket represents the year of the examination.

Q1. {12} (a) It is known that even on a clear day, the atmosphere absorbs an average of 26.8% of solar power. Find the maximum solar power per unit area reaching the Earth's surface. Given : solar constant = 1366 W m^{-2}. (1 mark)

(b) State the energy conversion of a solar cell and suggest a way to improve its absorption of energy. (2 marks)

(c) *Solar Impulse* is a Swiss project to make a solar-powered aircraft that can fly long distances. Its first prototype HB-SIA has four engines driven by batteries which are charged by the solar cells installed on the aircraft. HB-SIA made a successful international flight in May 2011. The specifications of HB-SIA are as follows :

- Power of each engine is 7.35 kW
- The surface area of each solar cell panel = 0.0172 m^2
- Conversion efficiency of solar cells = 12% during midday at normal incidence of solar radiation

(i) Assume that all the electrical power output of the solar cells is shared equally by the four engines. Estimate the number of solar cells required if each engine is driven to its full power. Assume that all the solar cells on HB-SIA receive the same solar power per unit area found in (a). (3 marks)

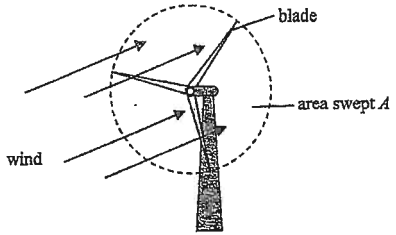
(ii) For the 2011 flight, a total of 11628 solar cells are installed on HB-SIA for a certain reason, which would not have been enough to drive the four engines to their full power. Suggest a practical reason for such a design. (1 mark)

(d) Explain why solar power is said to be a *renewable energy source*. Besides solar power, suggest a renewable energy source that is *most feasible* to be used in Hong Kong. Justify your choice. (3 marks)

Part B :

The following question marked with [ ] is the past HKAL question. The number inside the bracket represents the year of the examination.

Q2. [09] Wind carries a lot of kinetic energy and wind turbines can harness wind power as an alternative energy source. Suppose air of density ρ flows as wind with speed v and turns the blades of a wind turbine as shown. The blades sweep out a cross-sectional area A facing normally to the wind.



(a) By considering the amount of air passing through the wind turbine in one second and assuming that about 35% of its kinetic energy is converted to the mechanical energy of the turbine, show that the wind turbine delivers a power of $k\rho A v^n$ and find the values of the constants k and n. (5 marks)

(b) Suggest **TWO** advantages and **TWO** disadvantages of using wind power as an alternative energy source. (4 marks)

Part C :

The following questions are designed to give supplemental exercise for this chapter.

Q3. A solar heater is used to heat 250 kg of water initially at 15°C to a temperature of 60°C in a time of 8 hours. The solar constant is 1370 W m^{-2}. In average, the atmosphere absorbs 35% solar radiation. Given that the specific heat capacity of water is 4200 J kg^{-1} °C^{-1}.

(a) Calculate the power that should be supplied to the water to fulfil the above heating process. (2 marks)

Q3. (b) If the conversion efficiency of solar heater is 45%, what should be the area of the collecting panel that is required for the above heating process ? (3 marks)

(c) State TWO disadvantages of utilizing solar power. (2 marks)

Q4. A wind turbine is built to generate electrical energy. The blades sweep through an area of A during their rotation. Wind of speed v is incident onto the blades, and the average density of air is ρ.

(a) Derive an expression for the maximum power that can be extracted from the wind. (3 marks)

(b) State TWO assumptions in deriving the above expression. (2 marks)

(c) Suppose the average density of air is 1.2 kg m^{-3}. Wind of speed 10.5 m s^{-1} blows normally towards a wind turbine, with the length of each blade 1.6 m. Immediately after passing through the blades, the wind speed is reduced to 4.5 m s^{-1}. Calculate the maximum output power of the wind turbine. (3 marks)

Q1. (a) Maximum power per unit area = $1366 \times (1 - 26.8\%) = 1000$ W [1]

(b) Solar cell converts solar energy to electrical energy. [1]

An anti-reflective coating on the solar cell can improve the absorption of energy. [1]

(c) (i) $1000\ \text{W m}^{-2} \times 0.0172\ \text{m}^2 \times n \times 12\% = 7.35 \times 10^3\ \text{W} \times 4$ [2]

$n = 14200$ [1]

(ii) The total weight of the solar cells should not exceed the loading capacity of the aircraft. [1]

OR

The aircraft may not have enough surface area to carry too many the solar cells. [1]

(d) Solar power can be regenerated in a relatively short time, thus it has unlimited supply. [1]

Wind power should be most feasible to be used in Hong Kong. [1]

There are many coastal areas in Hong Kong, where wind is available to drive the wind turbines. [1]

Q2. (a) Volume of air passes through the wind turbine per second = $\frac{V}{t} = Av$

Mass of air passes through the wind turbine per second = $\frac{m}{t} = \rho V = \rho A v$ [1]

Kinetic energy of air passes through the wind turbine per second = $\frac{1}{2} \cdot \frac{m}{t} \cdot v^2 = \frac{1}{2}(\rho A v)v^2 = \frac{1}{2}\rho A v^3$ [1]

Power output of the wind turbine = $0.35 \times \frac{1}{2}\rho A v^3 = 0.175\,\rho A v^3$ [1]

$\therefore\ k = 0.175$ [1]

$\therefore\ n = 3$ [1]

(b) Advantages (any **TWO** of the following) [1+1]

* It is a renewable source of energy.
* Its cost is comparable to using fossil fuels.
* It is a relatively clean source of energy (i.e. without pollution).

(Accept any other reasonable answers)

Disadvantages (any **TWO** of the following) [1+1]

* It is not a reliable source of energy ; it could happen that there is no wind for the whole day.
* Low power output, thus very large area is required to install enough wind turbines to give a large amount of energy.
* Wind turbines often have to be installed far from urban areas, since they are unpleasant and noisy.

(Accept any other reasonable answers)

Q3. (a) $P = \frac{m}{t} c \Delta T = \frac{(250)}{(8 \times 3600)} \times (4200)(60 - 15)$ [1]

$= 1640$ W [1]

(b) Intensity of solar energy reaching the Earth's surface $= 1370 \times (1 - 35\%) = 890.5$ W m^{-2} [1]

$(890.5) \times A \times 45\% = 1640$ [1]

$\therefore A = 4.09$ m^2 [1]

(c) Any TWO of the followings : [2]

* Solar power is only available during the day.
* Solar power is not steady, as clouds may block the sunlight.
* Solar power has low power output.
* Solar power requires large area to collect sunlight.

Q4. (a) Volume of air passes through the wind turbine per second $= \frac{V}{t} = A v$ [1]

Mass of air passes through the wind turbine per second $= \frac{m}{t} = \rho V = \rho A v$ [1]

Kinetic energy of air passes through the wind turbine per second $= \frac{1}{2} \cdot \frac{m}{t} \cdot v^2 = \frac{1}{2} (\rho A v) v^2 = \frac{1}{2} \rho A v^3$ [1]

Maximum power that can be extracted from the wind $= \frac{1}{2} \rho A v^3$

(b) Assumptions : (any TWO of the followings) [2]

* The wind blows normally towards the wind turbine.
* All the wind is stopped by the wind turbine.
* The density of air is constant.

(c) $P = \frac{1}{2} \rho A v^3$ [1]

$= \frac{1}{2} (1.2) \times \pi \times (1.6)^2 \times [(10.5)^3 - (4.5)^3]$ [1]

$= 5150$ W [1]