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ijirset@gmail.com

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PID Control System Modeling and Simulation with the Matlab Program

Guntur Haryanto

Head of General Bureau,, BPPT (Agency for the Assessment and Application of Technology), Jakarta, Indonesia

ABSTRACT: The PID controller is by far the most dominating for control apparatus in use today. Integral, proportional and derivative (I, P, D) feedback is based on the past (I), present (P) and future (D) control error. It is quite surprising how much can be achieved with such simple study. It is the first solution that should be tried when feedback is used. Therefore it is highly appropriate to have a meeting like this which is focused on PID control. Modelling is an essential and inseparable part of all scientific activity, and many scientific disciplines have their own ideas about specific types of modelling. A simulation is the implementation of a model over time. A simulation brings a model to life and shows how a particular object or phenomenon will behave. It is useful for testing, analysis or training where real-world systems or concepts can be represented by a model. The objective of this paper is to study a system modeling and simulation of the PID type of control system. Simulation is intended to get the best configuration constant P, I and D, using the MatLab software.

KEYWORDS: PID control, modeling, simulation, response, error.

I. INTRODUCTION

The development of computer technology, both hardware and software, continues to develop along with the advancement of electronic technology, as well as control technology which has made many advances from conventional control to automatic control to intelligent control. Currently, automatic control provides a very large role in human life, especially in science and industry. Some of them are robots, temperature regulation of a tank, humidity regulation in a room, air pressure in a closed pipe that is kept fixed and so on. To be able to design a good control system, analysis is needed to get an overview of the system's response to controlling action. Before being able to design a control system, it is necessary to study dynamic systems modeling [1]. The control system is needed to improve the dynamic system response in order to get the desired output signal. A good control system has a good response to various input signals. In designing this control system, it is necessary to describe the system response with input signals and control actions which include: (1) system responses to input which can be in the form of a step function, a step function, an impulse function or other functions, (2) the stability of the system being designed, (3)) system responses to various types of control actions. [2]

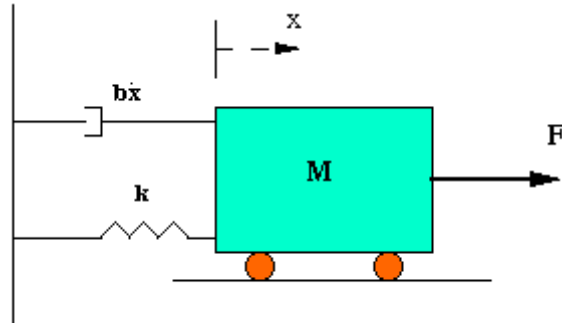
The steps that need to be done in designing a control system [3,4] as follows: (1) understanding how the system works, (2) looking for dynamic system models in differential equations, (3) obtaining system transfer functions with the Laplace transform, (4) provide control action by determining the constants K_p , K_i and K_d , (5) combining the transfer function that has been obtained with the type of control action, (6) testing the system with the input signal of the step function, step function and impulse into the new transfer function, (7)) perform the inverse Laplace transform to get the function in the time domain, (8) draw the system response in the time domain.

The purpose of this study is to study the modeling of a system and to simulate the type of PID control on the system. The simulation is intended to get the best P, I and D constant configuration using MatLab software.

II. MODELING SYSTEM

The system to be used in this simulation is a dynamic model from a simple mechanical circuit consisting of a spring, damper and mass as shown in Figure 2. Force F acts on mass M which then moves as far as X , assuming there is no friction on the wheel.

Fig.1. Schematic of system



By applying the d'Alembert principle [5] the mathematical equation model of the system is obtained as:

$$M \frac{d^2X}{dt^2} + b \frac{dX}{dt} + kX = F(t) \tag{1}$$

where b is the friction viscosity coefficient of the damper while k is the spring constant. The equation is then used as a transfer function using the Laplace transform[6] as follows:

$$Ms^2X(s) + bsX(s) + kX(s) = F(s) \tag{2}$$

So that the transfer function from displacement X (s) to input F (s) becomes:

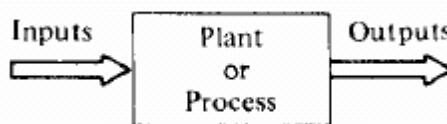
$$\frac{X(s)}{F(s)} = \frac{1}{Ms^2 + bs + k} \tag{3}$$

Open Loop System Response

From the transfer function equation (3), it can be seen that the system response to an input signal (in this case the signal step) as an open system (Figure 2). For that, take the value of M = 1 kg, b = 5 N.sec/m and k = 10 N/m, so the equation becomes:

$$\frac{X(s)}{F(s)} = \frac{1}{s^2 + 5s + 10} \tag{4}$$

Fig. 2. Open-loop system

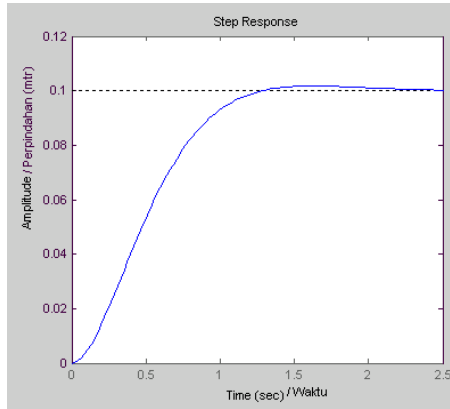


With the MatLab program equation (4) can be written as follows:

```
num=[1];
den=[1 5 10];
sistem1=tf(num,den);
step(sistem1)
```

while the system response to the step signal is shown in Figure 3.

Fig. 3. Response or displacement due to force F with time

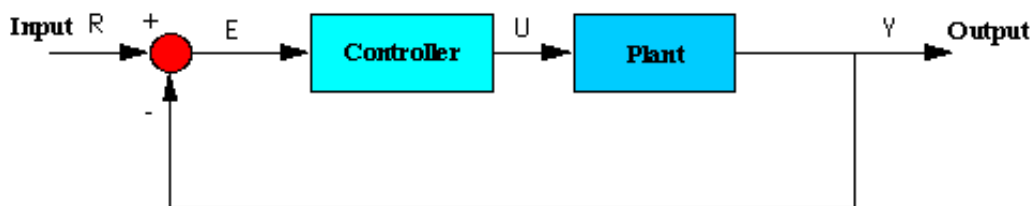


The magnitude of the gain from the transfer function equation (4) is 1/10, so that the output value that can be achieved by the input step signal is 0.1, this results in a steady-state error of 0.90 or 90%. From Figure 3, it can be seen that a rise time of about 1 second is required and a settling time of about 2 seconds.

III. METHODOLOGY

The signal response with the open-loop system above is undesirable in studying or measuring the characteristics or properties of the system. To improve this, the above system is converted into a closed-loop system by implementing control over the system with the aim of reducing the steady-state error, rise time and settling time [7]. The type of control used is PID. PID controller is one type of controller that is widely used. In addition, this system is easy to combine with other control methods such as Fuzzy and Robust, so that it can become a better control system [8]. The design of this system refers to the unity feedback system as in Figure 4.

Fig. 4. Closed-loop system with unity feedback



The PID control system consists of three control methods, namely P (Proportional), D (Derivative) and I (Integral) controls, each of which has advantages and disadvantages. In its implementation, each method can work alone or a combination of them. The transfer function $H(s)$ in the PID control system is a quantity whose value depends on the constant values of the P, I and D systems:

$$H(s) = \frac{K_d s^2 + K_p s + K_i}{s^3 + K_d s^2 + K_p s + K_i} \tag{5}$$

In designing a PID control system what needs to be done is to adjust the P, I or D parameters so that the response of the system output signal to a certain input signal is desired. The design of the PID control system is generally carried out by the trial and error method, this is because the parameters of K_p , K_i and K_d are not independent. The characteristics of each parameter [9] are presented in Table 1.



Table 1. Effect of PID control on closed-loop systems

Respon closed-loop	Rise time	Overshoot	Settling time	Steady-state error
K_p	decrease	increase	change slightly	decrease
K_i	decrease	increase	increase	eliminate
K_d	change slightly	decrease	decrease	change slightly

Exemplar based inpainting technique is used for inpainting of text regions, which takes structure synthesis and texturesynthesis together. The inpainting is done in such a manner, that it fills the damagedregion or holes in an image, with surrounding colour and texture. The algorithm isbased on patch based filling procedure. First find target region using mask image and then find boundary of target region. For all the boundary points it defined patch andfind the priority of these patches. It starts filling the target region from the highestpriority patch by finding the best match patch. Thisprocedure is repeated until entire target region is inpainted.

The algorithm automatically generates mask image without user interaction that contains only text regions to be inpainted.

IV. RESULTS AND DISCUSSION

Proportional Control

Referring to Table 1, the characteristics of the proportional control action are to reduce the rise time, increase the overshoot, and reduce the steady-state error. The system transfer function by adding the K_p control action becomes:

$$\frac{X(s)}{F(s)} = \frac{K_p}{s^2 + 5s + (10 + K_p)} \tag{6}$$

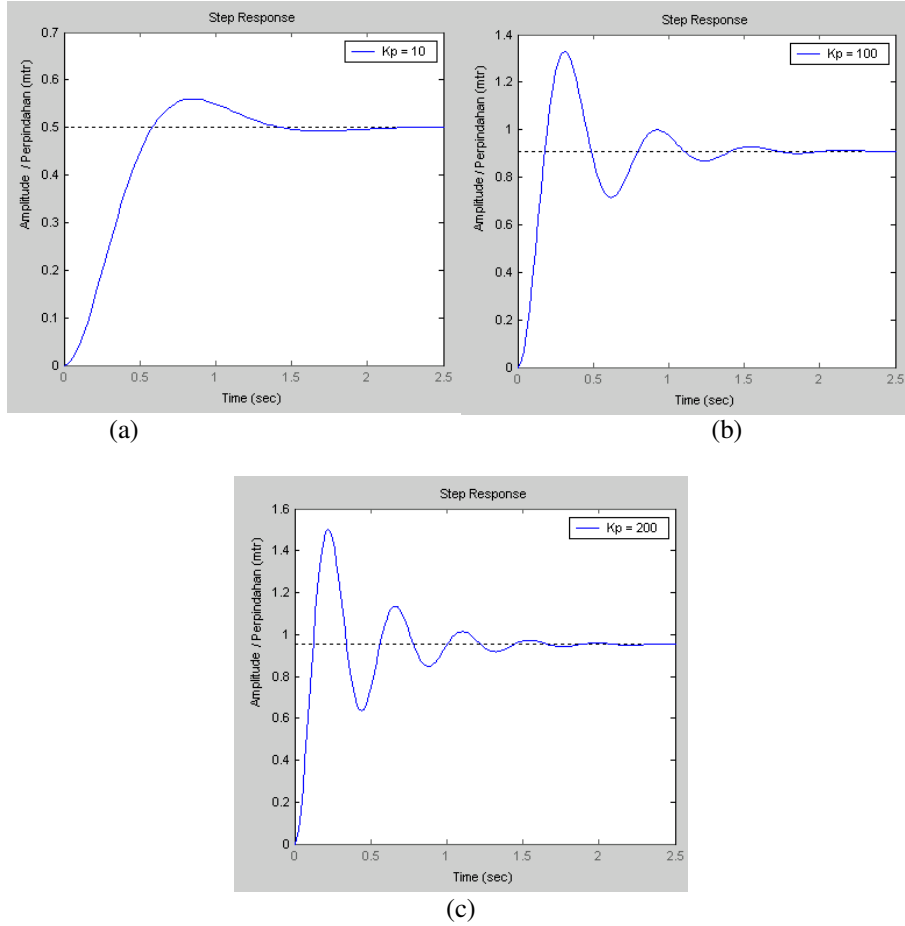
Because PID control is trial and error, several K_p values were tried to get the desired results. K_p values are given as 10, 100 and 200, the response plot is shown in Figure 4. From this figure, it can be seen that the addition of the P control action has the effect of reducing the rise time and ss error, while the settling time is relatively unchanged. The greater the K_p value, the better the rise time and the smaller ss error, but consequently the overshoot also increases quite large in proportion to the increase in the K_p parameter.

MatLab program for $K_p = 100$:

```
kp=100;
num=[kp];
den=[1 5 10+kp];
kp100=tf(num,den);
step(kp100)
```



Fig. 4. Response of closed-loop system with (a) $K_p = 10$, (b) $K_p = 100$ and (c) $K_p = 200$



Proportional-Derivative(PD)Control

As with proportional control parameters, the system transfer function with proportional-derivative (PD) control becomes:

$$\frac{X(s)}{F(s)} = \frac{K_d s + K_p}{s^2 + (5 + K_d)s + (10 + K_p)} \tag{7}$$

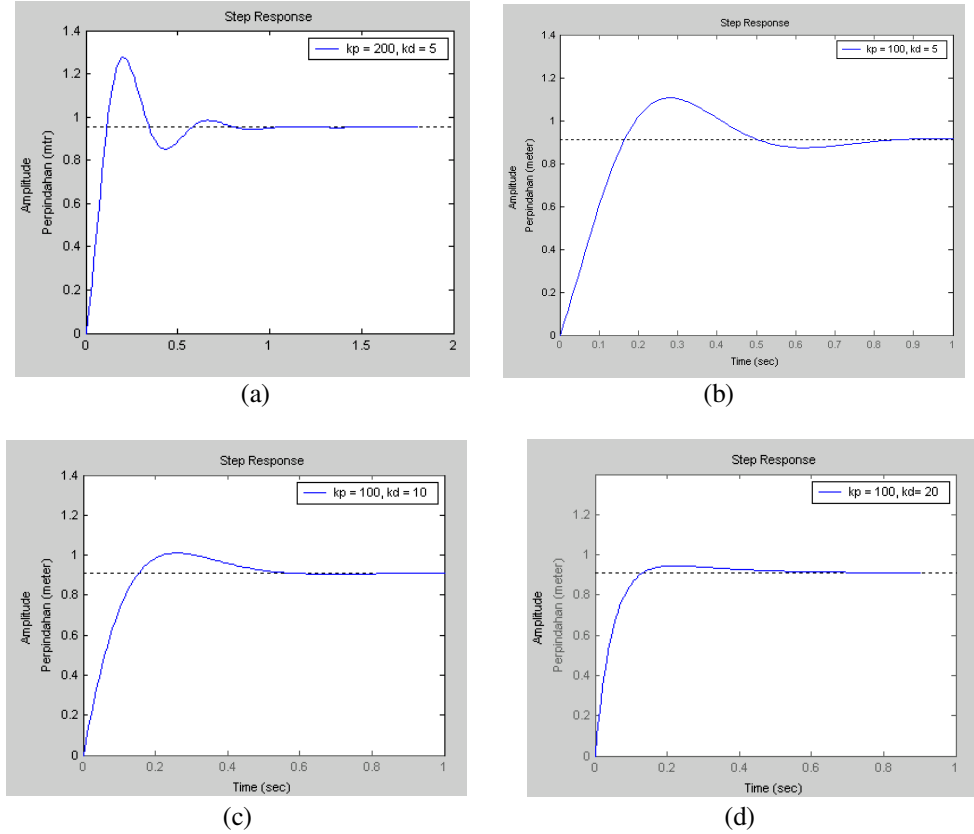
Furthermore, the system response will be seen by taking the value of $K_p = 100$ and the value of $K_d = 5$, $K_d = 10$ and $K_d = 20$. The system response to PD control is shown in Figure 5.

MatLab Program for $k_p = 200$ and $k_d = 15$:

```
kp=200;
kd=15;
num=[kp];
den=[1 5+kd 10+kp];
kp200d15=tf(num,den);
step(kp200d15)
```




Fig. 5. Response of system with (a) $K_p = 100, K_d = 5$; (b) $K_p = 100, K_d = 5$; (c) $K_p = 100, K_d = 10$ dan (d) $K_p = 100, K_d = 20$



It can be seen at Fig. 5 that the use of Proportional Derivative (PD) control can reduce overshoot and downtime, but the steady state error does not change significantly.

Proportional-Integral (PI) Control

The form of transfer function system with proportional-derivative (PI) control is:

$$\frac{X(s)}{F(s)} = \frac{K_p s + K_i}{s^3 + 5s^2 + (10 + K_p)s + K_i} \tag{8}$$

Integral control has the characteristics of reducing the rise time, increasing overshoot and decreasing time, but it has advantages that other types do not have, namely eliminating ss error. The P and I Controllers have the same characteristics in terms of rise time and overshoot. Therefore, the value of K_p must be reduced to avoid excessive overshoot. The value of K_i is taken to be greater than K_p , because it is desirable to eliminate the steady state error. If $K_p > K_i$, then the steady state error cannot be eliminated.

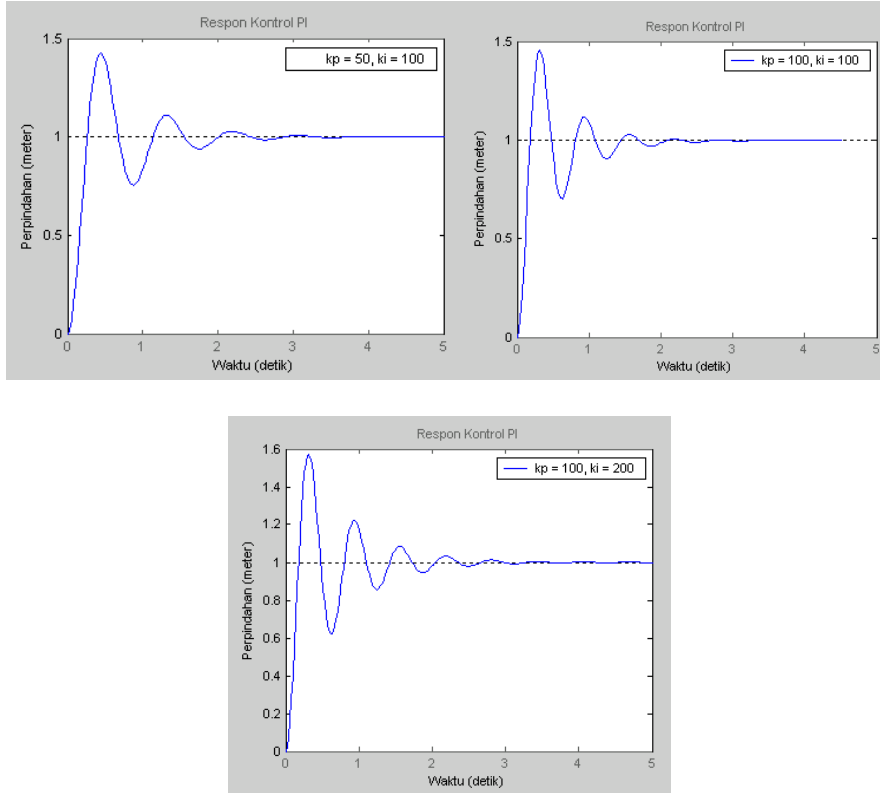
To see the closed-loop system response from PI control, take $K_p = 50$ and $K_i = 100$, $K_p = 100$ and $K_i = 100$, and $K_p = 100$ and $K_i = 200$. The response graph is shown in Figure 6, while the MatLab program is as follows :

```

kp=100;
ki=100;
num=[kp ki];
den=[1 5 10+kp ki];
kp100i100=tf(num,den);
step(kp100i100)
    
```



Fig. 6. System response to multiple PI control combinations



From Figure 6 above, it can be seen that the system's rise time decreases and the SS error can be minimized or even eliminated, but the result or system response with PI control is not optimal because it still experiences quite large overshoot compared to the previous control action.

Proportional-Integral-Derivative (PID)Control

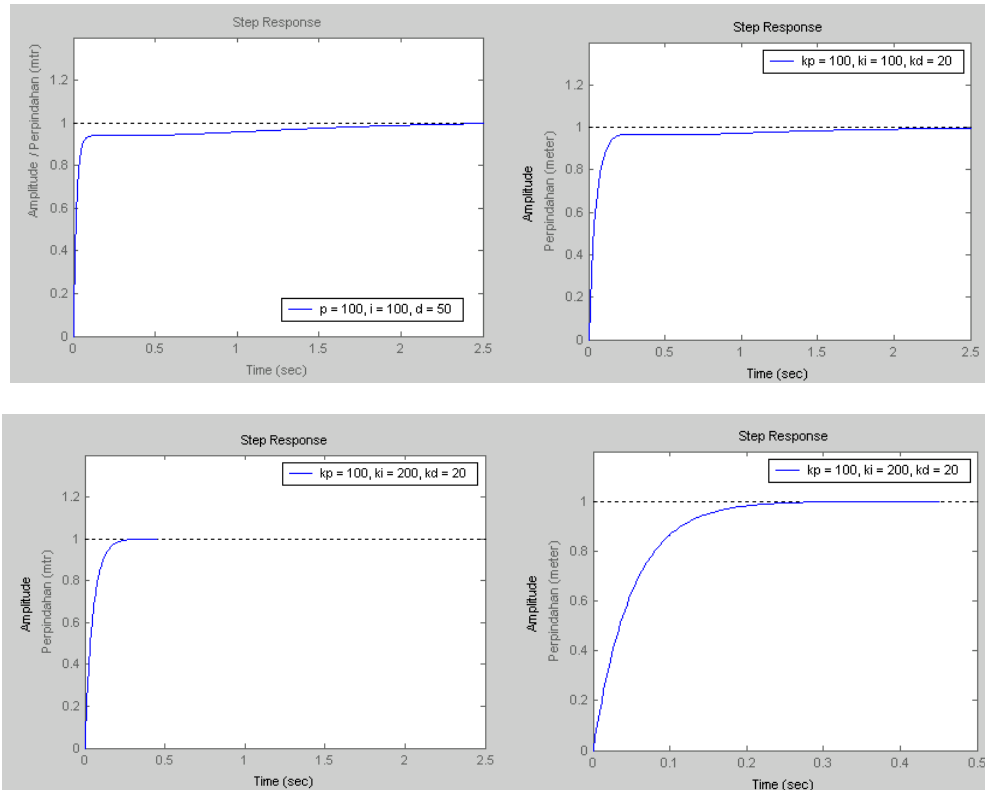
The PID control action is a combination of the P, I and D actions so that the system transfer function becomes:

$$\frac{X(s)}{F(s)} = \frac{K_d s^2 + K_p s + K_i}{s^3 + (5 + K_d) s^2 + (10 + K_p) s + K_i} \tag{9}$$

The equation above is written in the MatLab program as follows, while the system response to PID control can be seen in Figure 7.

```
kp=100;
ki=200;
kd=20;
num=[kd kp ki];
den=[1 5+kd 10+kp ki];
kp100i200d20=tf(num,den);
step(kp100i200d20)
```


Fig. 7. System response to PID control action



From Figure 7, it can be seen that the best response occurs at the values of $K_p = 100$, $K_i = 200$ and $K_d = 20$. In this combination of values, it can be seen that the output or system response is as desired, namely the response does not experience overshoot and does not have a steady-state error, rise.time and settling time is fast (about 0.1 second and 0.2 second respectively), much better than the open-loop system (without control) where the rise and settling times take 1 and 2 seconds.

V. CONCLUSION

1. System modeling is very useful in studying the characteristics of the system's response to an input, in this paper it is the displacement response to the force input applied to the system.
2. Using mathematical model as the transfer function is an important step in studying a model simulation. The transfer equation has been able to explain the model well.
3. The simulation of PID control on the mass-spring-damper system has been able to produce the desired output or response at values of $K_p = 100$, $K_i = 200$ and $K_d = 20$.

REFERENCES

- [1] Leigh JR, "Applied Digital Control: Theory, Design and Implementation", Prentice-Hall Englewoods Cliffs, New Jersey, 1985.
- [2] Bolton W, "Control System", Elsevier Pub. Co. (<http://www.sciencedirect.com>), 1992
- [3] Ogata K, "Teknik Kontrol Automatik", Jilid I dan II, Edisi 2, Penerbit Erlangga, Jakarta, 1997.
- [4] Manalu LP, "Sistem Pengontrolan Kondisi Udara pada Alat Pengering Terkendali", Jurnal Dinamika Penelitian Industri. vol 21, no 2, pp. 91-98, 2010.
- [5] Ziemer RE, Tranter WH and Fanin DR, "Signal and System, Continous and Discreet", 2nd Edition. McMillan Pub. Co., New York, 1990.
- [6] Anonimous, "Control tutorial for MatLab and and Simulink", (<http://www.library.cmu.edu/ctms>). 2008.



- [7] Manalu LP, “Aplikasi Kontrol Digital untuk Pemupukan Secara Variable Rate pada Sistem Pertanian Presisi”, Jurnal Sains dan Teknologi Indonesia, vol 15,no 3, 2013.
- [8] Doebelin, O, “Measurement System, Application and Design”, 4th Edition, McGraw-Hill Pub. Co., New York, 1990.
- [9] Suarga, “Fisika Komputasi, Solusi Problema Fisika dengan MatLab”, Penerbit Andi, Yogyakarta, 2007.



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