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Seat Number

King Mongkut's University of Technology Thonburi

MIDTERM EXAMINATION

3rd October 2018 Examination code: PHY103/2018/2

PHY103 GENERAL PHYSICS FOR ENGINEERING I

NAME________________**Student ID**__________**Department**________

Time allowed

- The total time allowed for this examination is **3 hours (9.00-12.00)**.

Instructions

- Use black, blue or red pens, or, pencils.
- There are 22 pages in total, including the cover page.
- Answer in English. You must answer the questions in the space provided.
- Fill in your name and your information in the space provided.
- Answer **ALL** questions in part A and part C. And answer only **TWO** question from three questions in part B. If you do ALL questions in part B, the FIRST TWO questions will only be marked. Write down the number of the questions that you do on the table in page 2. Part A contains 20 marks and part B contains 20 marks. And part C contains 20 marks. The total mark is 60.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Use of an approved calculator.

This examination paper has been approved by the committee of Physics department.

Fundamental constants

Gravitational constant:	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}
Gravitational acceleration at Earth's surface:	$g = 10$ m s^{-2}
Radius of the Earth:	$R_E = 6370$ km
Mass of the Earth:	$M_E = 5.972 \times 10^{24}$ km

PART A	
QUESTION	MARK
1A	
2A	
3A	
4A	
5A	
6A	

PART B	
QUESTION	MARK

PART C	
QUESTION	MARK
1C	

PART A - SHORT QUESTIONS [Do ALL questions in this part]

QUESTION 1A

A force $\underline{F} = 10\,\hat{\underline{\mathrm{i}}} - 20\,\hat{\underline{\mathrm{j}}} + 30\,\hat{\underline{\mathrm{k}}}$ N acts on an object such that it moves from point $(20, 0, 0)$ m to $(20, 10, 0)$ m. **Find the work done by the force on this object.** [3 marks]

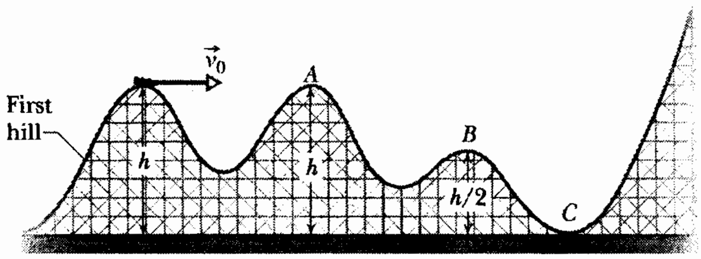
QUESTION 2A

How much work is used to accelerate a spacecraft of mass 2.9×10^5 **kg from rest to reach a speed of 11.2 km/s?** (Assuming that there are no gravity and air resistance) [3 marks]

QUESTION 3A

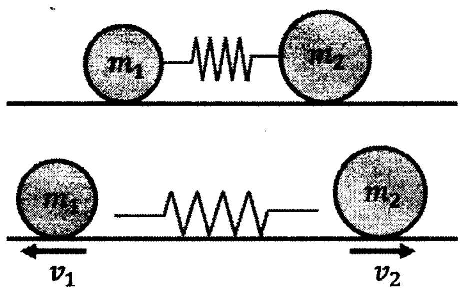
A single frictionless roller-coaster car of mass $m = 250$ kg tops the first hill with speed $v_0 = 10.0$ m/s at height $h = 20.0$ m. Assume that the rail bends smoothly and the car does not lift off the rail at all time. **What will be the difference between the speed at point B and point C?**

[4 marks]



QUESTION 4A

Two masses of $m_1 = 1$ kg and $m_2 = 2$ kg are pressed against opposite ends of a light spring of force constant $k = 24$ N/m, compressing the spring by $\Delta x = 2.0$ cm from its normal length on a frictionless horizontal table. When the spring is released,



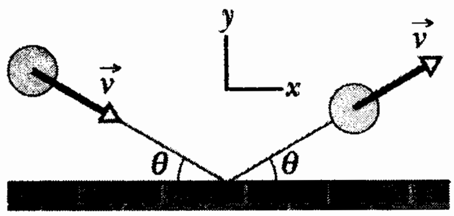
(a) **Find the speed v_1 of the mass m_1.** [2 marks]

(b) **Find the speed v_2 of the mass m_2.** [2 marks]

QUESTION 5A

A 300 g ball travels with a speed v of 6.0 m/s on a frictionless plane and strikes a wall at an angle $\theta = 30^\circ$ and then rebounds with the same speed and angle. The ball is in contact with the wall for 10 ms. **What is the magnitude of average force acted on the ball?**

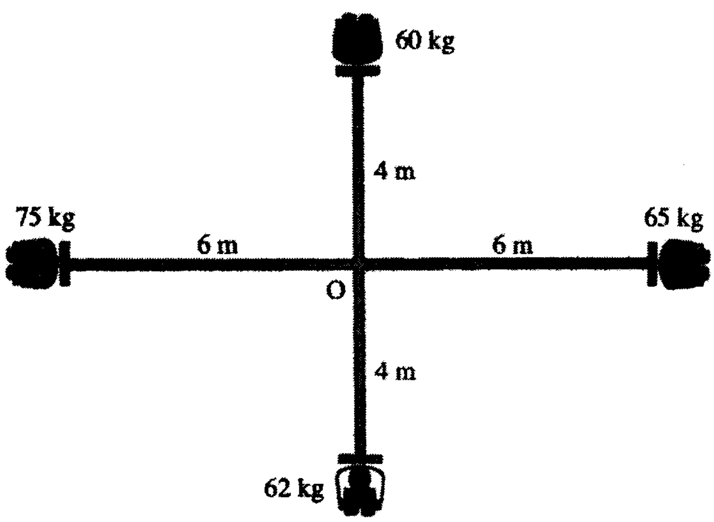
[3 marks]



QUESTION 6A

Four people of masses 60 kg, 65 kg, 62 kg and 75 kg sit on the seat of the fairground ride shown below. The seats and the connection arms are light. **Find the radius r of the circle described by the circular motion of the center of mass when the ride rotates about O.**

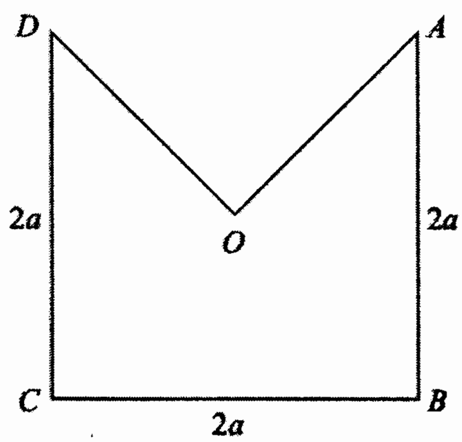
[3 marks]



PART B [Do TWO out of THREE questions in this part]

QUESTION 1B

(a) **Define centre of mass and centre of gravity of a rigid body.** [2 marks]



The uniform lamina $OABCD$, shown in the figure, is formed by removing the triangle OAD from the square $ABCD$ with centre O. The square has sides of length $2a$.

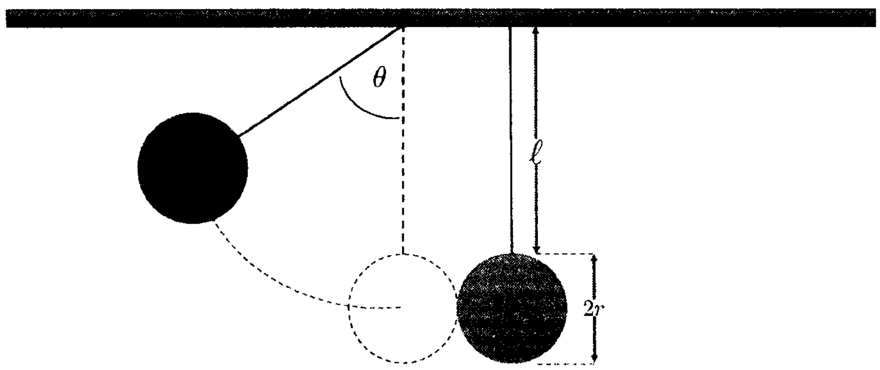
(b) **Show that the centre of mass of $OABCD$ is $2a/9$ from O.** [4 marks]

The mass of the lamina is M. A particle of mass kM is attached to the lamina at D to form the system S. The system S is freely suspended from A and hangs in equilibrium with AO vertical.

(c) **Find the value of k.** [4 marks]

QUESTION 2B

Suppose there are two spheres of radius r with masses m_1 and m_2, each of which is hanging from a horizontal bar above with a light string of the same length ℓ. Complete the following questions.



(a) Suppose that both masses are at rest at the beginning. Then m_1 is lifted in such a way that the string attached to it remains taut and makes an angle θ with the vertical as is shown in the figure. It is then released and starts to move towards m_2. **Compute the speed of m_1 just before it hits m_2** [2 marks]

(b) **Suppose the collision is *elastic*, find the *velocity* of each mass right after the collision.** [4 marks]

(c) **From the result in (b), find the *velocity* of each mass in the following special cases:**

1. $m_1 << m_2$ [2 marks]

2. $m_1 = m_2$ [2 marks]

QUESTION 3B

A fish is swimming horizontally in a lake with a constant velocity $\vec{v}$. Suppose the drag force caused by the water is $\vec{F}_{drag} = -b\vec{v}$, where b is a positive constant. Suppose also that the weight of the fish is exactly cancel out with the buoyancy (the force caused by the water that pushes the fish upwards), thus the fish does not need to swim upwards to oppose gravity. Complete the following tasks:

(a) **Show that, in order to keep its velocity constant, the fish needs to swim forward with the power**

$$P = b|\vec{v}|^2.$$

[4 marks]

(b) **Sketch the graph that shows the relationship between the magnitude of the velocity of the fish and the power it needs to keep that velocity constant.** [2 marks]

(c) **Show that the *energy* E the fish needs in order to keep swimming forward for the distance x at constant velocity is**

$$E = \sqrt{bP}x.$$

[2 marks]

(d) **Sketch the graph that shows the relationship between the distance the fish swims and the energy it needs to spend in order to keep its velocity constant.** [2 marks]

PART C [Everyone MUST DO this part]

Devastation of wind

Storm season is the period when storms usually form in a particular part of the world in a year. Unfortunately, these storms sometimes become very destructive and cause damage to the land and properties. The types of storm can be categorized by its wind speed as shown in the table below. In Asia, Japan has been recently hit by typhoon Jebi. This typhoon reports of winds up to 172 km/hour (BBC news). It made the landfall in the western areas and tear down the roofs of many buildings and railway stations. In 2018, the typhoon Mangkhut, one of the most powerful storm in history, also attacks southern China and destroys the city and transportation system. In this section. we will try to understand how a low density media like the air can be severely destructive and how we can protect our properties from it.

Types	Wind speed (km/hour)
Strong breeze	25-30
Strong storm	55-63
Violent storm	64-73
Hurricane	>74

Part A : Force from the wind

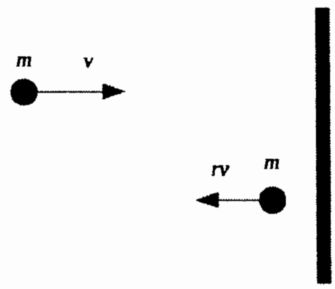


Figure 1:

To simplify the system, let's analyze the case where there is only one air molecule. Here, we will consider all air molecules as identical particles. In Figure 1, a single air molecule hits the wall with speed v. Then, the molecule bounces back with speed rv which could be less than its initial speed by the ratio r where $0 \leq r \leq 1$.

(a) If the air molecule has the mass of m, **Show that the change in momentum can be written by**

$$\Delta P = (1 + r)mv.$$

[2 marks]

(b) For the macroscopic view of the system, we will consider a column of wind with the cross section area A flowing with constant speed v as shown in Figure 2. The shaded block represents a small volume of this column of wind. There are a number of air molecules inside the block. If the air has the density of ρ_{air}, **show that the mass of the shaded block can be expressed by**

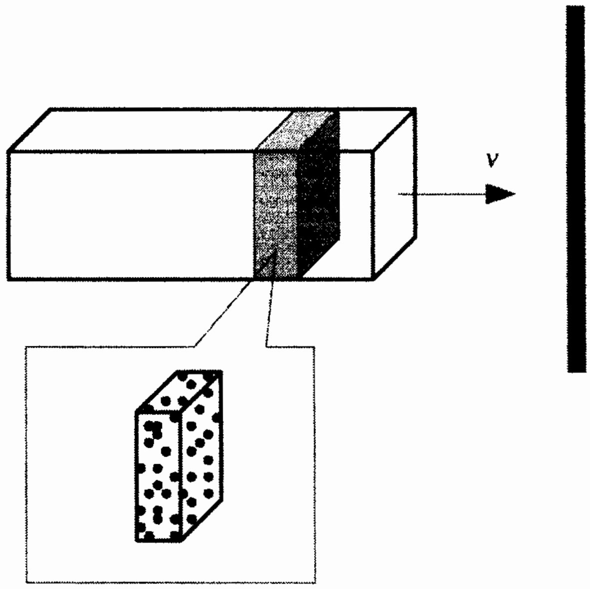


Figure 2:

$$m_{block} = \rho_{air} A v t,$$

where t is time.

[2 marks]

(c) Since all air molecules are identical, the number of molecules inside the shaded block in Figure 2 will be related to the mass of the block via the relation:

$$m_{block} = \frac{N}{N_{av}} M_{air},$$

where N is the number of molecules in the shaded block, N_{av} is Avogadro's number and M_{air} is a molecular mass of air ($28.97\ g/mol$).

Determine the number of air molecules in the shaded block.

[3 marks]

(d) **Use the definition of force, "the total change in momentum within the unit of time", to show that the force which the wind exerts on the wall is**

$$F = (1 + r)\rho_{air} A v^2.$$

[4 marks]

(e) A typical size of a window will be 80 cm by 60 cm. In this case, assume that the air molecules elastically hit the wall ($r = 1$). **Determine the force exerting on the wall if this wind is typhoon Jebi with wind speed of 172** km/h. **Given the air density is 1.40** kg/m^3. [2 marks]

Part B : Proper height of the building in hurricane area

If we happen to live in the area that the hurricane attacks from time to time, the height of the building is one of the factors that we need to consider. Sometimes, the hurricane can lift up the building and cause it to fall down as shown in Figure 3.

Figure 3:

To understand the safety margin in terms of the height of the building, we will build a model in which the building will be represented by a block with a square base of side d and height h. Assume that floor has enough friction to prevent the block from sliding when a force exerts on it. The force from the wind will apply on the whole shaded surface but we can approximate that ,on average, the force from the wind will push the block through its the center of mass as shown in Figure 4.

(f) **Draw a free body diagram of the situation in Figure 4.** [2 marks]

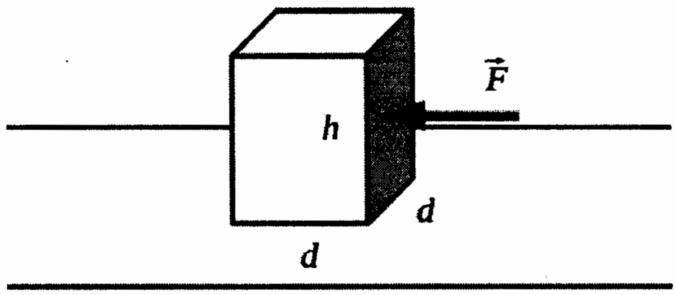


Figure 4:

(g) For the elastic collision ($r = 1$) between the wind and the object, **show that the maximum height h_{max} which the block can have in terms of the wind speed v can be expressed by**

$$h_{max} = \sqrt{\frac{Mg}{2\rho_{air}}} \cdot \frac{1}{v},$$

where M is the mass of the building, ρ_{air} is the density of air. (Hint: when the block starts to tilt due to the applying force, the base of the block will barely touch the floor.)

[3 marks]

(h) The materials for building a house weigh 50 tons. The house will be placed in the area that can experience the hurricane with wind speed 50 m/s. **Determine the maximum height for this building. Given the density of air is 1.40** kg/m^3

[2 marks]

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