6 Fig. 6.1 shows a simple harmonic oscillator that is lightly damped.
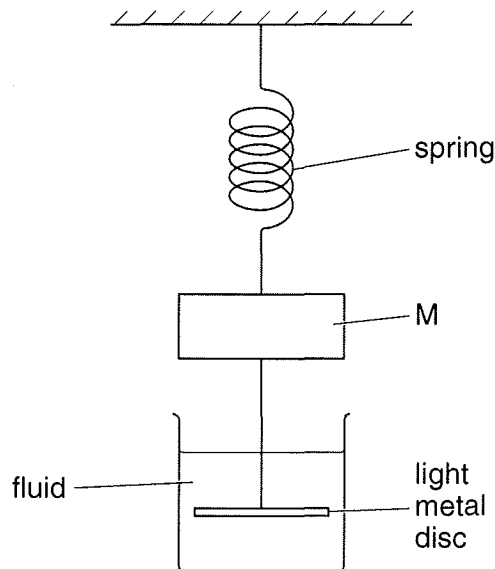

Fig. 6.1

An object M is attached to a spring that hangs vertically. Object M has a mass m of 200 g.

A light metal disc is attached to object M and immersed in a fluid. The disc and fluid cause the oscillations of M to be damped.

The disc and M are displaced downwards and released. Fig. 6.2 shows the variation with time t of the amplitude A of the oscillations of M.
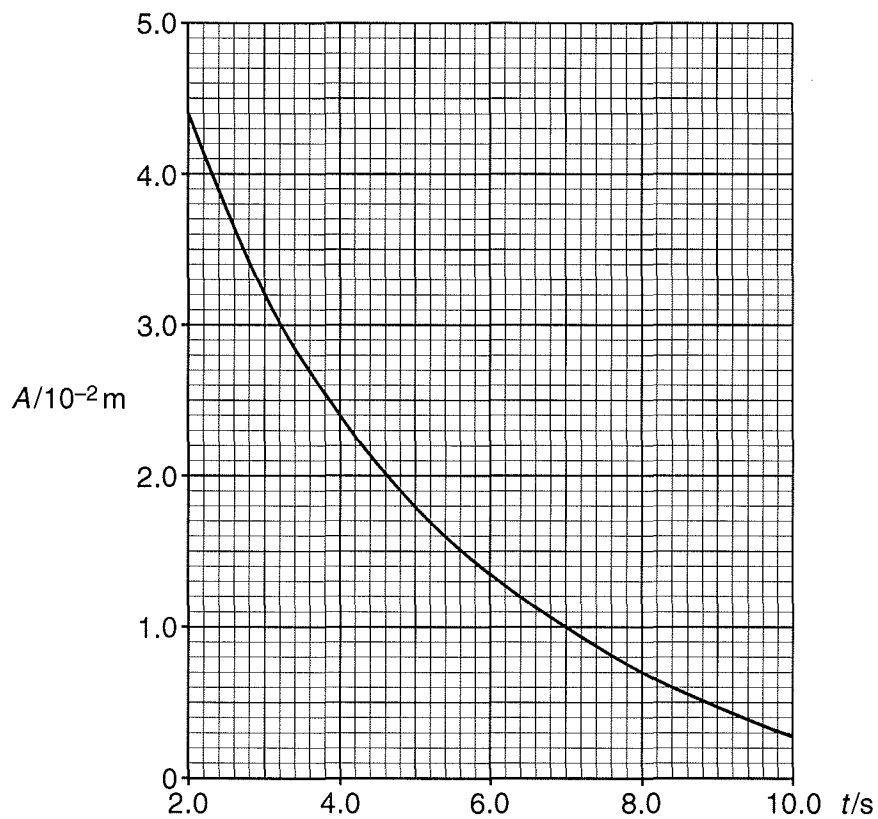

Fig. 6.2

(a) State and explain the variation with t of the **rate** of change of A.

....

.... [1]

(b) The variation with t of A is given by the expression

$$A = A_0 e^{-bt/2m}$$

where A_0 is the amplitude at $t = 0$ and A is the amplitude at t. The mass of the oscillator is m. The constant b is dependent on the fluid that produces the damping of the oscillator.

An experiment is carried out to determine b. The value of A is determined at $t = 5.0$ s for different values of m. A_0 is kept constant.

Fig. 6.3 shows the readings obtained.

m/kg	$\frac{1}{m}$/kg^{-1}	A/10^{-2}m	ln (A/m)
0.100	10.0	0.4	−5.5
0.125	8.00	0.7	−5.0
0.150	6.67	1.1	−4.5
0.200			
0.250	4.00	2.4	−3.7
0.300	3.33	2.9	−3.5
0.400	2.50	3.7	−3.3
0.500	2.00	4.4	−3.1

Fig. 6.3

(i) Use Fig. 6.2 to complete Fig. 6.3 for $m = 200$ g. [1]

(ii) Fig. 6.4 is a graph of some of the data of Fig. 6.3.

On Fig. 6.4,

1. plot the point corresponding to $m = 200$ g,

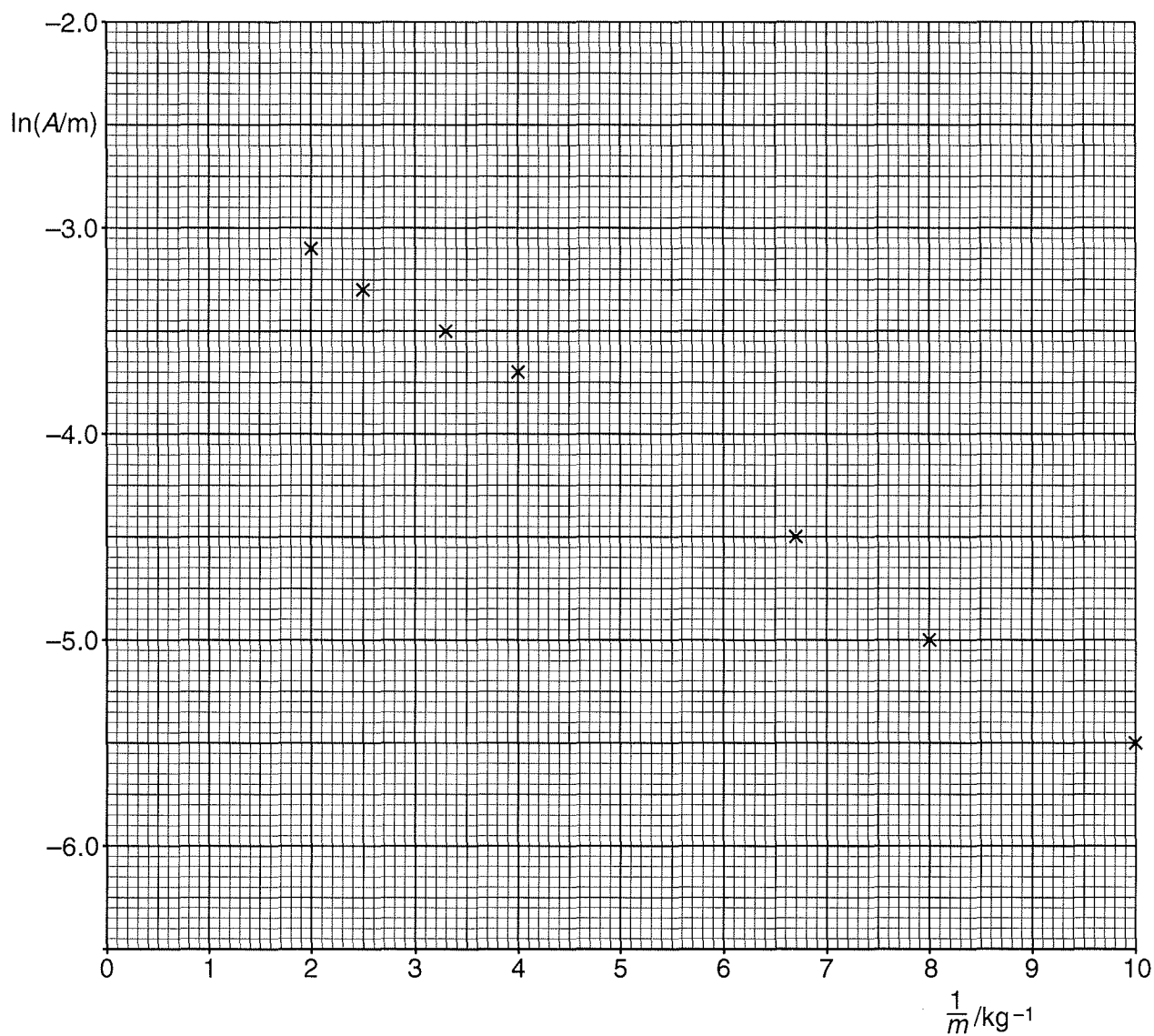**2.** draw the line of best fit for all the points.

[2]

Fig. 6.4

(iii) Determine the gradient of the line drawn in **(ii)**.

gradient = ... [2]

(iv) Explain why the graph of Fig. 6.4 supports the expression given in **(b)**.

....

....

.... [2]

(v) Determine

1. the constant b,

b = ... [2]

2. the constant A_0.

A_0 = ... m [1]

(c) Calculate the time taken for the amplitude of an oscillator of mass 500 g to decrease to half of its value at $t = 0$.

time = ... s [2]

(d) State and explain the relationship between the time taken for the energy of the oscillating system to decrease by a half, $T_{1/2}$, and the variable m.

....

....

....

.... [2]