University of Johannesburg

Faculty of Science

Academic Development Centre Doornfontein Campus	
Module Name Module Code	Physics (Mechanics) Theory PMIEDT01
Programme	Bachelor of Engineering Technology in Industrial Engineering Bachelor of Engineering Technology in Mechanical Engineering
November 2017 Examination	
Date Time and Duration Number of Pages Marks Examiners Moderator	20 November 2017 1230hrs – 1530hrs (3hrs) 7 116 Mr. K. Kheswa and Dr. N. Nokwara Mr. T. G. Mathe

Instructions

1. Please read and follow instructions.
2. Fill in all the required information on the front page of the answer booklet provided.
3. If you use more than one answer booklet, write your student number and full names on both booklets. Also make sure you label them 1 of 3, 2 of 3 and so forth.
4. Answer **all** questions in the answer booklet(s) provided. Your rough work must be done in the answer booklet(s), next to the particular question.
5. Number your work clearly.
6. Give all your answers in SI units and use $g = 9.81\text{m/s}^2$.
7. A data sheet is attached on the last page of this question paper.

Question 1

(a) State one difference between derived and fundamental quantities. Give an example of each. [3 marks]

(b) One of the terms in Bernoulli's equation is $\frac{1}{2}\rho v^2$, where ρ is density and v is speed. Show that this term has dimensions of pressure. [Hint: Pressure is defined as force per unit area.] [8 marks]

Question 2

(a) State two conditions necessary for free-fall. [2 marks]

(b) The height of a helicopter above the ground is given by

$$h = 3.00t^2,$$

where h is in meters and t is in seconds. At time $t = 2.00$s, the helicopter releases a small mailbag. How long after its release does the mailbag reach the ground? [7 marks]

(c) A boy attempts to shoot down a dove from the crown of a tree using a catapult. He misses and hits a branch of the tree, instead. The boy hears the sound of the impact 1.50s after releasing the stone from the catapult at a vertical speed of 9.81m/s. Taking the speed of sound in air to be 336m/s, calculate the height of the rod from the point at which stone was released (ignore the distance between the point of release and the boy's ear) if

(i) the stone is moving at a speed of 3.3m/s at the point of impact. [8 marks]

(ii) the stone just touches the rod. [6 marks]

Question 3

(a) What are the functions of the radial and tangential forces in circular motion? [2 marks]

(b) A hawk flies in a horizontal arc of radius 10.0m at constant speed 4.00m/s. Find its centripetal acceleration. [3 marks]

(c) A Northrop B-2 Stealth bomber is flying horizontally over level ground, with a speed of 225m/s at an altitude of 2.25km (see figure 1). Neglect air resistance in this problem.

(i) How far will a bomb travel horizontally between its release and its impact on the ground? [5 marks]

(ii) If a plane maintains its original course and speed, where will it be when the bomb hits the ground? [2 marks]

(iii) At what angle from the vertical should the bombsight be set so that the bomb will hit the target seen in the sight at the time of release? [2 marks]

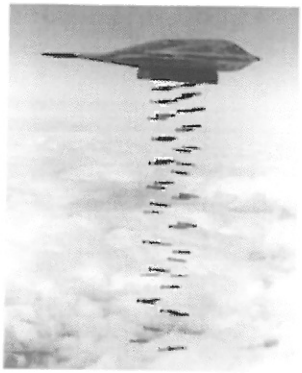


Figure 1: Stealth bomber for question 3(c).

Question 4

(a) When Jaguar launched its first sport utility vehicle, the F-Pace, the company decided to set a new world record by going through the biggest vertical, circular loop whose diameter is 19.08m (see figure 2). [You may need 1mi = 1609m.]

(i) Modeling this loop as a perfect circle, calculate the magnitude of the centripetal acceleration of the car if its speed is 51.5mi/h. [5 marks]

(ii) In which direction is this acceleration directed? [1 mark]

(iii) What is the magnitude of the centripetal force if the car and the stuntman (driver) weigh 1775kg and 70kg, respectively? [2 marks]

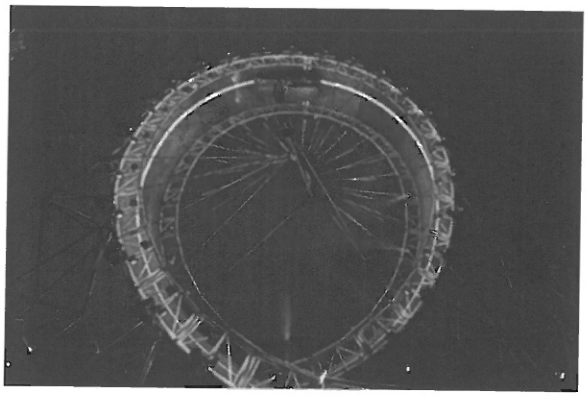


Figure 2: The Jaguar F-Pace going through the circular loop – question 4(a).

(b) An object of mass $m_1 = 4.00$kg is tied to an object of mass $m_2 = 3.00$kg with String 1 of length $l = 0.500$m. The combination is swung in a vertical circular path on a second string, String 2, of length $l = 0.500$m. During the motion, the two strings are collinear at all times as shown in figure 3. At the top of its motion, m_2 is traveling at $v = 4.00$m/s.

(i) What is the tension in String 1 at this instant? [7 marks]

(ii) What is the tension in String 2 at this instant? [3 marks]

(iii) Which string will break first if the combination is rotated faster and faster? Give a reason for your answer. [2 marks]

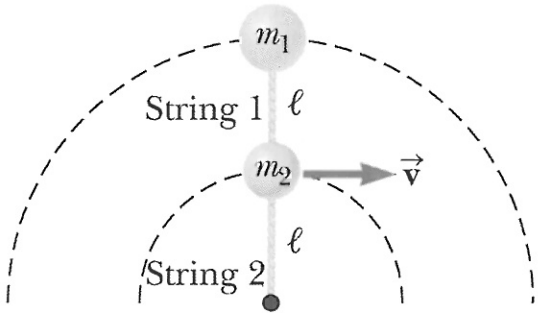


Figure 3: Connected bodies swinging – question 4(b).

Question 5

(a) What do you understand by a conservative force? [1 mark]

(b) A small particle of mass m is pulled to the top of a frictionless half-cylinder of radius R by a light cord that passes over the top of the cylinder as illustrated in figure 4.

(i) Assuming the particle moves at a constant speed, show that $F = mg\cos\theta$. [5 marks]

(ii) Find the work done in moving the particle at constant speed from the bottom to the top of the half-cylinder. [7 marks]

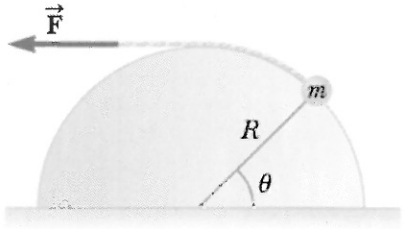


Figure 4: Object of mass m being pulled over a half-cylinder question 5(b).

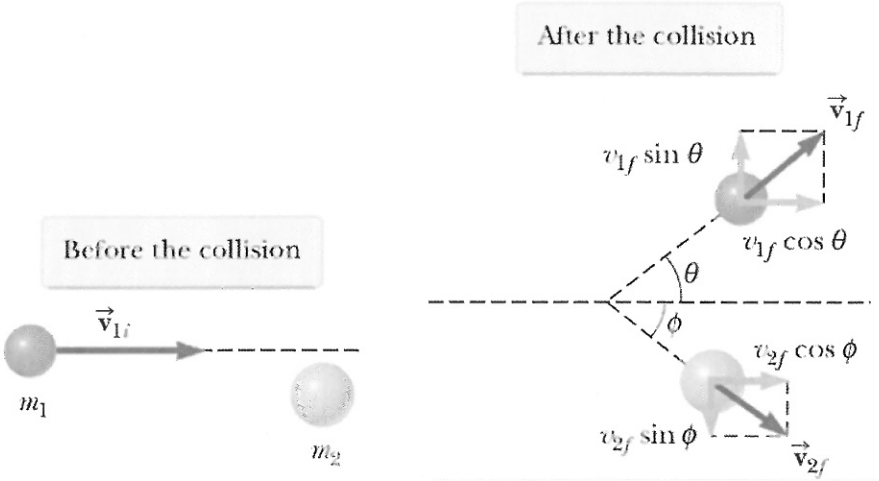
Question 6

(a) State the principle of conservation of linear momentum for a non-isolated system. [2 marks]

(b) A 0.300kg puck, initially at rest on a horizontal, frictionless surface, is struck by a 0.200kg puck moving initially along the x – axis with a speed of 2.00m/s, as shown in figure 6a. After the collision, the 0.200kg puck has a speed of 1.00m/s at an angle of $\alpha = 53.0^{\circ}$ to the positive x – axis as shown in figure 6b).

(i) Determine the velocity of the 0.300-kg puck after the collision. [4 marks]

(ii) Find the fraction of kinetic energy transferred away or transformed to other forms of energy in the collision. [3 marks]



(a) Before the collision. (b) After the collision.

Figure 5: Two hockey pucks colliding – question 6(b).

Question 7

(a) State the principle of conservation of angular momentum for an isolated system. [2 marks]

(b) A 3.0kg disc traveling at 2.0m/s strikes a 1.0kg stick of length 4.0m that is lying flat on nearly frictionless ice as shown in the bird's eye view of figure 6. The disc strikes at the endpoint of the stick. at a distance $r = 1.8$m from the stick's center. Assume the collision is elastic and the disk does not deviate from its original line of motion. Given that the moment of inertia of the stick about its center of mass is $1.33\text{kg} \cdot \text{m}^2$, calculate the following after the collision

(i) the translational speed of the disc, [10 marks]

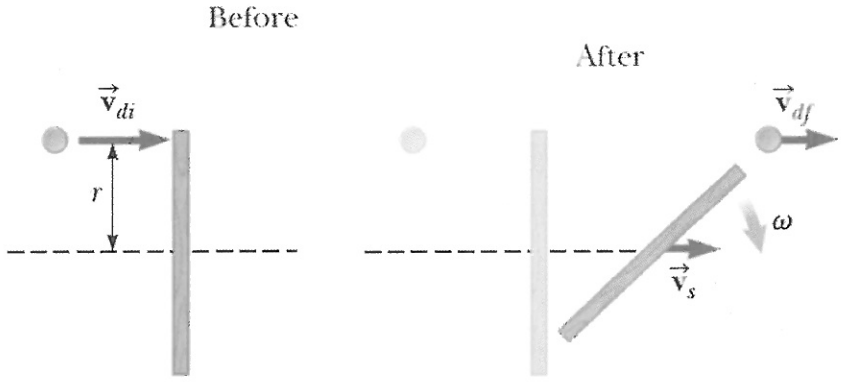
(ii) the translational speed of the stick. and [2 marks]

(iii) the angular speed of the stick. [2 marks]

(c) In the truss given in figure 7,

(i) determine the force in members CD, CJ, and KJ, and [6 marks]

(ii) state if these members are in tension or compression. [4 marks]



(a) Before the collision. (b) After the collision.

Figure 6: Disc striking a stick – question 7(b).

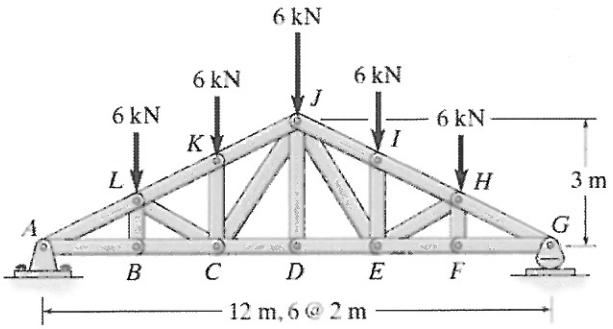


Figure 7: Truss for question 7(c).

Formula sheet

$$v_{xf} = v_{xi} + at$$

$$x_f = x_i + v_{xi}t + \frac{1}{2}at^2$$

$$v_{xf}^2 = v_{xi}^2 + 2a_x \triangle x$$

$$h = \frac{v_i^2 \sin^2\theta}{2g}$$

$$R = \frac{v_i^2 \sin(2\theta)}{g}$$

$$y = x\tan\theta - \frac{g}{2v_i^2\cos^2\theta}x^2$$

$$a_c = \frac{v^2}{r}$$

$$\omega = \frac{v}{r}$$

$$a_r = -a_c = -\frac{v^2}{r}$$

$$\sin(\alpha + \beta) = \sin\alpha\cos\beta + \sin\beta\cos\alpha$$

$$\sin(2\theta) = 2\sin\theta\cos\theta$$