NATIONAL JUNIOR COLLEGE

SENIOR HIGH 2 PRELIMINARY EXAMINATION

Higher 2

CANDIDATE NAME

SUBJECT CLASS

REGISTRATION NUMBER

PHYSICS
Paper 2 Structured Questions
Candidate answers on the Question Paper.

No Additional Materials are required.

9749/02

24 August 2023
2 hours

READ THE INSTRUCTION FIRST
Write your subject class, registration number and name on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answers **all** questions.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	**/ 10**
2	**/ 10**
3	**/ 8**
4	**/ 6**
5	**/ 6**
6	**/ 10**
7	**/ 10**
8	**/ 20**
Total (80m)	

This document contains **24** printed pages and **3** blank page.

Data

speed of light in free space	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{H\,m^{-1}}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
	$(1/(36\pi)) \times 10^{-9}\,\mathrm{F\,m^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
the Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
rest mass of electron	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
rest mass of proton	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
the Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
the Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^{2}\,kg^{-2}}$
acceleration of free fall	$g = 9.81\,\mathrm{m\,s^{-2}}$

Formulae

uniformly accelerated motion	$s = ut + \frac{1}{2}at^2$ $v^2 = u^2 + 2as$
work done on / by a gas	$W = p\Delta V$
hydrostatic pressure	$p = \rho gh$
gravitational potential	$\phi = -Gm/r$
temperature	$T/\text{K} = T/°\text{C} + 273.15$
pressure of an ideal gas	$p = \frac{1}{3}\frac{Nm}{V} < c^2 >$
mean translational kinetic energy of an ideal gas molecule	$E = \frac{3}{2}kT$
displacement of particle in s.h.m.	$x = x_0 \sin\omega t$
velocity of particle in s.h.m.	$v = v_0 \cos\omega t$ $= \pm\omega\sqrt{x_0^2 - x^2}$
electric current	$I = Anvq$
resistors in series	$R = R_1 + R_2 + \ldots$
resistors in parallel	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential	$V = \frac{Q}{4\pi\varepsilon_0 r}$
alternating current / voltage	$x = x_0 \sin\omega t$
magnetic flux density due to a long straight wire	$B = \frac{\mu_0 I}{2\pi d}$
magnetic flux density due to a flat circular coil	$B = \frac{\mu_0 NI}{2r}$
magnetic flux density due to a long solenoid	$B = \mu_0 nI$
radioactive decay	$x = x_0 \exp(-\lambda t)$
decay constant	$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}}$

1 A sphere is projected horizontally. The sphere is photographed at intervals of 0.10 s. The images of the sphere are shown against a grid in Fig. 1.1. Air resistance is negligible.

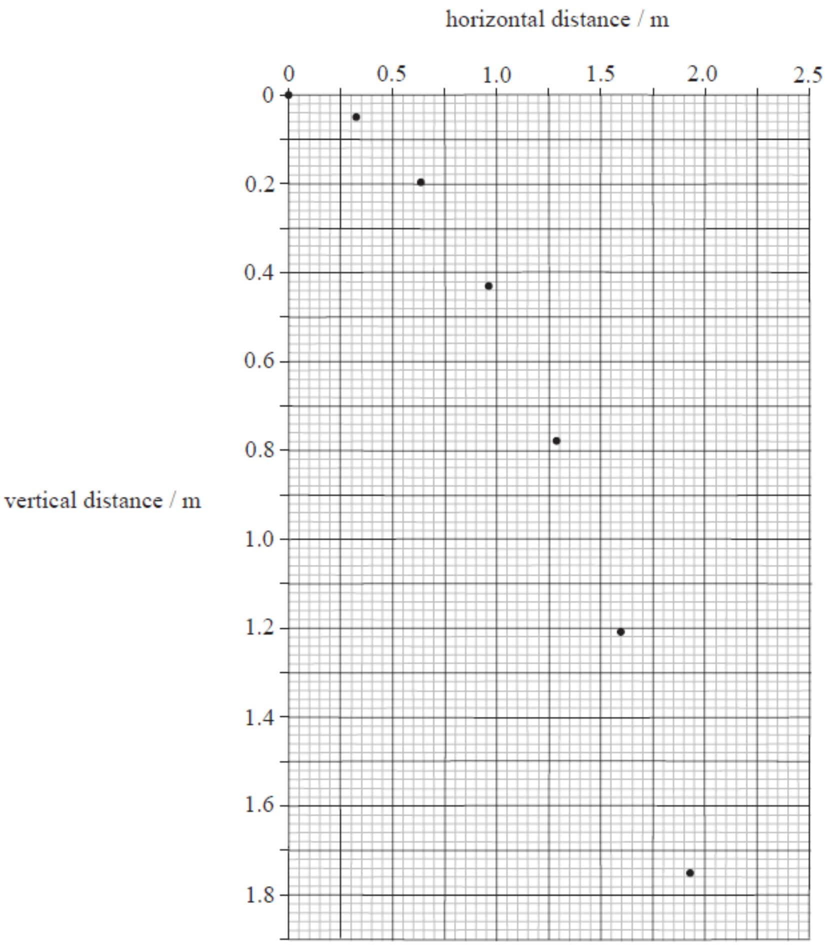

Fig. 1.1

(a) Use data from Fig.1.1 to determine the acceleration of free fall.

acceleration = ……………. m s^{-2} [2]

(b) Explain how your choice of the data point from Fig 1.1 helps to improve the reliability of your calculation in **(a)**.

………

………

……… [2]

(c) Determine the speed of the sphere 1.2 s after release.

speed = ………………. m s^{-1} [4]

(d) On the grid, draw the path of the sphere assuming air resistance is not negligible. [2]

[Total: 10]

2 **(a)** A prototype space shuttle attached to a rocket stands vertically on its launching pad. The total mass of the spaceship and rocket (inclusive of the mass of a man in it and its fuel) is 8.5×10^4 kg. On ignition, gas is ejected from the rocket at a speed of 6.0×10^3 m s^{-1} relative to the rocket, and the fuel is consumed at a constant rate of 138 kg s^{-1}.

Calculate

(i) the thrust on the rocket.

thrust = ……………………….. N [1]

(ii) the initial weight of the rocket.

weight = ……………………….. N [1]

(iii) the time it takes for the fuel to burn before the rocket leaves the launching pad.

time = ………………………… s [2]

(iv) the acceleration of the rocket after the fuel is consumed for 200 s.

acceleration = ………………………… m s^{-2} [2]

(b) Body A of mass 2.0 kg moves towards Body B of 3.0 kg as illustrated in Fig. 2.1.

Fig. 2.1

(i) Explain why it is not possible for both bodies to stop at the same instant.

....

.... [1]

(ii) Fig. 2.2 is a velocity-time sketch graph showing how the velocity of each body varies. The interaction between the bodies is elastic.

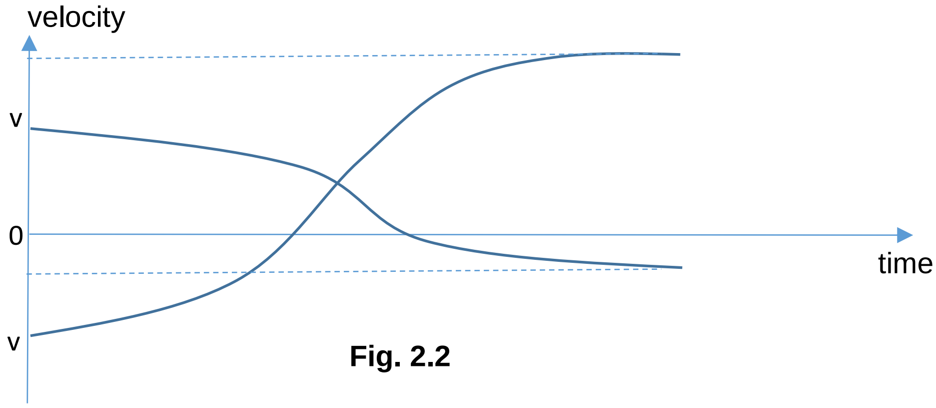

Fig. 2.2

Label the graph to show

1. which curve is for body A, [1]

2. the times at which each body stops, [1]

3. the time at which they are at their distance of closest approach. [1]

[Total: 10]

3 **(a)** Explain the origin of upthrust.

....

.... [1]

(b) A buoy is attached to a rope which is anchored to the seabed. Currents in the sea cause the buoy to be displaced so that the rope makes an angle of 25° with the vertical, as shown in Fig. 3.1. The buoy is in equilibrium.

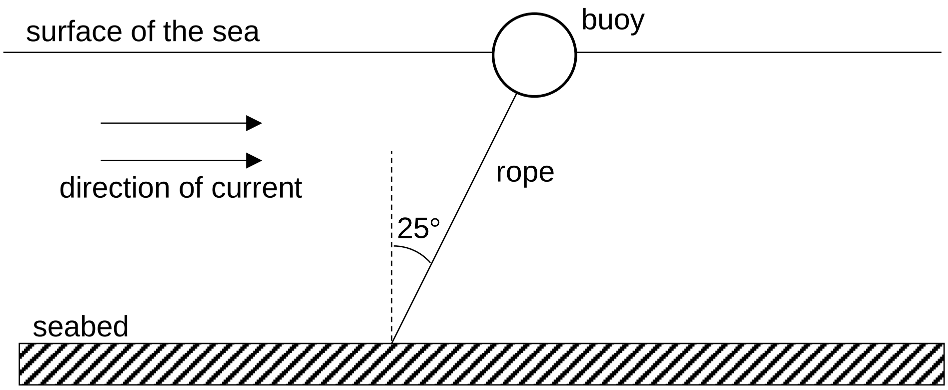

Fig. 3.1

The currents in the sea exert a horizontal force of 140 N on the buoy and the weight of the buoy is 130 N.

(i) Sketch the forces acting on the buoy in Fig. 3.2.

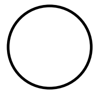

Fig. 3.2

[2]

(ii) Show that the upthrust acting on the buoy is 430 N.

[2]

(iii) Determine the percentage of the volume of the buoy that is submerged in the sea. The density of sea water is 1000 kg m^{-3} and density of the buoy is 230 kg m^{-3}.

percentage of volume of buoy submerged = ... % [3]

[Total: 8]

4 A rocket is midway between the Earth and Moon as shown in Fig. 4.1.

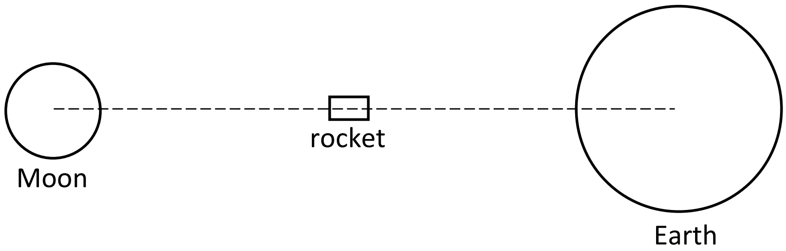

Fig. 4.1

The distance between the centers of mass of the Moon and Earth is 384×10^3 km. The mass of the Moon is 7.35×10^{22} kg and the mass of the Earth is 5.97×10^{24} kg.

(a) Calculate the escape velocity of the rocket when it is midway between the Earth and Moon.

escape speed = ... m s^{-1} [3]

(b) Explain qualitatively how the escape velocity of the rocket will change as its position is moved nearer the moon from its current position.

……..…………………………………………………………………………………………………..

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…………………………………………………………………………………………………….. [3]

[Total: 6]

5 Two small coherent sound sources S_1 and S_2 are set up as shown in Fig.5.1 below.

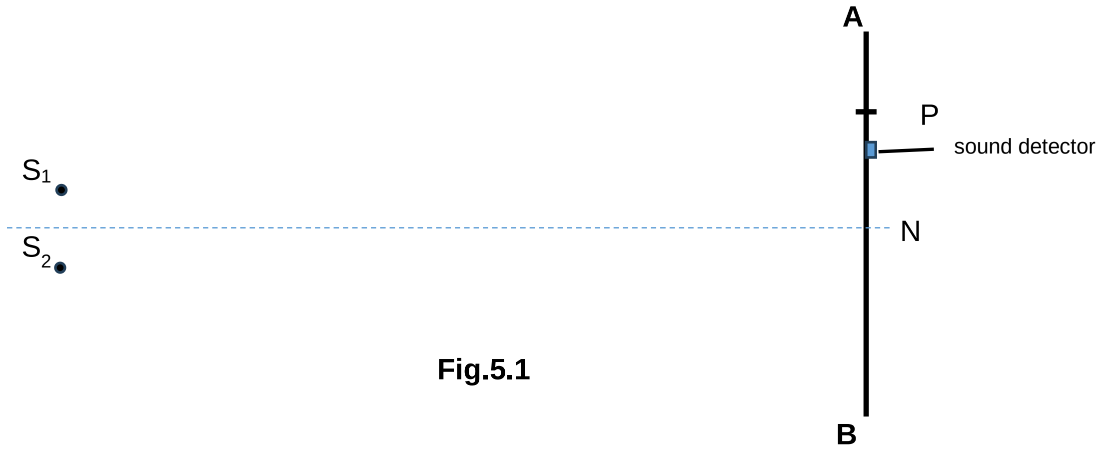

Fig.5.1

A sound detector is moved along a line AB that is parallel to S_1S_2. N is the point on AB such that $S_1N = S_2N$. The sound waves from S_1 and S_2 have frequency 2.80 kHz and speed 336 m s^{-1}.

(a) Show that the wavelength of the waves is 12.0 cm.

[1]

(b) The detector, when placed at N, indicates a maximum intensity of sound. As it is moved from N to a point P, the intensity varies between high and low values. At P, the distance S_1P is 372 cm and S_2P is 402 cm.

Determine, with suitable explanation,

(i) whether the intensity of sound at P is high or low,

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………… [2]

(ii) the number of high intensity regions that are found between N and P. Do not include the maximum at N.

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………………..

……………………………………………………………………………………………… [3]

[Total: 6]

[Turn over

6 The circuit is used to supply energy to the battery from the generator. A variable resistor of resistance *R* is used to control the current in a circuit, as shown in Fig. 6.1.

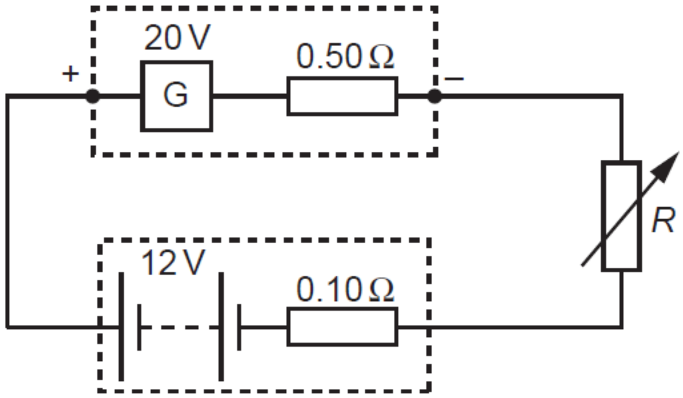

Fig. 6.1

The generator G has e.m.f. 20 V and internal resistance 0.50 Ω. The battery has e.m.f. 12 V and internal resistance 0.10 Ω. The current in the circuit is 2.0 A.

(a) Determine the resistance R.

resistance R = ………………..…… Ω [2]

(b) Calculate the total power generated by G

power = ... W [2]

(c) Calculate the power loss in the total resistance of the circuit.

Power loss = ... W [2]

(d) Determine the efficiency of the circuit.

efficiency = ... [3]

(e) A student suggests that the value of resistance R will not affect the efficiency calculated in **(d).** Explain if you agree with the student.

……

……….. [1]

[Total: 10]

7 **(a)** A spring that has an unstretched length of 0.500 m is attached to a fixed point. A mass of 0.400 kg is attached to the spring and gently lowered until equilibrium is reached. The spring has then stretched elastically by a distance of 0.150 m.

Calculate, for the stretching of the spring

(i) the loss in gravitational potential energy of the mass,

loss = …………………… J [1]

(ii) the elastic potential energy gained by the spring.

gain = ……………………. J [1]

(b) Explain why the two answers to **(a)** are different

……………………………………………………………………………………………………….

……………………………………………………………………………………………………….

…………………………………………………………………………………………………... [2]

(c) The load on the spring is now set into simple harmonic motion of amplitude 0.150 m.

Show that the angular frequency of the oscillation is 8.09 rad s^{-1}.

[3]

(d)

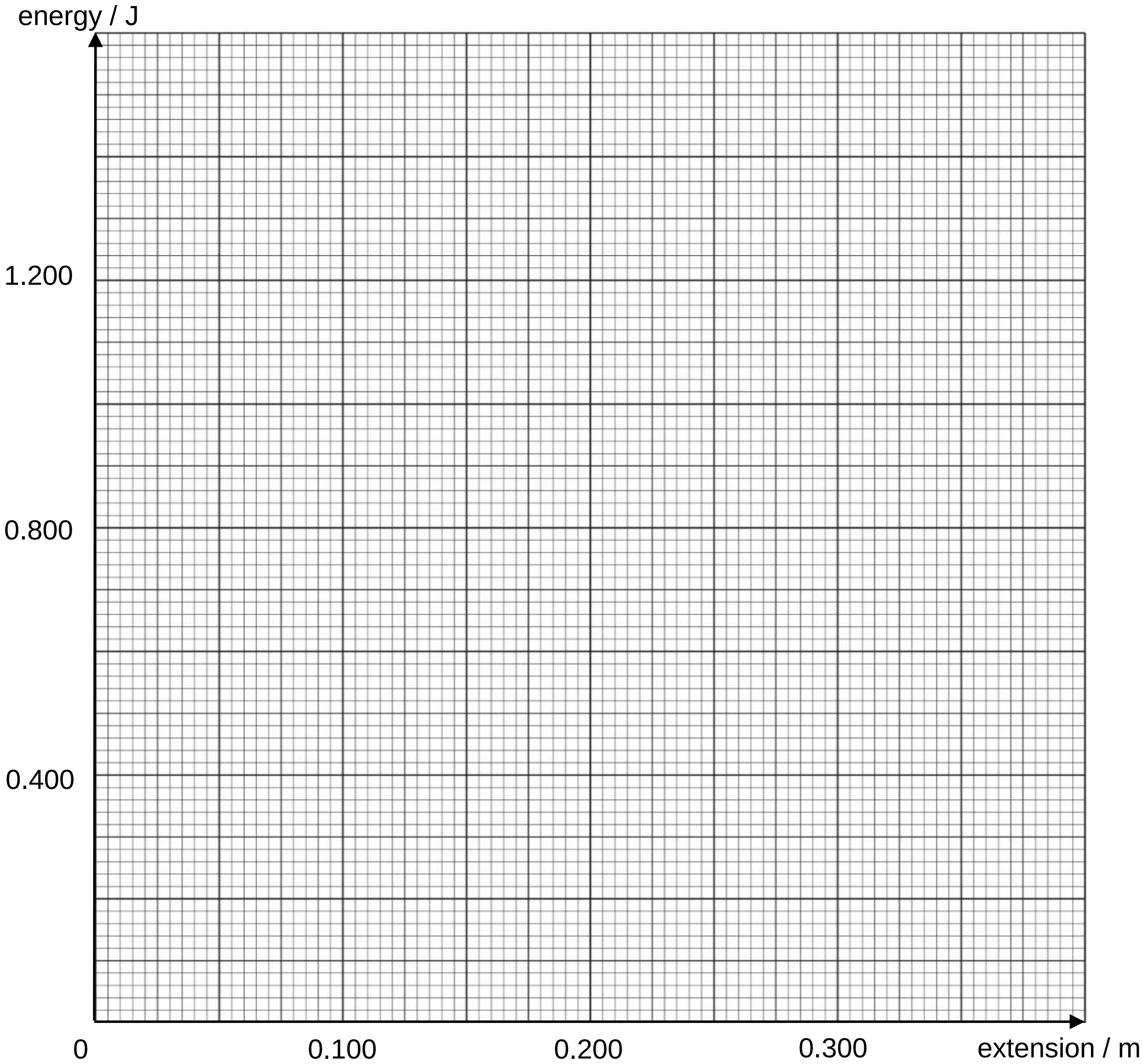

Fig. 7.1

The gravitational potential energy of the mass is 0 J when the spring is fully extended to the lowest point of the oscillation of the mass.

On Fig. 7.1, sketch the variation with extension of the spring, the kinetic energy and total potential energy for the oscillating mass. Label the graph for kinetic energy **T** and the graph for total potential energy **V**.

[3]

[Total: 10]

8 In a refrigeration system, a fluid known as a refrigerant undergoes alternating changes in its phase, pressure and volume to produce cooling. In this question, you will be guided to design a simple refrigeration system using the data provided.

Fig. 8.1 shows the variation of pressure against volume of the refrigerant as it cycles through four states P, Q, R and S. The four stages of the cyclic process are evaporation, condensation, compression and throttling (pressure releasing).

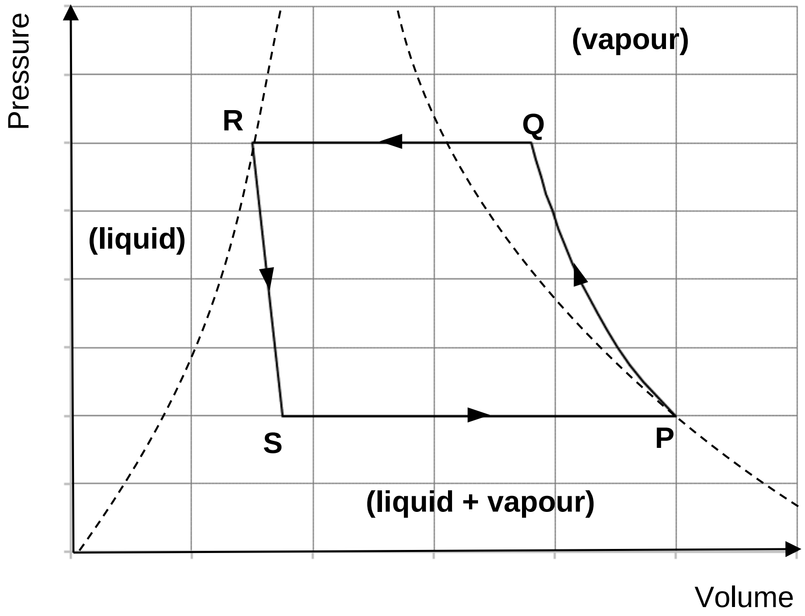

Fig. 8.1

The evaporation phase is considered the cooling phase of the cycle where heat is absorbed from the interior of the refrigerator. The compression phase requires an input of external work on the refrigerant. The performance rating of a refrigerator can therefore be thought as the ratio of the output of heat absorbed from the interior of the refrigerator against the input of work done during the compression phase.

The dotted lines on Fig. 8.1 separate the pressure-volume regions into the respective phase of matter in which the refrigerant exists at that pressure-volume state. For example, in the region labelled **(liquid + vapour)**, the refrigerant exists as a liquid-vapour mixture.

(a) Using the information provided in Fig. 8.1, match each stage in the cycle with its description in the chart below. P→Q has been matched.

Stage	*Description*
P→Q	Evaporation
Q→R	Condensation
R→S	Compression
S→P	Throttling (Pressure release)

[2]

The enthalpy of a system can be understood as the measure of a system's total thermal energy content per unit mass while the entropy of a system can be understood as the measure of a system's enthalpy per unit temperature that is unavailable for doing useful work.

Fig. 8.2 is a table showing the enthalpy and entropy of the refrigerant as a saturated vapour and as a saturated liquid at various pressures and temperatures.

Pressure P / kPa	Temperature T / K	Enthalpy h / kJ kg^{-1}		Entropy s / kJ kg^{-1} K^{-1}	
		Saturated Liquid	Saturated Vapour	Saturated Liquid	Saturated Vapour
100	246.8	17.3	234.5	0.072	0.952
200	263.1	38.5	244.5	0.155	0.938
300	273.9	52.8	250.9	0.208	0.931
400	282.1	64.0	255.6	0.248	0.927
500	288.9	73.4	259.3	0.280	0.924
600	294.8	81.5	262.4	0.308	0.922
700	299.9	88.8	265.1	0.332	0.920
800	304.5	95.5	267.3	0.354	0.918
900	308.7	101.6	269.3	0.374	0.917
1000	312.6	107.4	271.0	0.392	0.916
1200	319.5	117.8	273.9	0.425	0.913
1400	325.6	127.3	276.2	0.453	0.911
1600	331.1	136.0	277.9	0.479	0.908
1800	336.1	144.1	279.2	0.503	0.905
2000	340.7	151.8	280.1	0.525	0.902

Fig. 8.2

(b) When the refrigerant is at the boundary between a pure liquid and a liquid-vapour mixture, it is considered a saturated liquid and a small expansion will cause it to start evaporating.

(i) Deduce what a saturated vapour is.

……

………………………………………………………………………………………………….. [1]

(ii) By referring to Fig. 8.1, identify the state (P, Q, R or S) at which the refrigerant is a saturated vapour, and another at which it is a saturated liquid.

saturated vapour: ………………… , saturated liquid: ………………… [1]

(c) Fig. 8.3 is an incomplete table showing the thermal properties of the refrigerant at states P, Q, R and S in the cyclic process.

State	Pressure *P* / kPa	Temperature *T* / K	Enthalpy *h* / kJ kg^{-1}	Entropy *s* / kJ kg^{-1} K^{-1}
P	300			
Q	1200	322.0		
R				
S				0.443

Fig. 8.3

(i) Using Fig. 8.2 and your answer to **(b)(ii)**, fill in the missing values in Fig. 8.3 for state P. [2]

(ii) At state Q, the enthalpy and entropy of the refrigerant at various pressures are shown in the graphs in Fig. 8.4 and Fig. 8.5.

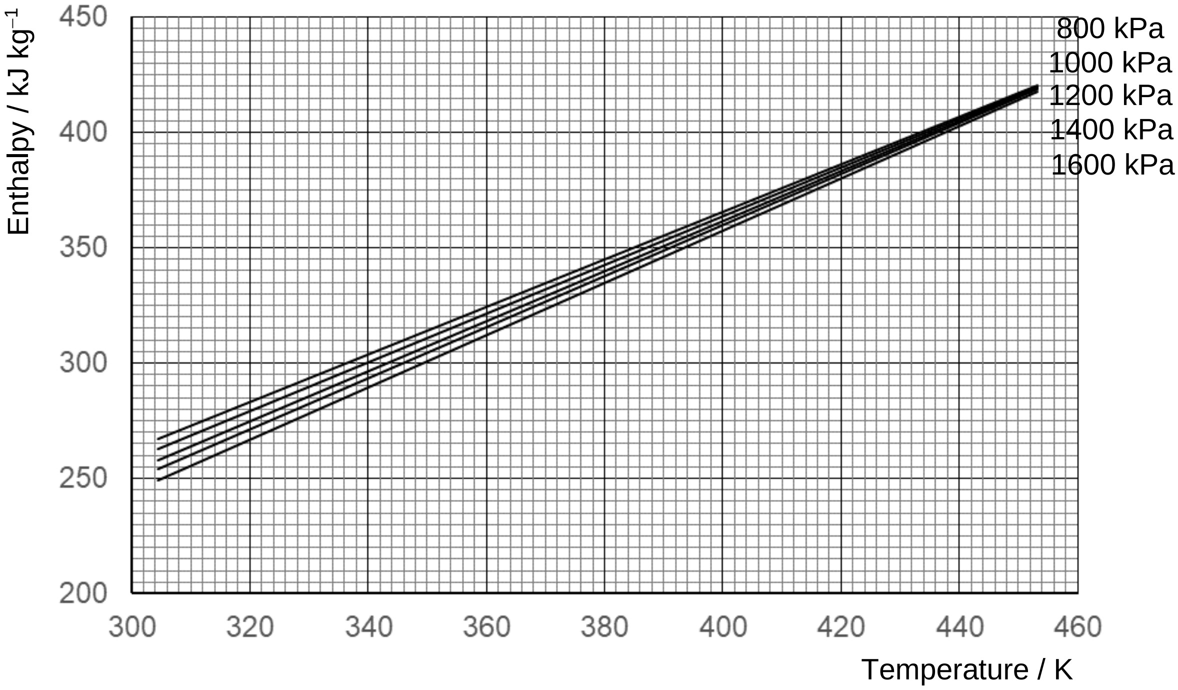

Fig. 8.4

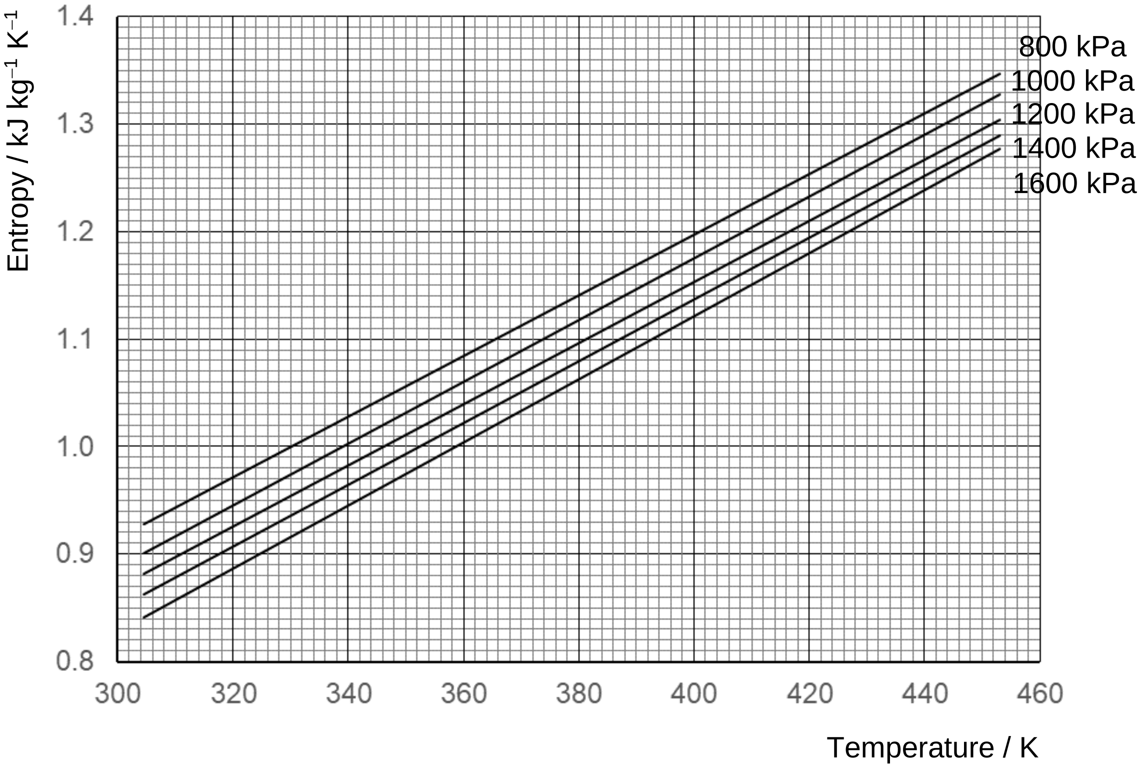

Fig. 8.5

The process P→Q takes place at constant entropy as the pressure of the refrigerant increases to 1200 kPa.

1. Use Fig. 8.5 to verify that the temperature of the refrigerant at state Q is 322.0 K.

....

.... [1]

2. Fill in the missing values in Fig. 8.3 for <u>state Q</u>. [1]

(iii) The process Q→R takes place at constant pressure.
Using Fig. 8.2 and your answer to **(b)(ii)**, fill in the missing values in Fig. 8.3 for <u>state R</u>. [2]

(iv) The process R→S takes place at constant enthalpy while the process S→P takes place at constant temperature and pressure.
Fill in the missing values in Fig. 8.3 for <u>state S</u>. [1]

(d) **(i)** There is energy input during the compression stage of the refrigeration process. The work done by the compressor during this stage can be calculated using

$$W = m\Delta h_c$$

where m is the mass of the system, and Δh_c is the change in enthalpy during the compression stage.

If the compressor compresses 3.20 kg of refrigerant in 1.0 second, calculate the rate of work done by the compressor.

rate of work done = ……………………………… kW [2]

(ii) The enthalpy h of a system is given by

$$h = \frac{U + pV}{m}$$

where U is the internal energy of the system,
p is the pressure of the system,
V is the volume of the system, and
m is the mass of the system.

The product pV can be understood as the amount of work needed to be done for the system to displace its volume at a particular environmental pressure.

1. State the First Law of Thermodynamics.

……………………………………………………………………………………………

……………………………………………………………………………………………

…………………………………………………………………………………………… [1]

2. Show, using the First Law of Thermodynamics, that for a process taking place at constant pressure, the heat Q absorbed by a system is given by

$$Q = m\Delta h$$

where m is the mass of the system, and Δh is the change in enthalpy during this stage.

[2]

3. Cooling is achieved during the evaporation stage of the cycle as heat is transferred from the surroundings to the refrigerant.

For the same system in **(d)(i)**, calculate the rate of heat removal by the refrigeration process.

rate of heat removal = ……………………………… kW [2]

(e) The typical operating temperature of a freezer is −18 °C.

Explain, with reference to the direction of heat transfer, why the refrigeration system cannot be used to cool a freezer.

……..

……..

……

……

……………………………………………………………………………………………………….. [2]

[Total: 20]

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