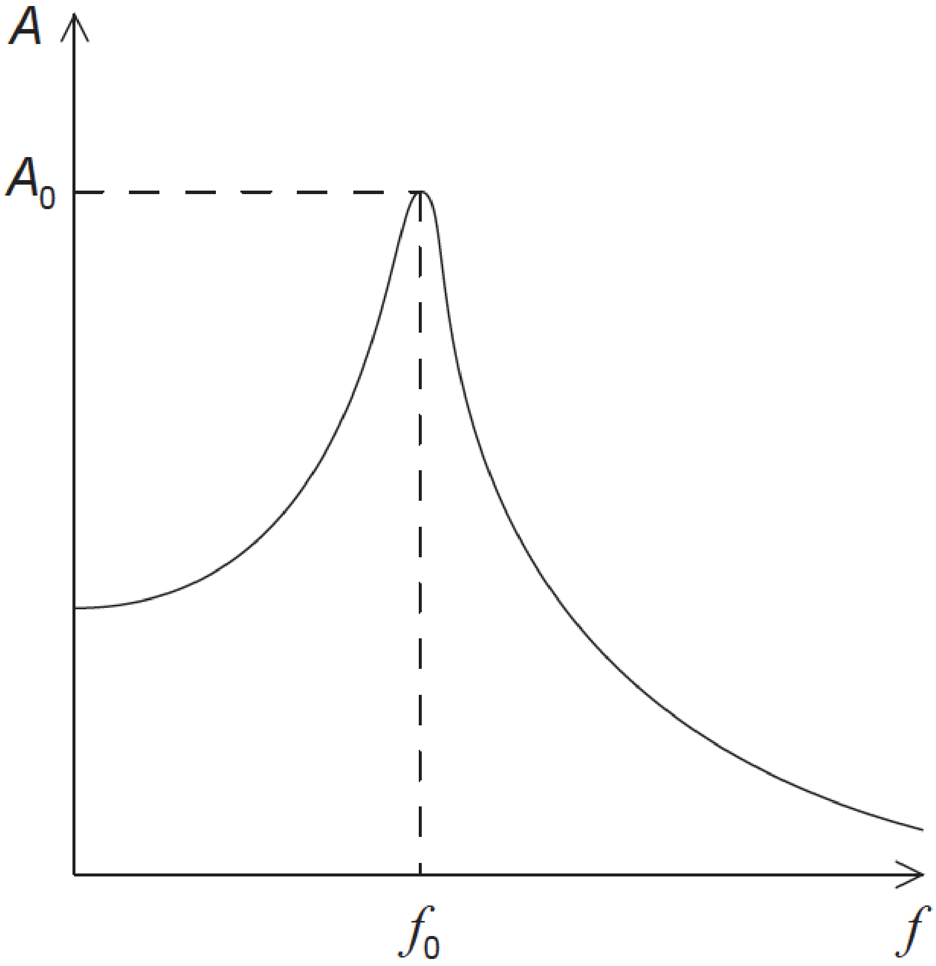
TB *[103 marks]*

1. A periodic driving force of frequency f acts on a system which undergoes forced oscillations of amplitude A. The graph below shows the variation with f of A. The maximum amplitude A_0 of the oscillations occurs at frequency f_0. *[1 mark]*



The damping of the system is now increased.
Which describes the change in f_0 and the change in A_0?

	f_0	A_0
A.	decrease	increase
B.	decrease	decrease
C.	increase	increase
D.	increase	decrease

2. The effects of resonance should be avoided in *[1 mark]*

A. quartz oscillators.

B. vibrations in machinery.

C. microwave generators.

D. musical instruments.

3. An ideal gas undergoes adiabatic expansion from state X to a new state of volume *V*. During this process the work done by the gas is *W*. What is the change in internal energy and the work done in an **isothermal** expansion of this gas from X to *V*? *[1 mark]*

	Change in internal energy	Work done
A.	0	greater than *W*
B.	0	less than *W*
C.	greater than 0	less than *W*
D.	less than 0	same as *W*

4. A block of ice at 0°C is placed on a surface and allowed to melt completely to give water at 0°C. During this process the entropy of the *[1 mark]*

A. molecules in the block has decreased.

B. surroundings has increased.

C. universe has increased.

D. universe has decreased.

This question is about thermal properties of matter.

5a. Explain, in terms of the energy of its molecules, why the temperature of a pure substance does not change during melting. *[3 marks]*

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5b. Three ice cubes at a temperature of 0°C are dropped into a container of water at a temperature of 22°C. The mass of each ice cube is 25 g and the mass of the water is 330 g. The ice melts, so that the temperature of the water decreases. The thermal capacity of the container is negligible. *[4 marks]*

The following data are available.

Specific latent heat of fusion of ice $= 3.3 \times 10^5$ J kg^{-1}

Specific heat capacity of water $= 4.2 \times 10^3$ J kg^{-1} K^{-1}

Calculate the final temperature of the water when all of the ice has melted. Assume that no thermal energy is exchanged between the water and the surroundings.

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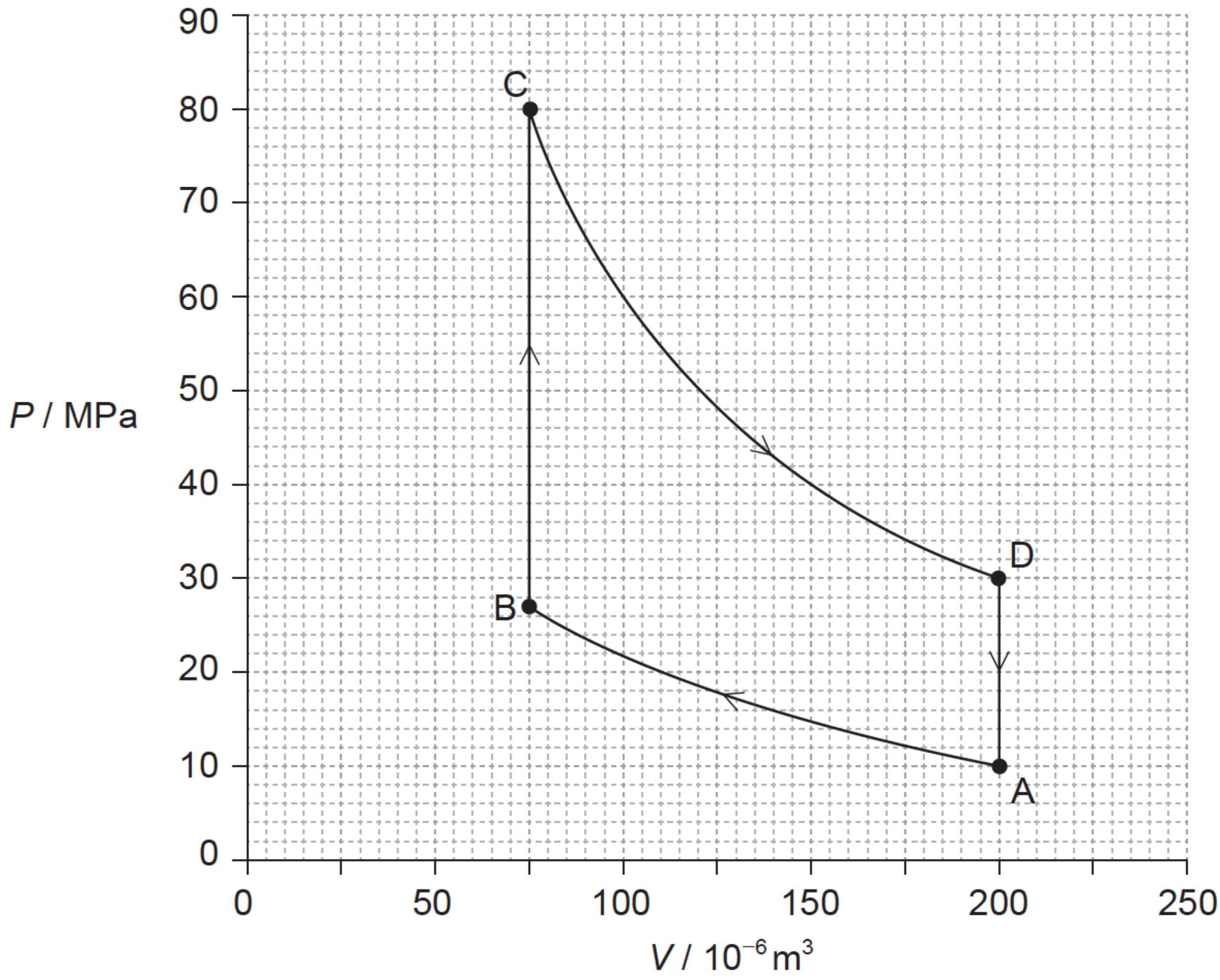
This question is about an ideal gas cycle.

The *P*–*V* diagram shows a cycle ABCDA for a fixed mass of an ideal gas.



6a. Estimate the total work done in the cycle. *[3 marks]*

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6b. The change **AB** is isothermal and occurs at a temperature of 420K. Calculate the number of moles of gas. *[3 marks]*

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6c. Identify and explain the change, if any, in the entropy of the gas when it has completed one cycle. *[2 marks]*

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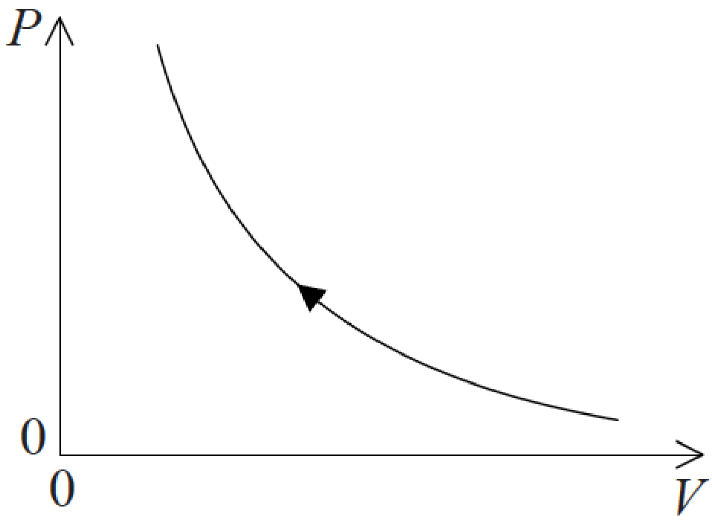
7. The pressure–volume (*P*–*V*) graph shows an adiabatic compression of a fixed mass of an ideal gas. *[1 mark]*



Which of the following correctly describes what happens to the temperature and the internal energy of the gas during the compression?

	Temperature	Internal energy
A.	decreases	decreases
B.	increases	no change
C.	decreases	no change
D.	increases	increases

8. In which of the following systems is it desirable that damping should be as small as possible? *[1 mark]*

A. Suspension bridge

B. Quartz oscillator

C. Car suspension

D. Airplane/aeroplane wing

9. Which process will increase the entropy of the local surroundings? *[1 mark]*

A. The melting of a block of ice

B. Evaporation of water vapour

C. The isothermal expansion of a gas

D. The adiabatic expansion of a gas

This question is in **two** parts. **Part 1** is about solar radiation and the greenhouse effect. **Part 2** is about a mass on a spring.

Part 1 Solar radiation and the greenhouse effect

The following data are available.

Quantity	Symbol	Value
Radius of Sun	R	7.0×10^{8} m
Surface temperature of Sun	T	5.8×10^{3} K
Distance from Sun to Earth	d	1.5×10^{11} m
Stefan-Boltzmann constant	σ	5.7×10^{-8} W m^{-2} K^{-4}

10a. State the Stefan-Boltzmann law for a black body. *[2 marks]*

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10b. Deduce that the solar power incident per unit area at distance *d* from the Sun is given by *[2 marks]*

$$\frac{\sigma R^2 T^4}{d^2}$$

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10c. Calculate, using the data given, the solar power incident per unit area at distance *d* from the Sun. *[2 marks]*

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10d. State **two** reasons why the solar power incident per unit area at a point on the surface of the Earth is likely to be different from your answer in (c). *[2 marks]*

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10e. The average power absorbed per unit area at the Earth's surface is 240Wm^{-2}. By treating the Earth's surface as a black body, show that the average surface temperature of the Earth is approximately 250K. *[2 marks]*

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10f. Explain why the actual surface temperature of the Earth is greater than the value in (e). *[3 marks]*

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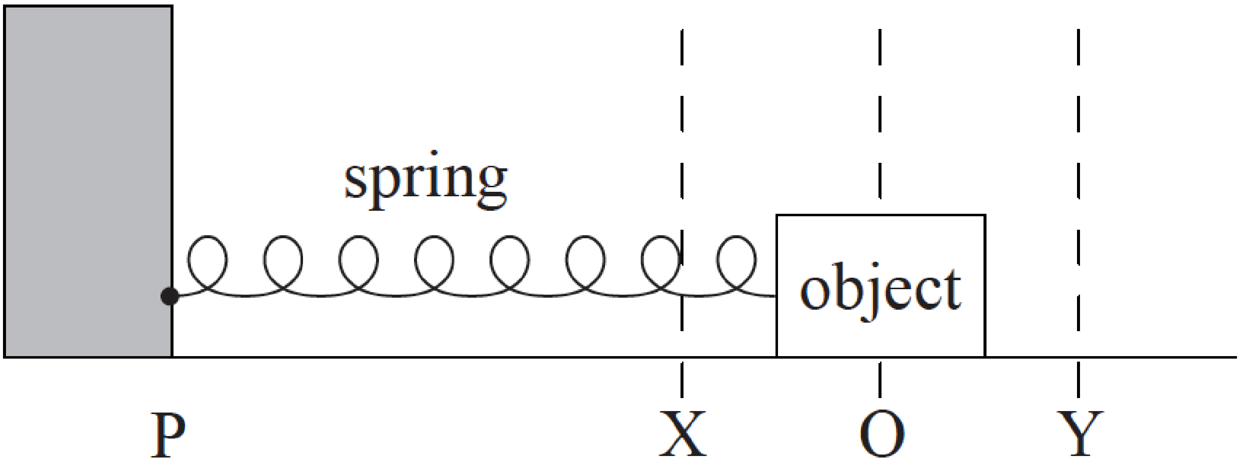
Part 2 A mass on a spring

An object is placed on a frictionless surface and attached to a light horizontal spring.



The other end of the spring is attached to a stationary point P. Air resistance is negligible. The equilibrium position is at O. The object is moved to position Y and released.

10g. Outline the conditions necessary for the object to execute simple harmonic motion. *[2 marks]*

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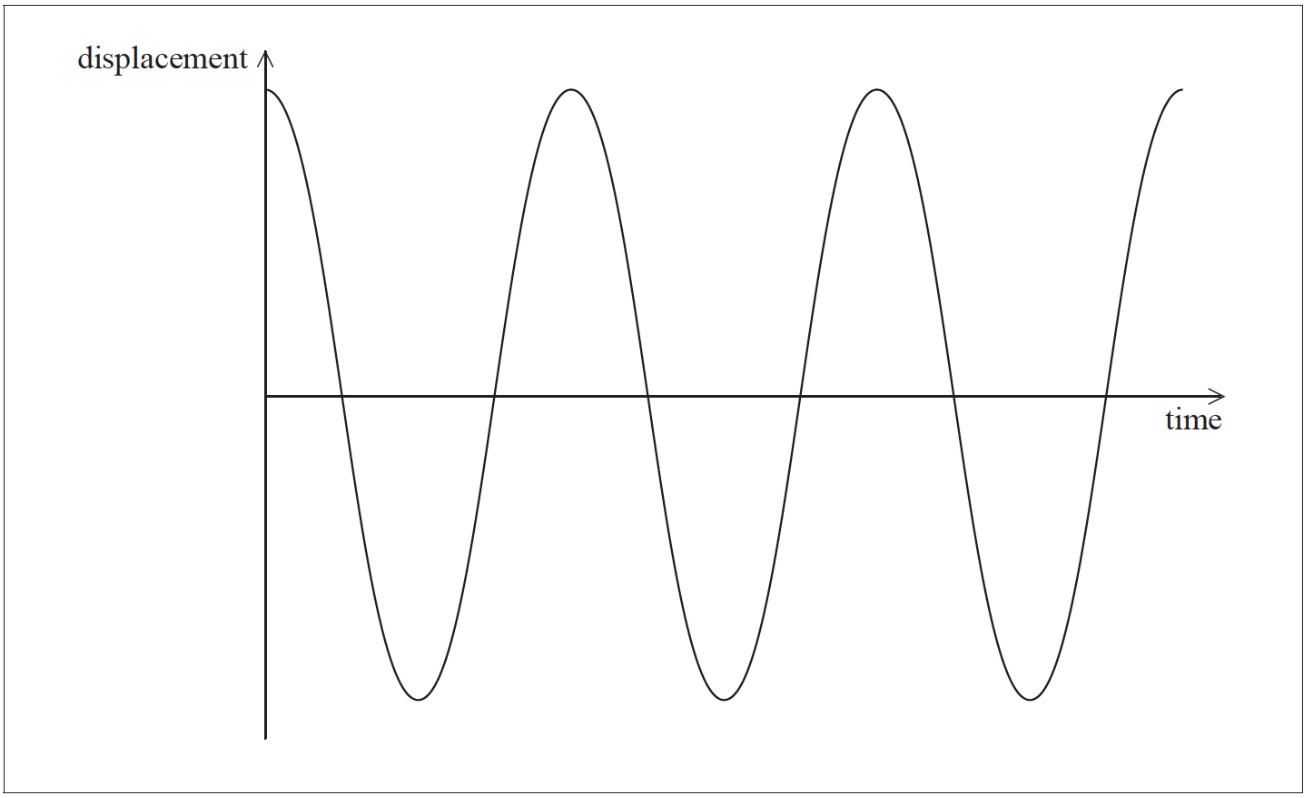
10h. The sketch graph below shows how the displacement of the object from point O varies with time over three time periods. *[4 marks]*



(i) Label with the letter A a point at which the magnitude of the acceleration of the object is a maximum.

(ii) Label with the letter V a point at which the speed of the object is a maximum.

(iii) Sketch on the same axes a graph of how the displacement varies with time if a **small** frictional force acts on the object.

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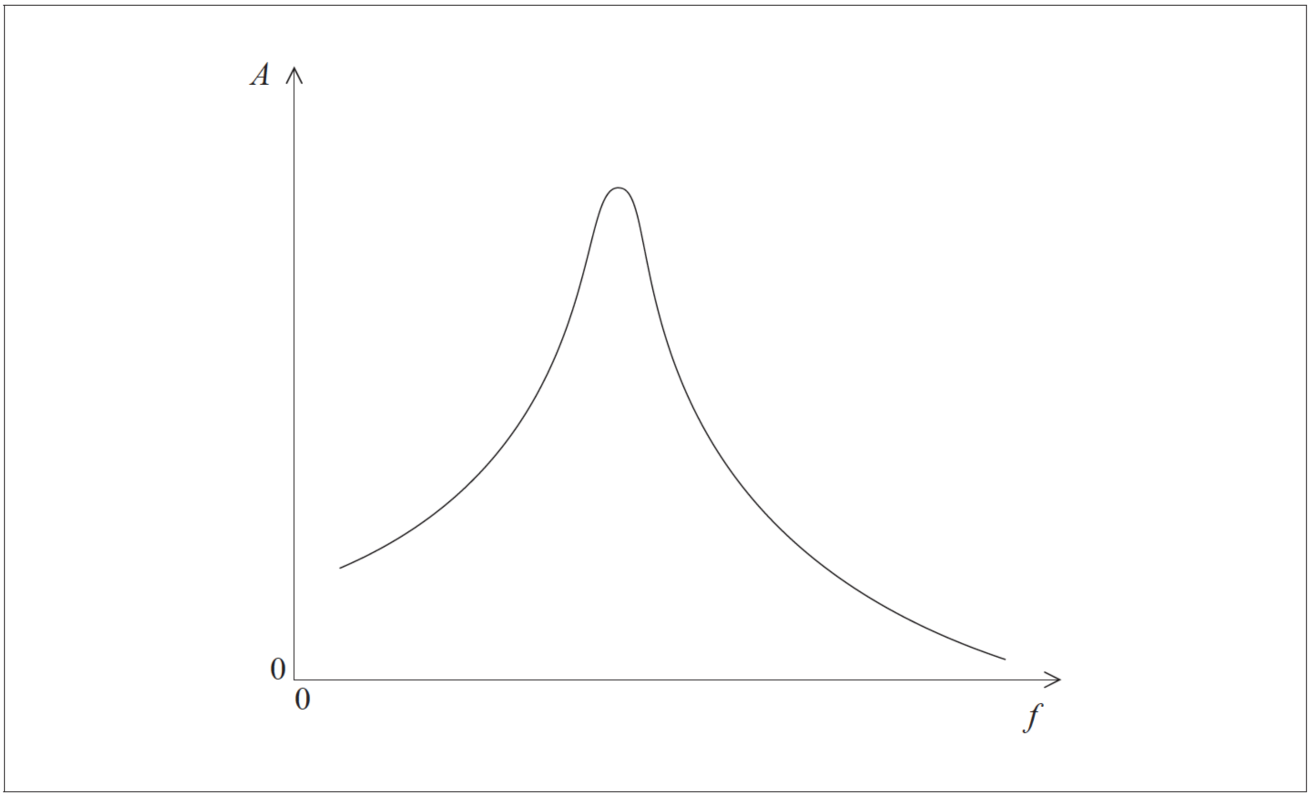
10i. Point P now begins to move from side to side with a small amplitude and at a variable driving frequency *f*. The frictional force is still small. *[4 marks]*

At each value of *f*, the object eventually reaches a constant amplitude *A*.

The graph shows the variation with *f* of *A*.



(i) With reference to resonance and resonant frequency, comment on the shape of the graph.

(ii) On the same axes, draw a graph to show the variation with *f* of *A* when the frictional force acting on the object is increased.

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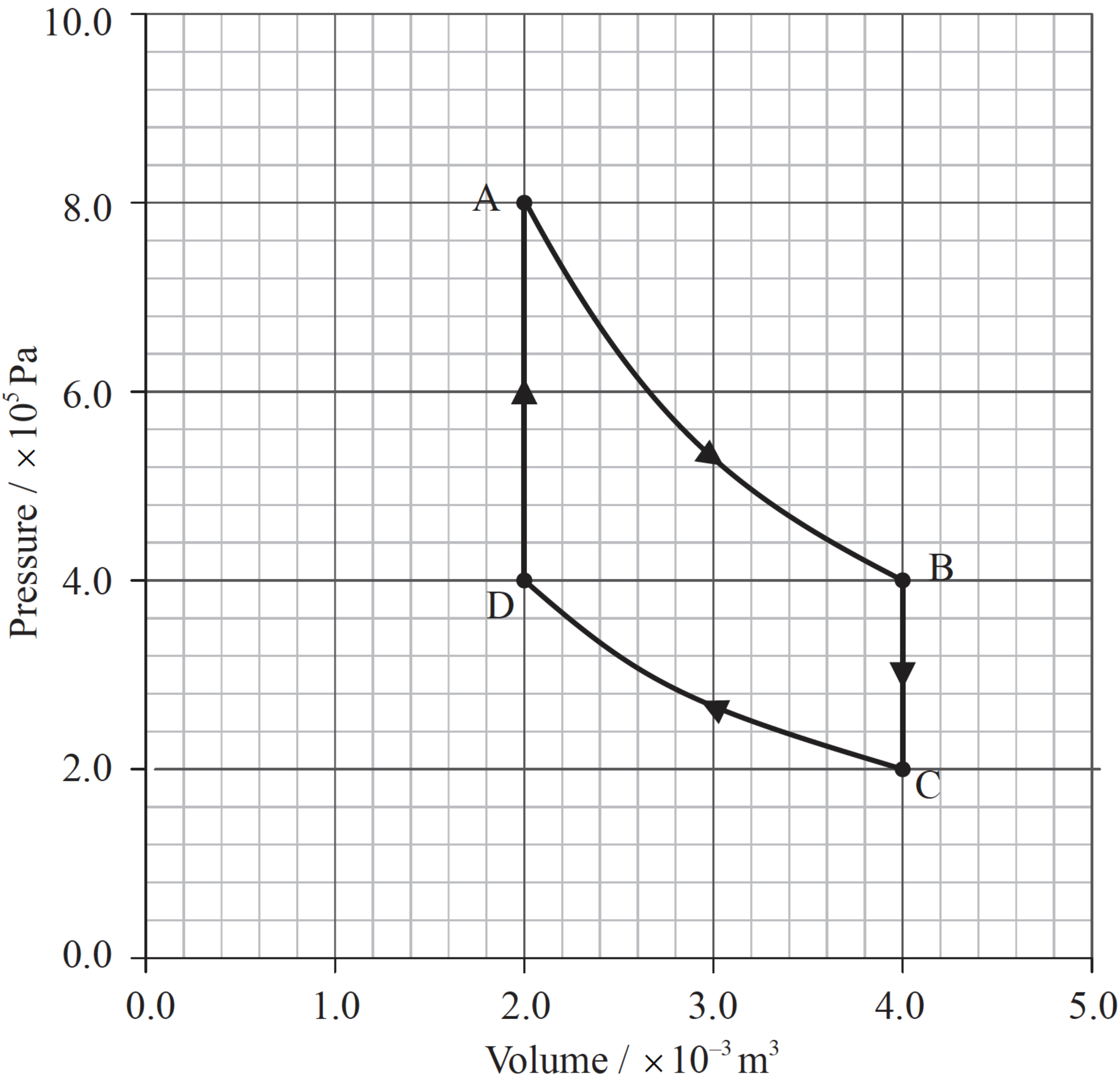
Part 2 A heat engine

The piston of an engine contains a fixed mass of an ideal gas. During one cycle of the engine, the gas undergoes the thermodynamic processes shown below.



11a. (i) State what is meant by an isothermal process. *[4 marks]*

(ii) Show that process AB is isothermal.

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11b. State the nature of process BC. *[1 mark]*

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11c. During the cycle ABCD, the net work done by the gas is 550J. Calculate the net thermal energy absorbed by the gas. *[2 marks]*

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11d. Explain why it is not possible for this engine, operating in this cycle, to be 100% efficient. *[3 marks]*

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12. Which of the following can be deduced from the second law of thermodynamics? *[1 mark]*

A. Thermal energy cannot spontaneously transfer from a low temperature region to a high temperature region.
B. Thermal energy cannot spontaneously transfer from a high temperature region to a low temperature region.
C. The entropy of an isolated system always decreases with time.
D. The entropy of an isolated system is the measure of the internal energy of the system.

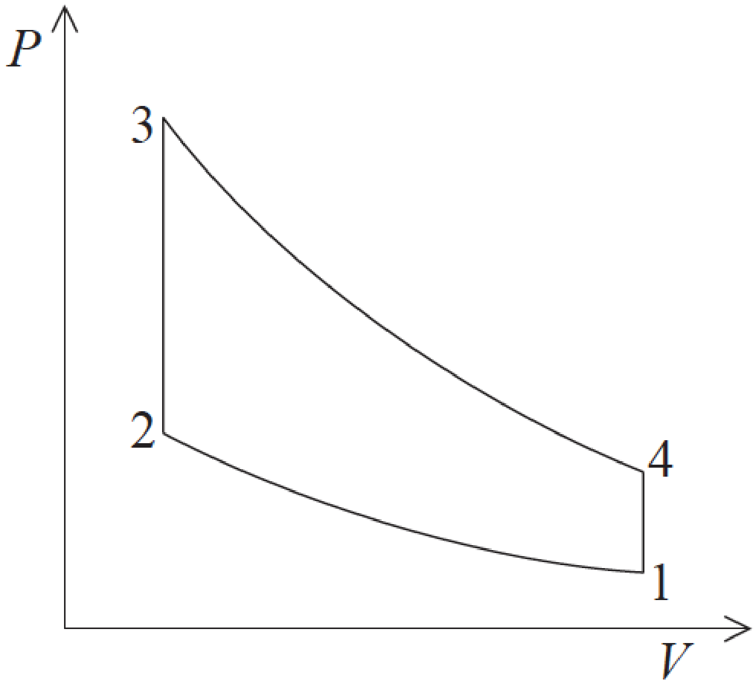
13. The entropy of a system is a measure of the system's *[1 mark]*

A. total energy only.
B. degree of disorder and total energy.
C. degree of disorder only.
D. degree of disorder and average kinetic energy.

14. What property of a driving system must be approximately equal to that of the oscillating system for resonance to occur? *[1 mark]*

A. Amplitude
B. Displacement
C. Frequency
D. Kinetic energy

15. The diagram shows a *P*–*V* cycle for a particular gas. *[1 mark]*



In which of the following changes is **no** work being done?

A. 1 → 2
B. 1 → 2 → 3
C. 1 → 2 → 3 → 4
D. 2 → 3

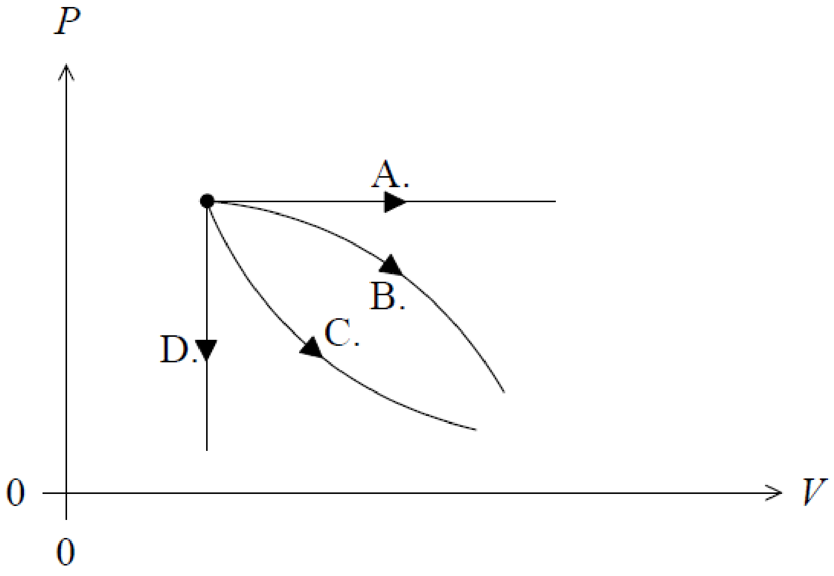
16. An ideal gas expands adiabatically. What energy change is **true** for the gas? *[1 mark]*

A. It gains thermal energy from the surroundings
B. It loses thermal energy to the surroundings
C. Its internal energy increases
D. Its internal energy decreases

17. Water in a container freezes. Which of the following correctly describes the change in entropy of the water and its surroundings? *[1 mark]*

	Change in entropy of water	Change in entropy of surroundings
A.	decrease	decrease
B.	decrease	increase
C.	increase	decrease
D.	increase	increase

18. In the *P*–*V* diagram below, which line could represent an adiabatic change for an ideal gas? *[1 mark]*



19. The entropy of a system *[1 mark]*

A. will decrease if the system's temperature is increased.

B. is related to the degree of disorder in the system.

C. must always increase.

D. is always conserved.

20. Which of the following gives the conditions for maximum amplitude in forced, but damped, oscillations? *[1 mark]*

	Driving frequency	Damping
A.	greater than natural frequency	as large as possible
B.	equal to natural frequency	as large as possible
C.	greater than natural frequency	as small as possible
D.	equal to natural frequency	as small as possible

21. *The following statement refers to question 11 and question 12.* *[1 mark]*

A gas is contained in a thermally insulated cylinder by a freely moving piston. The volume of the gas is increased reversibly by moving the piston.

Which term identifies the change of state of the gas?

A. Isobaric
B. Isochoric
C. Isothermal
D. Adiabatic

22. *The following statement refers to question 11 and question 12.* *[1 mark]*

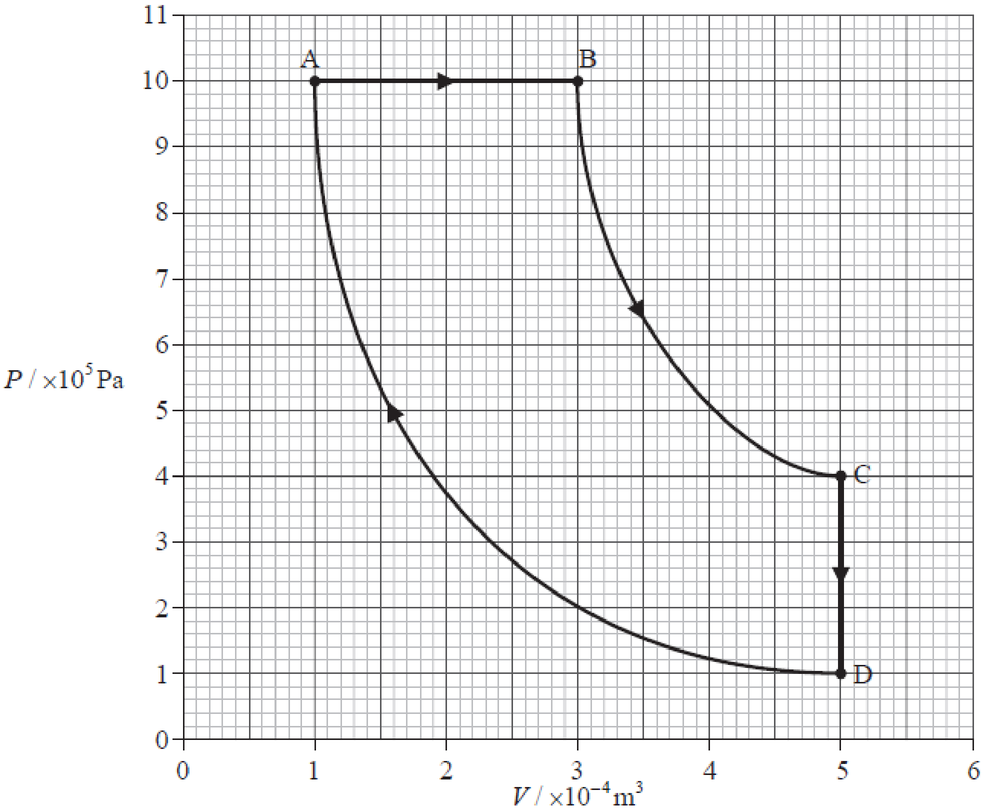
A gas is contained in a thermally insulated cylinder by a freely moving piston. The volume of the gas is increased reversibly by moving the piston.

Which of the following gives the correct entropy change of the gas and the surroundings?

	Entropy change of the gas	Entropy change of the surroundings
A.	decrease	decrease
B.	no change	decrease
C.	decrease	no change
D.	no change	no change

Part 2 Thermodynamic cycles

23a. A gas undergoes a thermodynamic cycle. The *P–V* diagram for the cycle is shown below. *[3 marks]*



In the changes of state B to C and D to A, the gas behaves as an ideal gas and the changes in state are adiabatic.

(i) State the circumstances in which the behaviour of a gas approximates to ideal gas behaviour.

(ii) State what is meant by an adiabatic change of state.

23b. With reference to the first law of thermodynamics, explain for the change of state A to B, why energy is transferred from the surroundings to the gas. *[4 marks]*

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23c. Estimate the total work done in the cycle. *[3 marks]*

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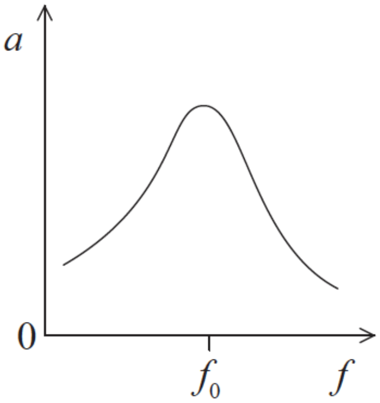
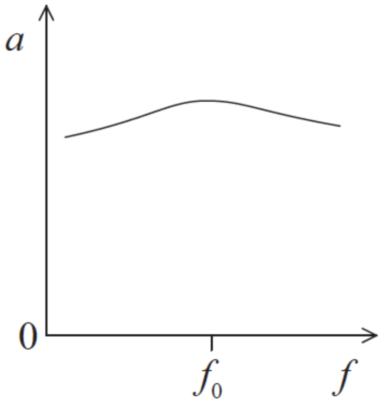
24. An object is undergoing simple harmonic motion with light damping. The natural frequency of oscillation of the object is f_0. A periodic force of frequency f is applied to the object. Which of the following graphs best shows how the amplitude a of oscillation of the object varies with f? *[1 mark]*

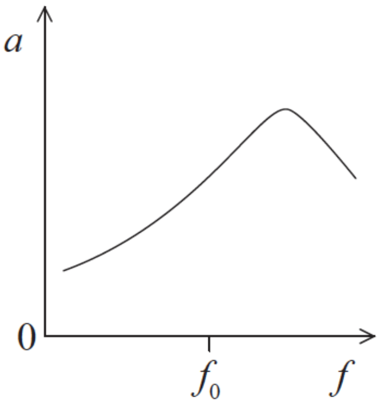
A.



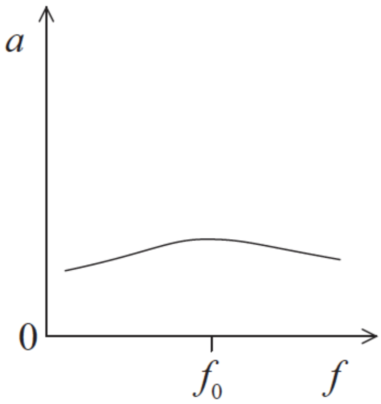
B.



C.



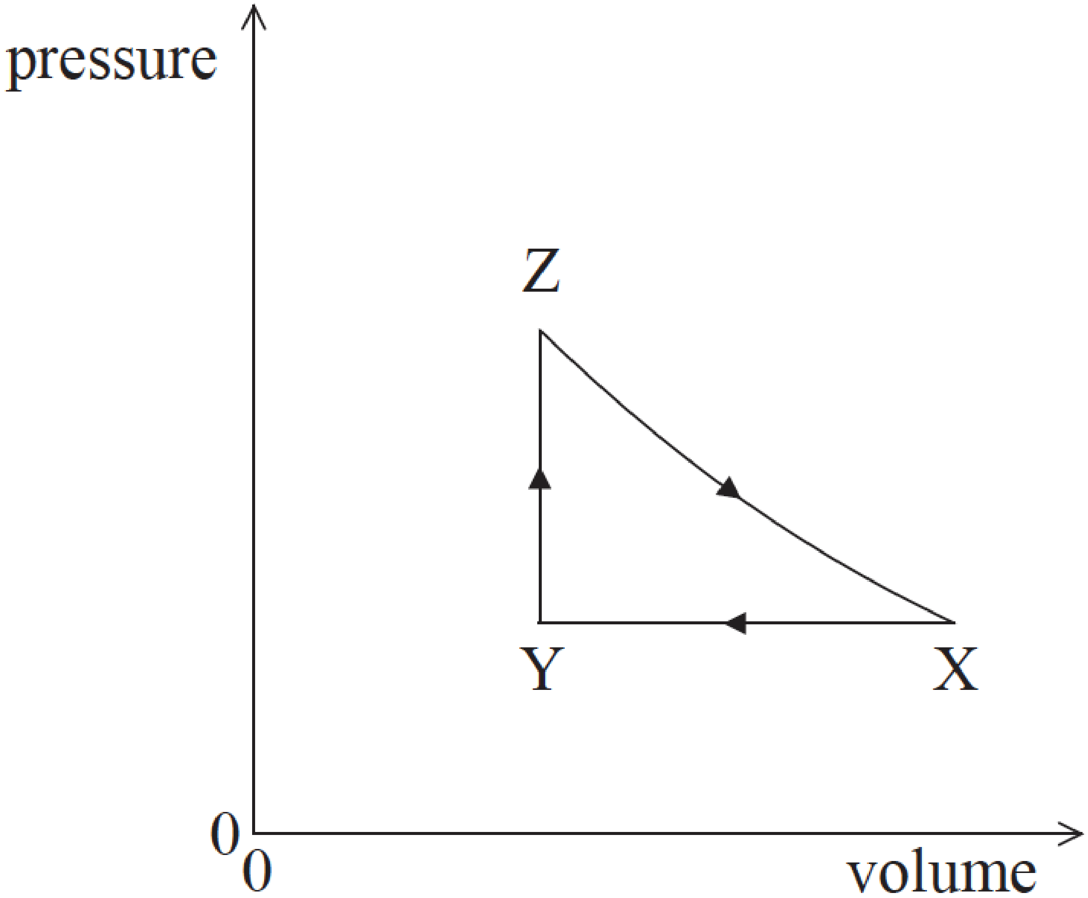
D.



25. During an adiabatic expansion, a gas does 50J of work against the surroundings. It is then cooled at constant volume by removing 20J of energy from the gas. The magnitude of the total change in internal energy of the gas is *[1 mark]*

A. 70 J.
B. 50 J.
C. 30 J.
D. 20 J.

26. The diagram shows the pressure volume relationship for a fixed mass of an ideal gas that undergoes a cycle XYZ. *[1 mark]*



In which part(s) of the cycle is external work done **on** the gas?

A. Y→Z only

B. Y→Z and Z→X only

C. X→Y and Z→X only

D. X→Y only

This question is in **two** parts. **Part 1** is about simple harmonic motion (SHM) and a wave in a string. **Part 2** is about the unified atomic mass unit and a nuclear reaction.

Part 1 Simple harmonic motion and a wave in a string

27a. By reference to simple harmonic motion, state what is meant by amplitude. *[1 mark]*

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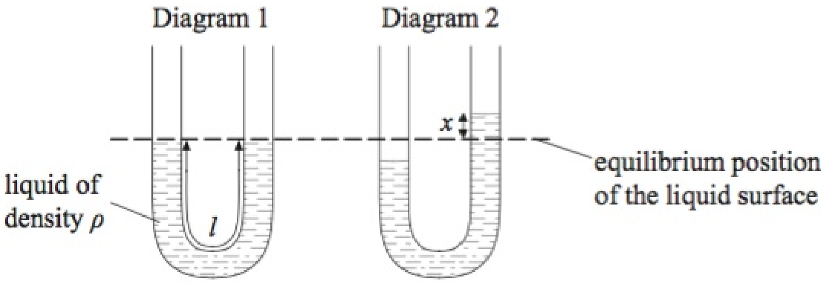
27b. A liquid is contained in a U-tube. *[5 marks]*



The pressure on the liquid in one side of the tube is increased so that the liquid is displaced as shown in diagram 2. When the pressure is suddenly released the liquid oscillates. The damping of the oscillations is small.

(i) Describe what is meant by damping.

(ii) The displacement of the liquid surface from its equilibrium position is *x*. The acceleration *a* of the liquid in the tube is given by the expression

$$a = -\frac{2g}{l}x$$

where *g* is the acceleration of free fall and *l* is the total length of the liquid column. The total length of the liquid column in the tube is 0.32m. Determine the period of oscillation.

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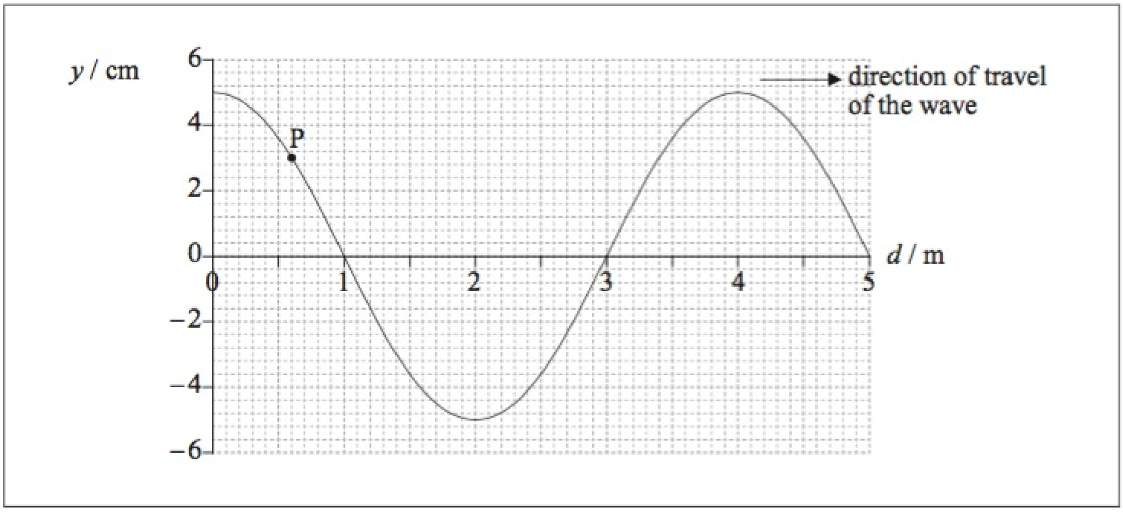
27c. A wave is travelling along a string. The string can be modelled as a single line of particles and each particle executes simple harmonic motion. The period of oscillation of the particles is 0.80s. *[9 marks]*

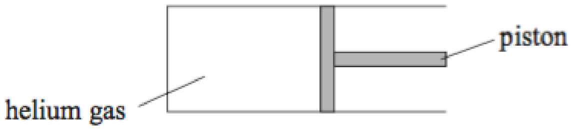
The graph shows the displacement *y* of part of the string at time *t*=0. The distance along the string is *d*.



(i) On the graph, draw an arrow to show the direction of motion of particle P at the point marked on the string.
(ii) Determine the magnitude of the velocity of particle P.
(iii) Show that the speed of the wave is 5.0 ms^{-1}.
(iv) On the graph opposite, label with the letter X the position of particle P at *t*=0.40 s.

This question is about changes of state of a gas.

28a. A cylinder fitted with a piston contains 0.23 mol of helium gas. *[3 marks]*



The following data are available for the helium with the piston in the position shown.

Volume = $5.2\times10^{-3}m^3$
Pressure = 1.0×10^5 Pa
Temperature = 290K

(i) Use the data to calculate a value for the universal gas constant.
(ii) State the assumption made in the calculation in (a)(i).

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28b. The gas is now compressed isothermally by the piston so that the volume of the gas is reduced. Explain why the compression must be carried out slowly. *[2 marks]*

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28c. After the compression, the gas is now allowed to expand adiabatically to its original volume. Use the first law of thermodynamics to explain whether the final temperature will be less than, equal to or greater than 290K. *[4 marks]*

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