Access Tuition

A-Level Physics

Reversed Heat Engine

Mark Scheme

Time available: 44 minutes
Marks available: 32 marks

1. (a) $Q_C = Q_H - W = 65 - 28 = 37$ W ✓$_1$

COPref = 37/28 = 1.32 ✓$_2$

COPref for ideal refrigerator = 278/(308 – 278) = 9.3 ✓$_3$

If temperatures not changed to K, do not award marks ✓$_3$ and ✓$_4$

Condone consistent use of Celsius in the denominator.

Actual COP is very low compared to ideal so claim is valid ✓$_4$

No ECF for ✓$_4$ from incorrect values of COP, unless from arithmetic error.

4

(b)
- One factor from ✓$_1$
- Thermoelectric cooler is small/convenient/of simple construction/(highly) portable
- can run off batteries/solar panel
- has no moving parts
- requires low maintenance
- no risk of leaking fluids
- temperature is about 5 °C, not cooler
- low energy/power consumption (28W)

✓$_1$ for advantage from bullet point list

For ✓$_1$ accept application, eg use in hot countries, by campers, climbers, walkers etc.

For ✓$_2$

- convenience outweighs poor COP
- any COP >1 means cooling power > power supplied
- waste of electrical energy from having low COP is acceptable

✓$_2$ mark for relating answer to COP

2

[6]

2. (a) The efficiency is 50% when the kelvin temperature of the hot source is twice the kelvin temperature of the cold sink. ✓

1

(b) Identifies $Q_H = 3 \times W$ and $Q_C = Q_H - W$ ✓

In reverse $COP_{ref} = QC / W$

Leading to $COP_{ref} = 2$ ✓

MP1 can be awarded for

$Q_H - Q_C = 0.33Q_H$ or $Q_C = 0.67Q_H$

Give credit for substituting numbers in equations eg

$W = 1$ $Q_H = 3$, $Q = 2$

OR $W = 33$ $Q_H = 100$, $Q_C = 67$

Accept working shown on a diagram

Accept working using temperatures T_H T_C with numbers substituted eg $T_H = 300$ (K), $T_C = 200$ (K)

No credit for simply quoting formulae from Formulae Booklet.

2

[3]

3. (a) Tick against answer B ✓

1

(b) COPref = $\frac{272}{343\ \ 272}$ (= 3.8 (3.83)) ✓

$3.8 = Q_C/(100 - Q_C)$ giving $Q_C = 79$ (W) (79.3W) ✓

$P_{IN} = 79/3.8 = 21$ (W) (20.7 W) ✓

OR for 2nd and 3rd marks

COPref = Q_C/W and $Q_C + W = Q_H = 100$ ✓
$3.8\,W + W = 100$
So $W = 21$ (W) ✓

OR for 2nd and 3rd marks
COPhp = COPref + 1 ✓
W = $Q_H/4.8 = 100/4.8 = 21$ (W) ✓

3

[4]

4.

(a) The ratio $\frac{\text{energy given to hot space/area to be heated}}{\text{work input}}$ ✓

OR COP = Q_{IN} / W with Q_{IN} and W explained / defined ✓

It must be clear that Q_{IN} is energy delivered <u>to the area to be heated / hot space</u>. Do not accept 'heat input' or any wording that is vague

1

(b) (i) $\eta_{max} = \frac{1600 - 290}{1600} = 0.82$ / 82% ✓

input power = $\frac{\text{output power}}{\text{efficiency}} = \frac{80}{0.82}$ = 98 kW ✓

fuel flow rate × CV = 98 kW

fuel flow rate = 98000 / (49 × 10^6) = 2.0 × 10^{-3} ✓

kg s^{-1} ✓

OR 7.2 ✓ kg h^{-1} ✓

If first 2 steps in calculation are not seen and 80 kW used for input power give 1 mark for:

fuel flow rate = 80000 / (49 × 10^6) = 1.6 × 10^{-3} ✓

The unit mark is an independent mark

4

(ii) $COP_{HP} = \frac{Q_2}{W}$

So Q_2 =16 × 2.6 = 41.6 or 42 kW ✓

Q_1 = 98 − 80 = 18 kW ✓

Total $Q_1 + Q_2$ = 60 kW ✓

CE for Q_1 if incorrect input power from i is used, but NOT 80 −16 or 80 − 80

3

(iii) Heat pump delivers more heat energy than the electrical energy input ✓

Reason: it adds energy from external source to electrical energy input ✓

Accept $Q_{IN} = W + Q_{OUT}$ if explained correctly e.g. by diagram

2

[10]

5. (a) (A device in which) an input of work ✓

(causes) heat to transfer from a cold space / reservoir to a hot space / reservoir ✓

2

(b) Heat transfer to hot space equals work done plus heat transfer from cold space / $Q_{IN} = W + Q_{OUT}$

Either written statement or expressed in symbols

so Q_{IN} (is always) > Q_{OUT} *reason must be seen* ✓

$COP_{HP} = \frac{Q_{IN}}{W}$ and $COP_{REF} = \frac{Q_{OUT}}{W}$

So $COP_{HP} > COP_{REF}$ ✓

The COP formulae are in formulae booklet so no marks for simply quoting them. i.e 2nd mark cannot be awarded without first mark.

OR

$Q_{IN} = W + Q_{OUT}$ ✓

$COP_{HP} \times W = \quad + COP_{REF} \times W$ or $COP_{HP} = \frac{Q_{IN}}{W} = \frac{W + Q_{OUT}}{W}$

So $COP_{HP} = 1 + COP_{REF}$

So $COP_{HP} > COP_{REF}$ ✓

2

[4]

6. (a) (refrigerator operates between a cold space and a hot space)

Q_{out} is the energy removed from the fridge contents (or from the cold space) **(1)**

Q_{in} is the energy given to the surroundings (or to outside the fridge/hot space) **(1)**

2

(b) (i) power for cooling ice = 5.5 × (420 × 10^3)/3600 = 642 W **(1)**

P_{in} = 642/4.5 = 142 W **(1)**

or energy taken from ice in 1 hour = 5.5 × 420 × 10^3 = 2310 kJ

W_{in} = 2310/4.5 = 513 kJ **(1)**

$P_{in} = \frac{513 \times 10^3}{3600}$ = 142 W **(1)**

2

(ii) Q per s = 142 + 642

= 784 W (give CE) **(1)**

or $Q_{in} = Q_{out} + W_{in}$ = 513 kJ + 2310 kJ = 2820 kJ

Q_{in} per s = $\frac{2820 \times 10^3}{3600}$ = 784 W **(1)**

1

[5]