4 The piston in the cylinder of a car engine is made to move in the cylinder with simple harmonic motion.

Fig. 4.1 shows the highest and lowest positions of the piston.

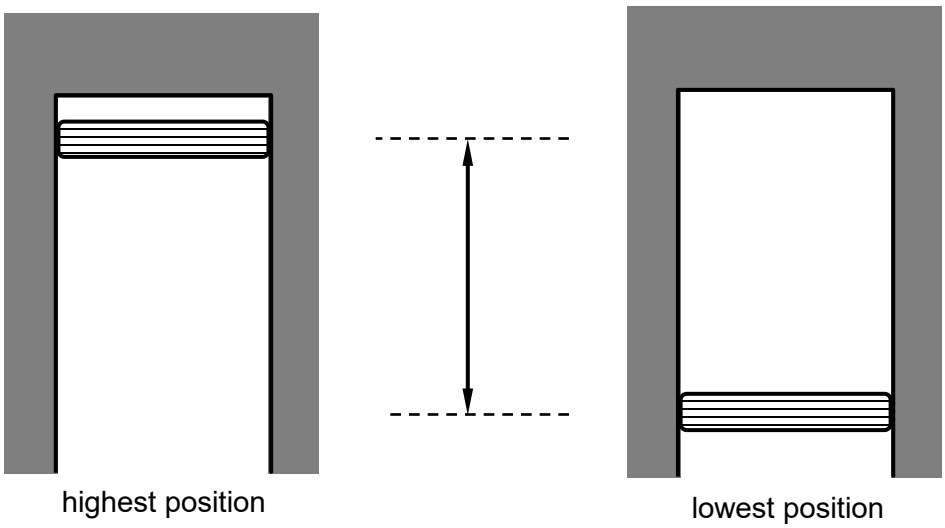

Fig. 4.1

The variation of the acceleration *a* of the piston with its displacement *x* from position O is as shown in Fig. 4.2.

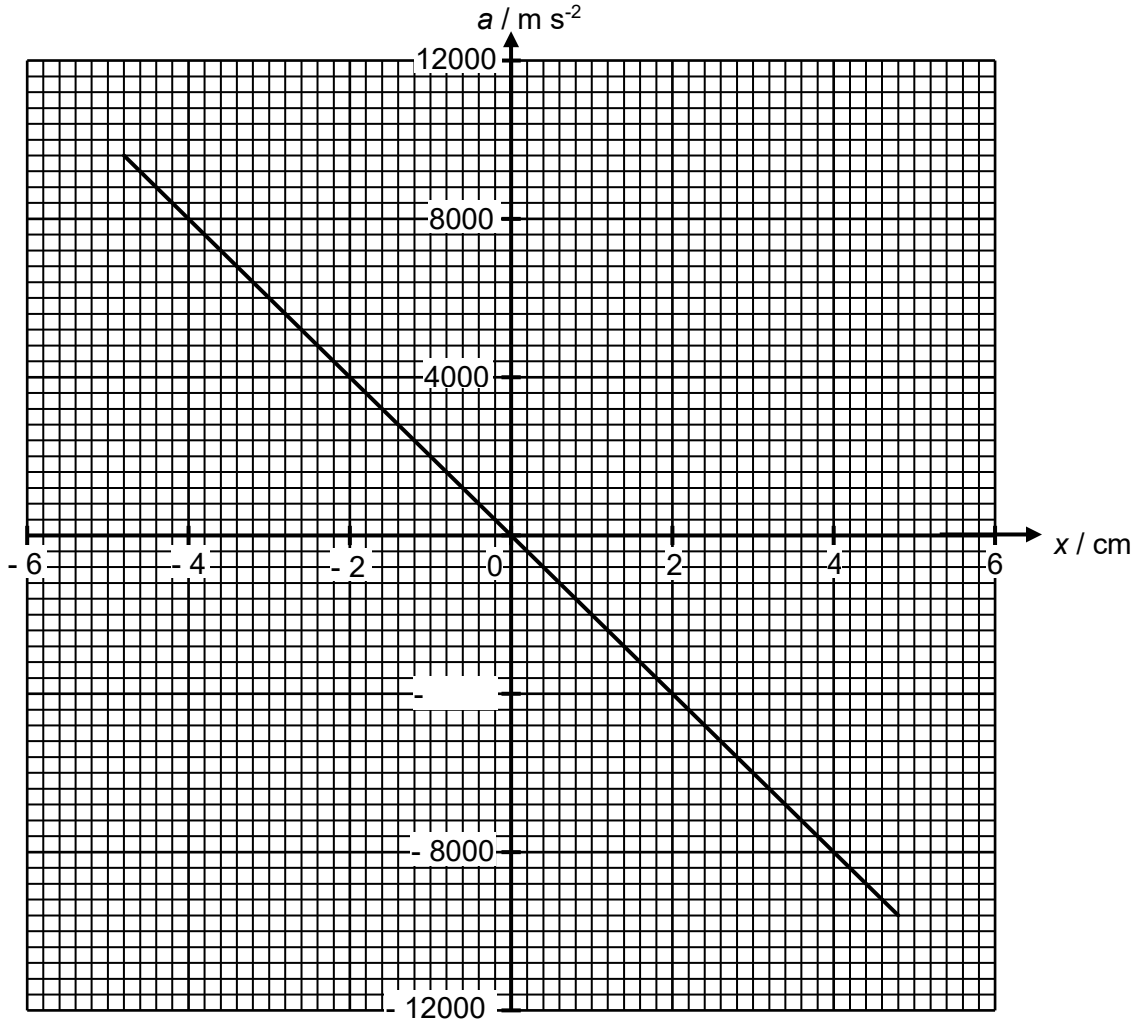

Fig. 4.2

(a) State and explain the features of Fig. 4.2 that indicate that the motion of the piston is simple harmonic.

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(b) Determine the maximum speed of the piston.

maximum speed = ... m s^{-1} [2]

(c) With reference to Fig. 4.2,

(i) explain why the time taken for the piston to move from x = 3.3 cm to x = 0 cm is the same as that from x = 0 cm to x = -3.3 cm.

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(ii) The area under the graph in Fig. 4.2 from x = 0 to x = 4.8 cm is given by Z.

A student calculates K, the maximum kinetic energy of the piston, using the relationship

$$K = Z \times M$$

where M is the mass of the piston.

Explain why this relationship is valid.

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(d) The piston is made to move by connecting a rod to a rotating crankshaft as shown in Fig. 4.3. As the pivot P on the crankshaft rotates, the piston will move up and down.

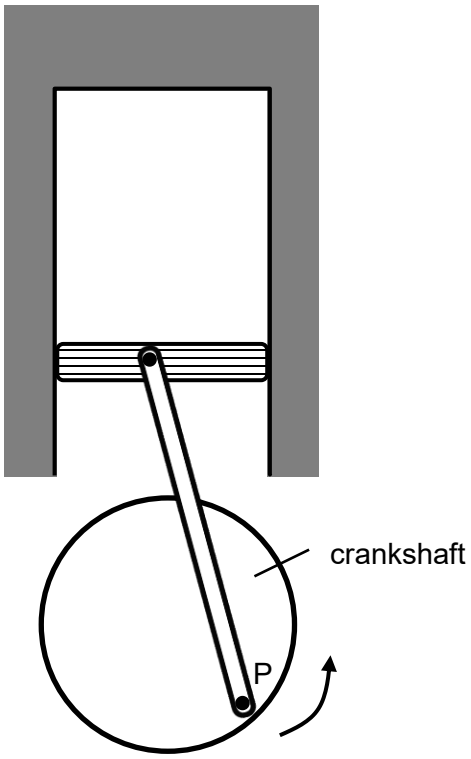

Fig. 4.3

When pivot P is at the position shown in Fig. 4.3, the piston is moving upward with a position of x = -3.3 cm.

Indicate on Fig. 4.3 the position of pivot P when the piston is at the following positions,

(i) x = 3.3 cm moving upwards. (Indicate this position with A)

(ii) x = 3.3 cm moving downwards. (indicate this position with B)
[2]

[Total: 10]