UNIVERSITAS GADJAH MADA
FAKULTAS TEKNIK
Departemen Teknik Elektro dan Teknologi Informasi

Program Studi S1 Teknik Elektro, Teknologi Informasi dan Teknik Biomedis
Soal Ujian Akhir Semester Genap 2020/2021
Fisika Teknik (TKIE161202)
Bersifat Buku Terbuka
Waktu 110 Menit + 20 Menit untuk foto, editing dan upload jawaban Anda

Learning Objectives :

[LO4] Mahasiswa dapat menyelesaikan masalah terkait Rotasi benda rigid & dinamikanya
[LO5] Mahasiswa dapat menyelesaikan masalah terkait gerakan periodis dan gelombang akustik
[LO6] Mahasiswa dapat menyelesaikan masalah terkait temperatur, bahang, properti termal materi, hukum Thermodinamika I & II

General Instructions:

1. **There are 4 problems given this exam.**
2. **In your work, show the detailed steps of your calculations to demonstrate your understanding. Failing to do so will cost you point deductions.**
3. **No collaboration is allowed in any form. If you discuss with others, you are unlikely to finish all the problems. Focusing on your work will be the best way.**
4. **Each student has mostly unique problems and hence unique answers. Even for the same problem, you should in most cases have unique answers. Very similar answers to your friends will draw my attention to check if you collaborate with others.**
5. **You must copy the following paragraph before start working on the problems. Failing to do so will result in getting ZERO point.**

"Saya yang bertandatangan di bawah ini, secara sadar dan sungguh-sungguh akan mengerjakan soal Ujian Akhir Semester Fisika Teknik dengan jujur, tidak bertanya, berdiskusi dan bekerjasama dengan teman/orang lain, tidak mencari pertolongan dengan cara, media dan bentuk apapun, dan tidak akan saling membagi jawaban selama masa ujian berlangsung. Bila saya melanggar, saya siap menerima konsekuensi berupa UAS saya tidak akan dinilai sama sekali dan dianggap bernilai NOL."

(Kota, Tanggal/Bulan/Tahun)
<Tanda Tangan>
(Nama Lengkap)

0) Initializing the Variables

Before you start working on the problems, let us perform an initialization to set up the value of variables β_1, β_2, β_3, β_4 and β_5 that we are going to use throughout this test. The values depend on the combination of your own 6-digit NIU (Nomor Induk Universitas) and 5-digit NIF (Nomor Induk Fakultas). The β_i value is calculated using the following function:

$$\beta_i = 1 + (NIU_{i+1} + NIF_i)\ modulo\ 6$$

Where NIU_{i+1} indicates the ($i+1$)-th digit of your NIU, and NIF_i indicates the i-th digit of your NIF. As an example, suppose that your NIU is 488263 and your NIF is 46238. We can arrange the following table:

i	**1**	**2**	**3**	**4**	**5**	**6**
NIU_i	4	8	8	2	6	3
NIU_{i+1}	8	8	2	6	3	-
NIF_i	4	6	2	3	8	-
NIU_{i+1} + NIF_i	12	14	4	9	11	-
(NIU_{i+1} + NIF_i) *modulo 6*	0	2	4	3	5	-
$\boldsymbol{\beta_i}$	**1**	**3**	**5**	**4**	**6**	**-**

Therefore, the β_i values for your case are:

$$\beta_1 = 1 \ \ ; \ \ \beta_2 = 3 \ \ ; \ \ \beta_3 = 5 \ \ ; \ \ \beta_4 = 4 \ \ ; \ \ \beta_5 = 6$$

Note : Your calculation must be WRONG if your β_i value is less than ONE or more than SIX.

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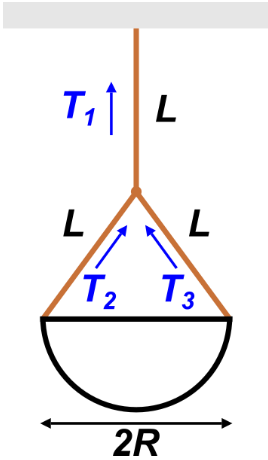
1) [25 points] Hanging Flower Pot



Consider a hanging flower pot shown in the figure above. For simplicity, let us assume that the flower pot is supported by 3 different strings (T_1, T_2 and T_3) with length L given by

$$L = (4\beta_1 \times 10)\ cm$$

The flower pot can be modeled as a half-sphere with total weight W and radius R given by

$$R = \left(\frac{\beta_2}{2} \times 10\right) cm$$

a) **[5 points]** Determine the value of η, which is defined as

$$\eta = 1 - \left(\frac{R}{L}\right)^2$$

b) **[15 points]** Suppose that the flower pot's weight is given by

$$W = \left(40 \times \sqrt{\beta_1^2 - \left(\frac{\beta_2}{8}\right)^2}\right) N$$

Determine the tension of <u>all strings</u>!

It is known that the maximum tension that can be allowed by the strings is

$$T_{max} = (\beta_3 \times 50) N$$

before the strings break.

c) [5 points] Determine the value of W_{max}, the maximum flower pot's weight that still can be supported by the strings!

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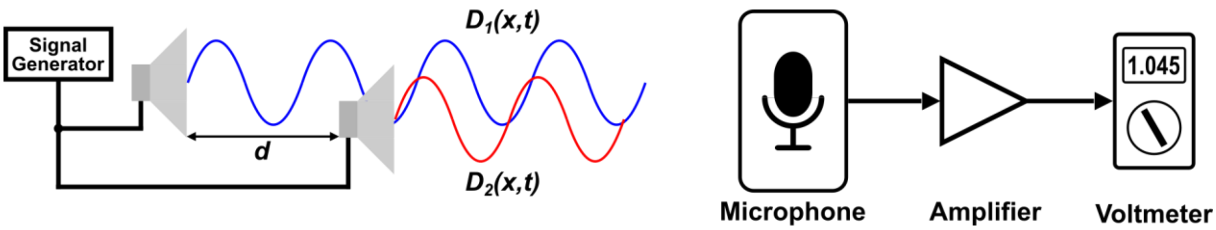
2) [25 points] Measuring Speed of Sound

Jeon Jung-Kook (전정국), who is an electrical engineering student, is playing his flute inside his bedroom. However, the flute sounds out-of-tune, and he is 100% sure that the flute itself is fully fine, nothing is broken. So he thinks that the speed of sound inside his bedroom must be deviating from the normal value due to the temperature inside his bedroom.

To verify his hypothesis, he then prepares a simple experiment to measure the speed of sound inside his bedroom, adopting the concept of interference which he learnt in physics class. He uses a signal generator, 2 (two) speakers, a micropohone, an amplifier, and a voltmeter for his experiment. Signal generator and speakers are utilized to generate sound waves with a specific frequency, whereas the microphone, with the help of amplifier and voltmeter, is utilized to detect the resulting sound intensity generated by the two speakers.

Experimental Setup



The experimental setup is shown in the figure above. A sinusoidal wave with frequency f is generated by the signal generator. Then the two speakers, which are separated by distance d from each other, produce sound waves with the same frequency. Suppose that the speed of sound inside the room is v_s.

a) **[8 points]** Determine the value of f_{min} and f_{max}, the sound frequency when the the two speakers produce destructive and constructive interference, respectively! Express your answer in terms of d and v_s!

Experimental Data

Jung-Kook starts collecting experimental data by changing the frequency f generated by signal generator, and then he measures the resulting sound intensity using voltmeter. Let us assume that the relation between sound intensity I received by the microphone, and the voltage V measured by the voltmeter is given by

$$V = c\left|\sqrt{I}\right|$$

where c is a proportional constant. The experimental data collected by Jung-Kook is shown in the table below.

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f (Hz)	*V* (Volt)
225	1.384
450	1.055
675	0.568
900	0.000
1125	0.557

f (Hz)	*V* (Volt)
1350	1.016
1575	1.308
1800	1.393
2025	1.264
2250	0.949

f (Hz)	*V* (Volt)
2475	0.503
2700	0.000
2925	0.481
3150	0.869
3375	1.109

f (Hz)	*V* (Volt)
3600	1.171
3825	1.056
4050	0.788
4275	0.416
4500	0.000

Suppose that the distance between the two speakers is given by

$$d = \left(\frac{\beta_1}{\beta_2} \times 20\right)\ cm$$

b) **[13 points]** Based on this experimental data, please help *Oppa* Jung-Kook to determine the speed of sound v_s inside his bedroom!

Validation

To verify whether his experimental result is valid or not, Jung-Kook performs one final experiment. He changes the distance between the speakers into

$$d = \left(\frac{\beta_3}{\beta_4} \times 10\right)\ cm$$

Starting from 0 Hz, he then slowly increases the sound frequency generated by the speakers.

c) **[4 points]** At what frequency *Oppa* Jung-Kook will find the first destructive ($f_{min,1}$) and constructive ($f_{max,1}$) interference at this condition?

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3) [25 points] Measuring Acceleration of Gravity

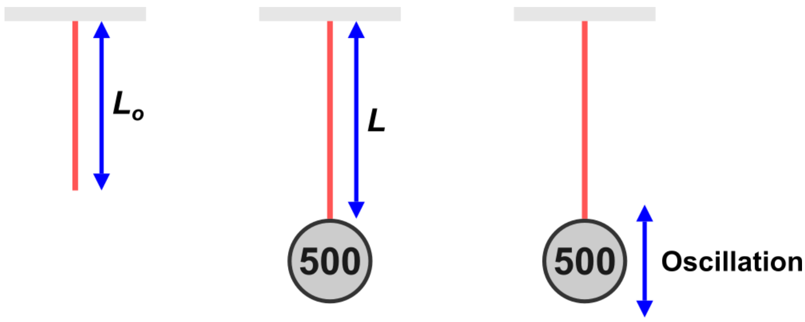
It is known that the oscillation period of a spring-mass system put on a horizontal table is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

However, when the system is in vertical position, it can be proved that the oscillation period will be the same as the one in a horizontal position.

Based on this knowledge, Im Na-Yeon (임나연) performs an experiment to determine the acceleration of gravity inside her apartment. She only has a rubber band, 3 coins (500 Korean Won each), a cello tape, a ruler, and stopwatch from her smartphone. She then uses the cello tape to attach the coins to rubber band, and starts performing her experiment.

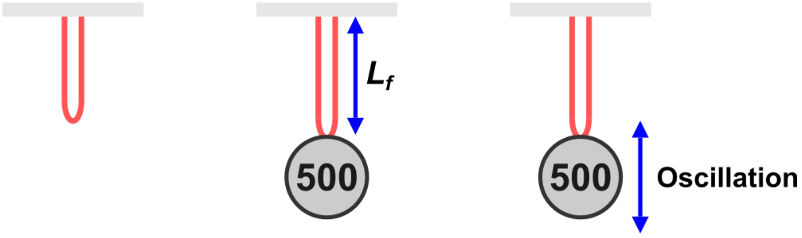
Experimental Data



Initially, the rubber band has length $L_o = 10\ cm$. She then puts the rubber band and coin system in a vertical position, and then measures the rubber band's length L. Finally, she gives a small displacement to the coins, so that the system is oscillating up and down, and then she measures the oscillation period T. She then performs this experiment for different number of coins N, and the experimental data is shown in the table below.

N	L (cm)	T (s)
1	17.3	0.551
2	24.6	0.780
3	31.9	0.955

a) **[15 points]** Based on this experimental data, please help *Noona* Na-Yeon to determine the acceleration of gravity g inside her apartment!



She then performs one final experiment by folding the rubber band in half, and then once again attach all coins to the rubber band.

b) **[5 points]** Determine the rubber band's length (L_f) in this position!

c) **[5 points]** Determine also its oscillation period when it is given a small displacement!

Mathematical Proof (Bonus Question)

d) **[10 points]** Show that the equation of motion of the rubber band-coin system in vertical position can be written as

$$\frac{d^2L}{dt^2} + c_1 L = 0$$

where L, the rubber band's length, is defined as

$$L = \Delta L + c_2$$

Variables c_1 and c_2 in these equations are arbitrary constants, where ΔL is defined as the coins' displacement from the equilibrium position.

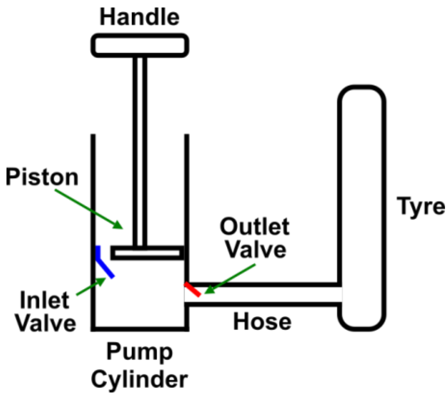
e) [**3 points]** Determine the the value of c_1 and c_2!

f) **[2 points]** Prove that the oscillation period T of a spring-mass system in vertical position is given by

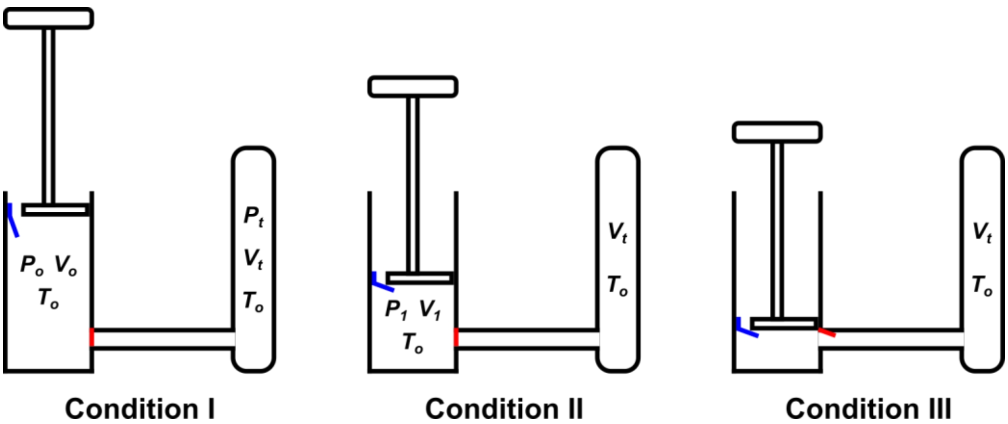
$$T = 2\pi\sqrt{\frac{m}{k}}$$

4) [25 points] Why a Bicycle Pump is getting hot?

A bicycle pump is a device utilized for pumping bicylce tyres. A bicycle pump is getting hot (increase in temperature) during the pumping process compared to the temperature before the pumping process is started. In this problem, we want to take a look at the process of pumping a bicycle tyre, and to understand why there is an increase in temperature during the pumping process.



A bicycle pump consists of several parts as shown in the figure above. It consists of a cyclinder with a piston, connected to a handle, to compress or expand the air inside the cylinder. It also consists of a hose which is used to connect the pump cylinder with the tyre. Finally, it has 2 (two) valves (inlet and outlet valve) to control the air flow inside the pump. For simplicity, we will use the model shown in the figure above for our analysis. There are 3 (three) conditions that we would like to analyze during one pumping cycle as shown in the figure below.



For simplicity, we assume that the heat exchange between the pump, the tyre and the surrounding environment takes place rapidly so that the <u>temperature</u> inside the pump and the tyre are <u>constant</u> during one pumping cycle. We will assume also the <u>tyre's volume is constant</u> during one pumping cycle. Finally, we will assume that the hose's volume is very small compared to the volume of pump cylinder and tyre, so that it can be neglected in this problem.

Initial Condition

Initially, the pump is full of air with pressure P_o, which is equal to the atmospheric pressure outside the pump, whereas inside the tyre, the pressure is P_t (Condition I). The temperature inside both pump and tyre are T_o.

a) [**5 points]** Determine the value of n_o and n_t, number of mol inside the pump and inside the tyre, respectively! Express your answer only in terms of P_o, V_o, P_t, V_t, T_o and universal gas constant R!

Process I

The air inside the pump is then compressed by pushing the piston down, increasing the pressure inside the pump and causing the inlet valve to close. This process is continued until the pressure inside the pump is equal to the pressure inside the tyre (Condition II).

b) **[6 points]** Determine the value of P_1 and V_1, air pressure and volume inside the pump at the end of Process I (Condition II), respectively! Express your answer only in terms of P_o, V_o, and P_t!

c) **[4 points]** Determine the value of Q_1, total heat added to/extracted from the pump during Process I! Express your answer only in terms of P_o, V_o, and P_t!

Process II

Equal air pressure inside the pump and the tyre causes the outlet valve to open, and the air starts to flow from the pump into the tyre. This process is continued until all the air inside the pump has been pumped into the tyre (Condition III).

d) **[6 points]** Determine the value of P_2, air pressure inside the tyre at the end of Process II (Condition III)! Express your answer only in terms of P_o, V_o, P_t, and V_t!

e) **[4 points]** Determine the value of Q_2, total heat added to/extracted from the pump during Process II! Express your answer only in terms of P_o, V_o, P_t, and V_t!

Process III (Bonus Question)

One pumping cycle is finished by pulling the piston up, closing the outlet valve and opening the inlet valve. As the result, the air from outside the pump is flowing into the pump. This process is continued until the pump reaches its initial condition (Condition I).

f) **[5 points]** Determine the value of Q_3, total heat added to/extracted from the pump during Process III!

g) **[5 points]** Finally, determine the value of Q, total heat added to/extracted from the pump during one pumping cycle! Based on this result, can you explain why the pump is getting hot during the pumping process?