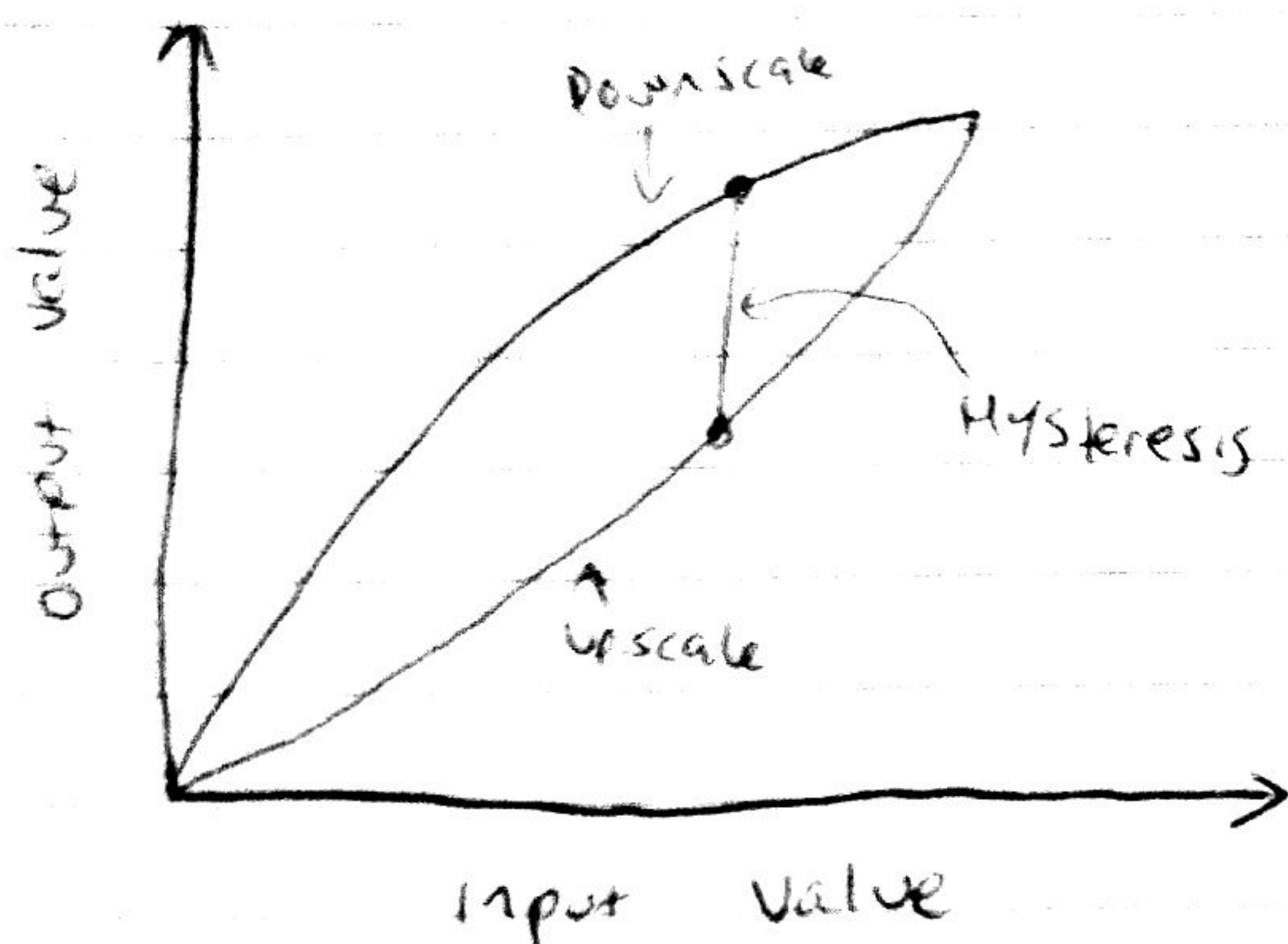


ONE

a) the ideal relationship would be a linear relationship

$$\Delta O_0 \propto \Delta I_0$$

b) Transducers can give different output value depending on whether instrument is being loaded or unloaded in terms of quantity being measured. Hysteresis error is maximum difference in output for increasing and decreasing values.



c) resistance strain gauges can be used to ~~measure~~ as a secondary element in pressure measurement. They can be joined together with bellows and diaphragms to effectively measure pressure.

2 of 10

ONE

$$d) i) \frac{C}{R} = \frac{(75 \times 10^{-3})}{0.075} \frac{(150 \times 10^{-3})}{0.15} \times 100 \times \frac{17.8}{17.8}$$

$$= \cancel{2.0025} \quad 20.025 \text{ mm}$$

$$\frac{\cancel{L}}{\cancel{mm}} \times \frac{\cancel{L}}{\cancel{L}} \times \frac{\cancel{L}}{\cancel{L}} \times \frac{\cancel{mm}}{\checkmark}$$

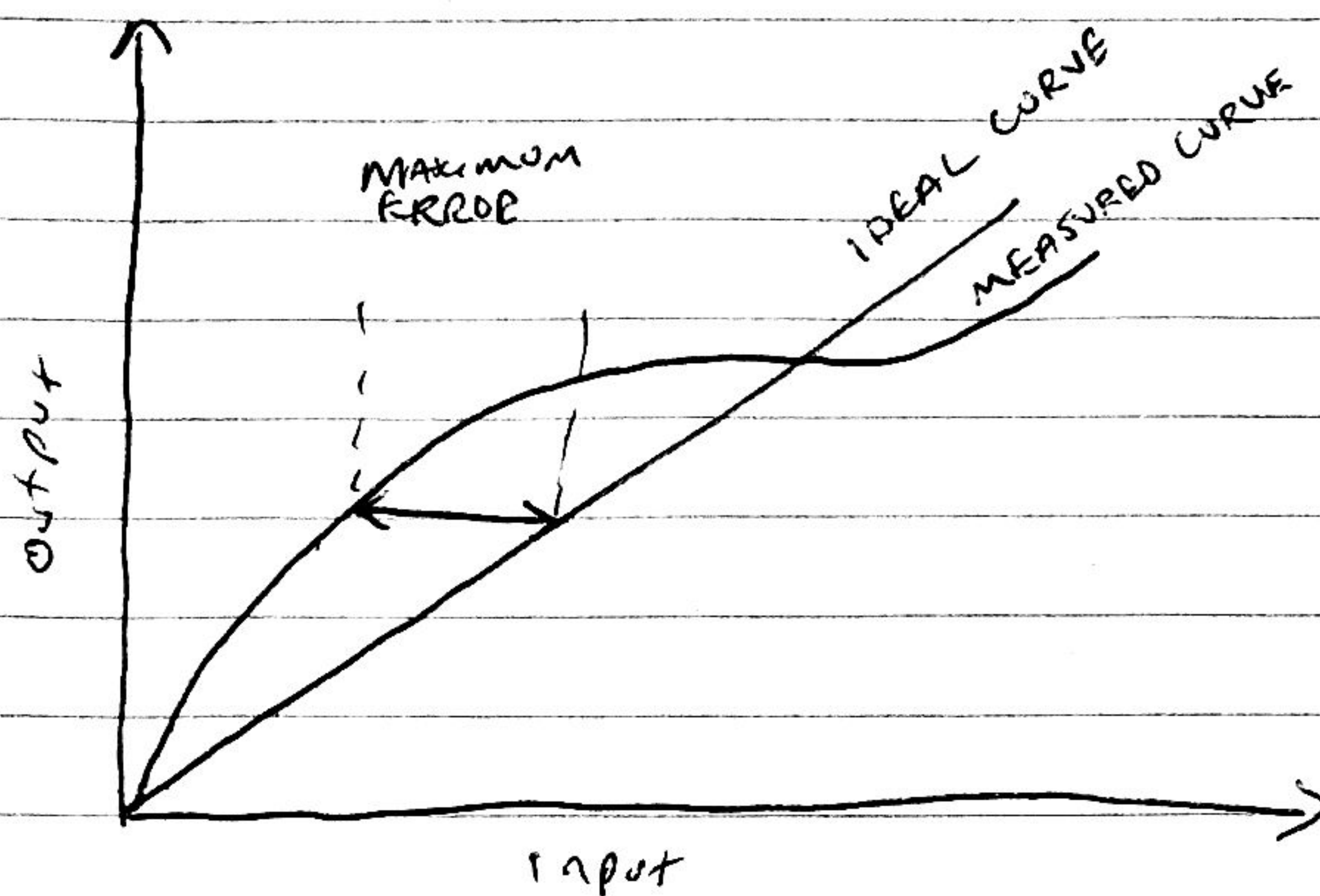
$$ii) \cancel{128} R = \frac{127.5}{20.025} \text{ mm} = 6.367 \text{ mm}$$

iii) the wheatstone bridge calculates unknown resistance in the measurement circuit. it does this by balancing two legs of the bridge circuit, one leg includes the component of unknown resistance

ONE

e)

non linearity $\neq$: relationship of output / input being truly linear is rare. When output curve produced, maximum error is determined for either input or output quantity; expressed as percentage of full range (for either input or output)



$$y = mx^2 + c \quad - \text{describes non linear curve}$$

TWO

a) a Control System is a system, which provides the desired response by controlling the output. ~~the following figure shows the system~~

Automatic process control came into being when people learned to adapt automatic regulatory procedures to manufacture products or process material more efficiently.

Such procedures are termed automatic because no human intervention is required to regulate them, allowing them to function 24/7 with reduced human costs.

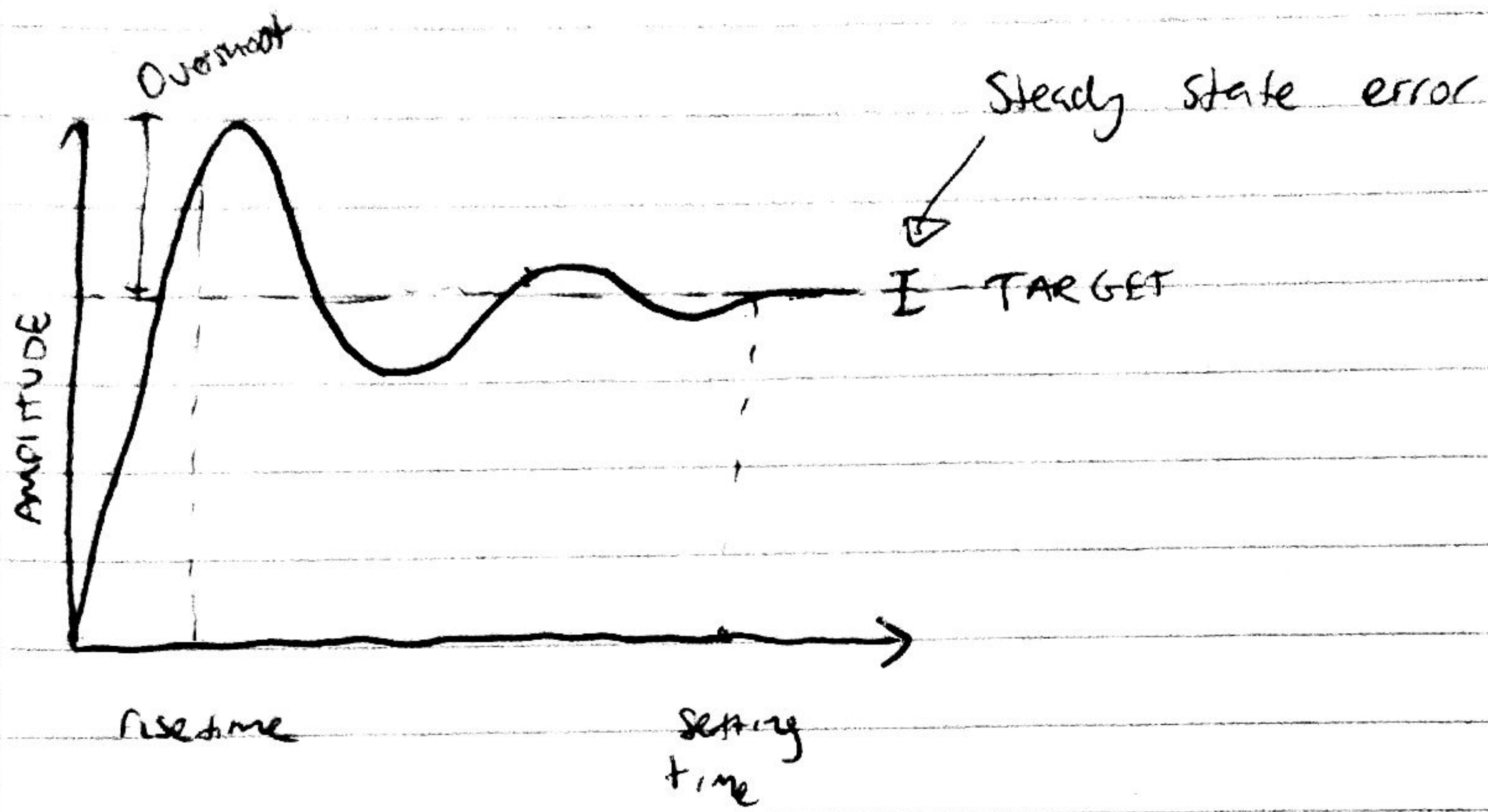
b) proportional integral derivative (PID) controller is an automatically optimized and accurate control system used to regulate different parameters like temperature, pressure and speed at desired values. The basic mechanism used in PID controllers is closed loop feedback.

A PID calculates the error by calculating difference between actual value and desired value and then sets the deciding parameters accordingly. This error is continuously being calculated until the process stops.

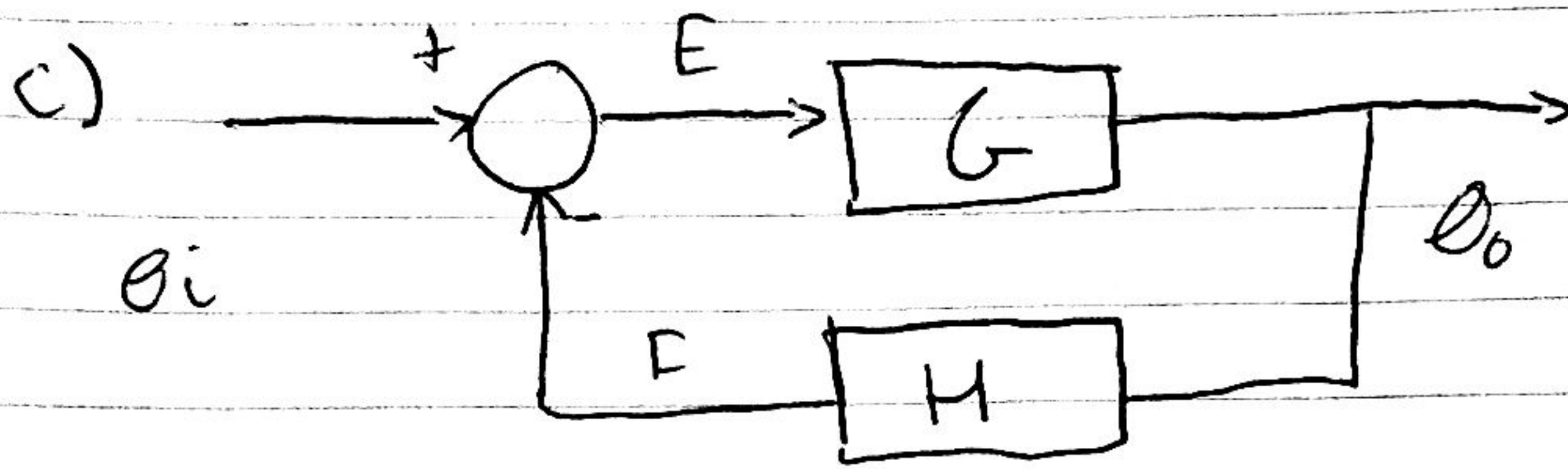
5 of 10

Two

b cont



6 of 10

Two

$$G = \frac{\theta_o}{E} \Rightarrow E = \frac{\theta_o}{G}$$

$$H = \frac{F}{\theta_o} \Rightarrow F = H \cdot \theta_o$$

$$\text{Now, } E = \theta_i - F$$

$$\therefore \frac{\theta_o}{G} = \theta_i - H \cdot \theta_o \Rightarrow \frac{\theta_o}{G} + H \theta_o = \theta_i$$

$$\text{So } \theta_o \left(1 + \frac{G \cdot H}{G} \right) = \theta_i$$

$$\therefore \frac{\theta_o}{\theta_i} = \frac{G}{1 + GH}$$

7 of 10

TWO

d)

$$\frac{\theta_o}{\theta_i} = \frac{G_1 \cdot G_2}{1 + G_1 \cdot G_2 \cdot H}$$

$$= \frac{(10 \times 2.5)}{1 + (10 \times 2.5 \times 0.15)}$$

$$\frac{\theta_o}{\theta_i} = 5.263 \text{ mm/v}$$

e) Speed control of conveyor belt
 Temperature control of brewing process

FOUR

$$a) \quad m \frac{d^2 x}{dt^2} + C \frac{dx}{dt} + kx = F$$

$$S.F = \frac{d^2 x}{dt^2} + \frac{C}{m} \frac{dx}{dt} + \frac{k}{m} x = \frac{F}{m}$$

~~1. Appt~~ values

$$\frac{d^2 \theta_o}{dt^2} + 2\zeta \omega_n \frac{d\theta_o}{dt} + \omega_n^2 \theta_o = b_1 \omega_n^2 \theta_i$$

$$\omega_n^2 = \frac{k}{m} \quad \theta_o = x \quad \& \quad 2\zeta \omega_n = \frac{C}{m}$$

$$\omega_n^2 = \frac{4000}{14.5} \quad \omega_n = \sqrt{275.87}$$

$$\omega_n = 16.61$$

$$2\zeta \omega_n = \frac{C}{m} = \frac{200}{14.5}$$

$$\zeta = \frac{200}{14.5 \times 16.61 \times 2} = 0.415$$

 $\therefore$ underdamped

Four

b)

$$P_0 = e^{\left(\frac{-0.415\pi}{\sqrt{1-0.415^2}} \right)} \times 100$$

$$= e^{\left(\frac{-1.304}{0.91} \right)} \times 100$$

$$= 23.86 \% \quad \text{peak overshoot}$$

$$\text{rise time} = \omega t_r = \pi/2$$

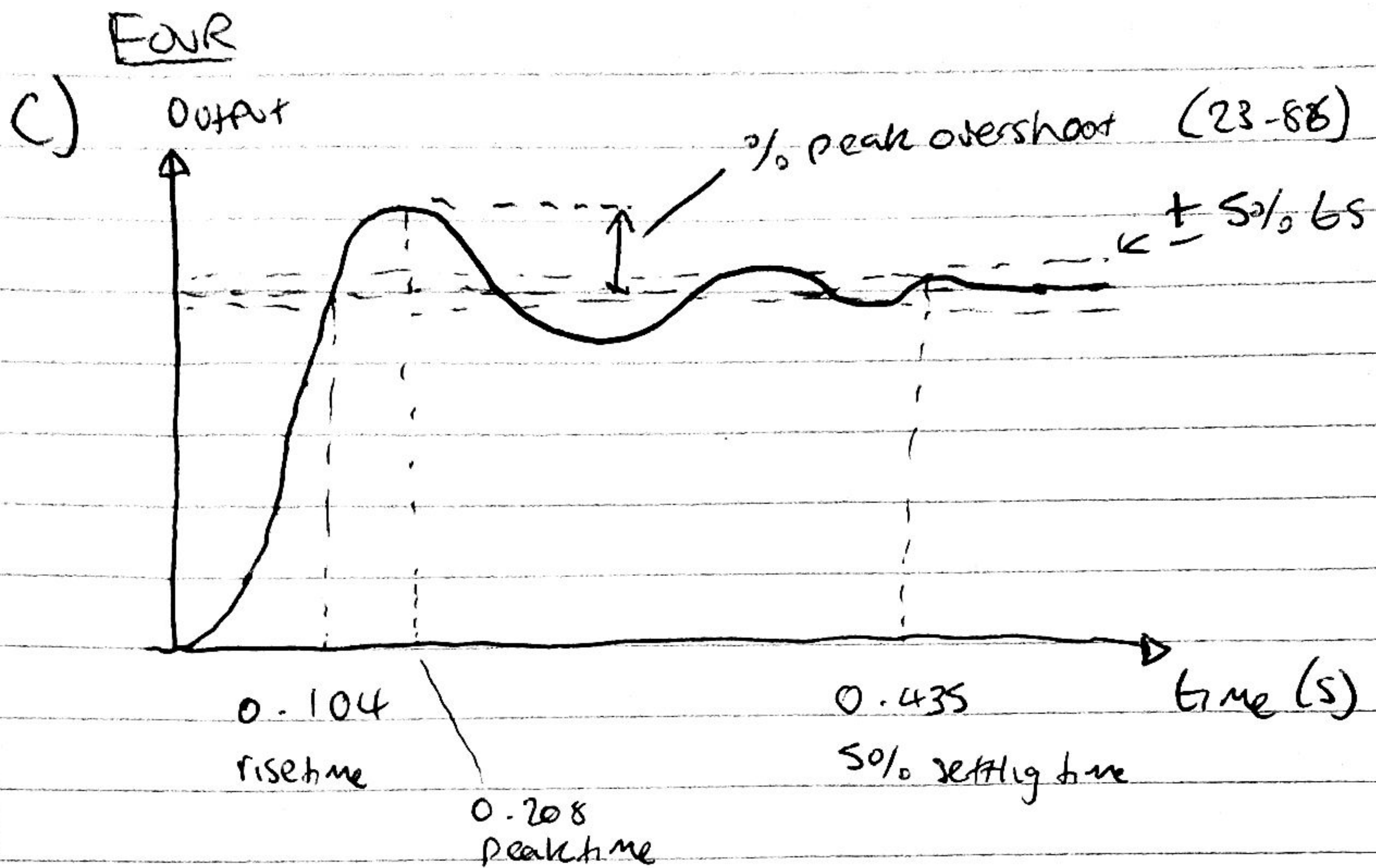
$$\omega = 16.61 \sqrt{(1-0.415^2)}$$

$$= 15.112$$

$$t_r = \frac{\pi}{15.112 \times 2} = 0.104$$

$$\text{Peak time} = \frac{\pi}{15.112} = 0.208$$

$$5\% \text{ } t_s = \frac{3}{0.415 \times 16.61} = 0.435$$



$$d) 12.5 = e^{\left(\frac{-\pi \zeta}{\sqrt{1-\zeta^2}}\right)} \times 100$$

$$\ln 0.125 = \frac{-\pi \zeta}{\sqrt{1-\zeta^2}}$$

$$-2.079 (\sqrt{1-\zeta^2}) = -\pi \zeta$$

$$4.324 (1-\zeta^2) = 9.87 \zeta^2$$

$$4.324 - 4.324 \zeta^2 = 9.87 \zeta^2$$

$$4.324 = 14.194 \zeta^2$$

$$\sqrt{0.305} = \zeta$$

$$\text{or } \zeta = 0.552$$