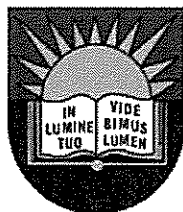


# UNIVERSITY OF FORT HARE



University of Fort Hare  
*Together in Excellence*

## MECHANICS OF A PARTICLE (PHY 111)

**DATE:** June 2023

**DURATION:** 3 HOURS

**MARKS:** 100

**INTERNAL EXAMINER**

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**MODERATOR**

**Dr V. Xuza**

**THIS PAPER CONSISTS OF ...8...PAGES INCLUDING COVER PAGE**

### **INSTRUCTIONS:**

1. Answer all questions.
2. Write neatly and legibly.
3. Unless otherwise stated, all symbols retain their usual meanings.
4. Values of constants, formulae sheet and periodic table elements appear at end of the question paper.

### QUESTION 1 [20 Marks]

- 1.1. Name and discuss the five vector relations. (5)
- 1.2. Three dogs are pulling on a stick in different directions as shown in Figure 1. The first dog pulls with force  $\vec{F}_1 = (10.0\vec{i} - 20.4\vec{j} + 2.0\vec{k})$ , the second dog pulls with force  $\vec{F}_2 = (-15.0\vec{i} - 6.2\vec{k})$ , and the third dog pulls with force  $\vec{F}_3 = (5.0\vec{i} + 12.5\vec{j})$ . Find the angle between  $\vec{F}_1$  and  $\vec{F}_2$ .

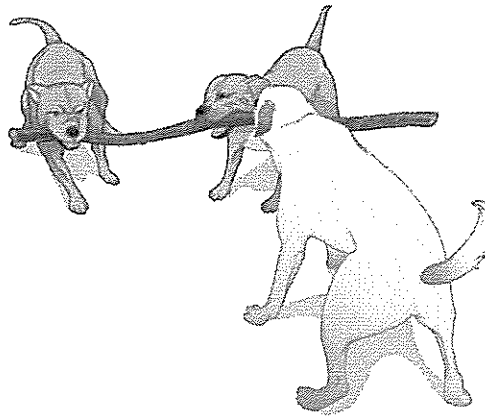


Figure 1

- 1.3. Differentiate between kinematics and dynamics. (2)
- 1.4. A bird is flying due east. Its distance from a tall building is given by  $x(t) = 28.0m + (12.4 m/s)t - (0.0450 m/s^2)t^3$ . What is the instantaneous velocity of the bird when  $t = 8.00s$ ? (4)
- 1.5. Calculate the displacement and velocity at times of (a) 0.500 s for a rock thrown straight down with an initial velocity of 14.0 m/s from the top of the bridge. The roadway of this bridge is 70.0 m above the water. (4)

[20]

### QUESTION 2 [20 Marks]

- 2.1. State Newton's second law of motion. (2)
- 2.2. A particle has a position function  $\vec{r}(t) = \cos(1.0t)\hat{i} + \sin(1.0t)\hat{j} + t\hat{k}$ , where the arguments of the cosine and sine functions are in radians.
- a) What is the velocity vector? (2)
- b) What is the acceleration vector? (2)
- 2.3. A particle's acceleration is  $(4.0\hat{i} + 3.0\hat{j}) \text{ m/s}^2$ . At  $t = 0$ , its position and velocity are zero.
- 2.3.1. What are the particle's position and velocity as functions of time? (4)
- 2.3.2. Find the equation of the path of the particle. (2)
- 2.4. A 4.80-kg bucket of water is accelerated upward by a cord of negligible mass whose breaking strength is 75.0 N. If the bucket starts from rest, what is the minimum time required to raise the bucket a vertical distance of 12.0 m without breaking the cord? (5)
- 2.5. A particle travels in a circle of radius 10 m at a constant speed of 20 m/s. (3)  
What is the magnitude of the acceleration?

[20]

### QUESTION 3 [20 Marks]

- 3.1. State the following:
- 3.1.1. Impulse-momentum theorem (2)

3.1.2. Work-Energy Theorem

(2)

- 3.2. Consider a particle with mass  $m$  moving along the  $x$ -axis under the action of a constant net force with magnitude  $F$  directed along the positive  $x$ -axis (Figure 2). Suppose the speed changes from  $v_1$  to  $v_2$  while the particle undergoes a displacement  $s = x_2 - x_1$  from point  $x_1$  to  $x_2$ .

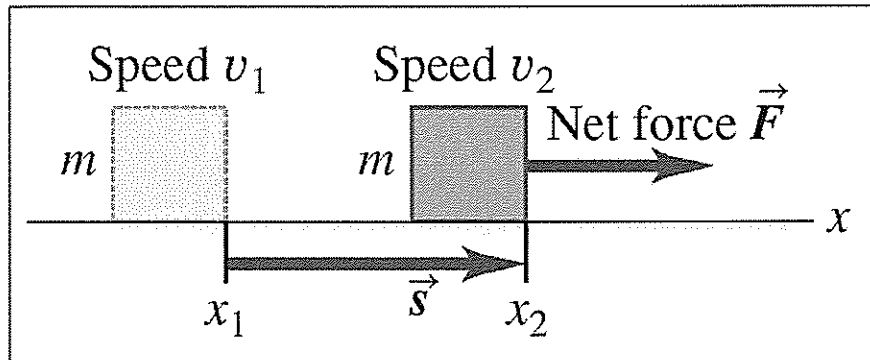


Figure 2

(6)

Show that

$$W = K_2 - K_1$$

- 3.3. Calculate the final speed of a 110-kg rugby player who is initially running at 8.00 m/s but collides head-on with a padded goalpost and experiences a backward force of  $1.76 \times 10^4$  N for  $5.50 \times 10^{-2}$  s. (5)
- 3.4. Calculate the work done by an 85.0-kg man who pushes a crate 4.00 m up along a ramp that makes an angle of  $20.0^\circ$  with the horizontal as shown in Figure 3 below. He exerts a force of 500 N on the crate parallel to the ramp and moves at a constant speed. Be certain to include the work he does on the crate and on his body to get up the ramp. (5)

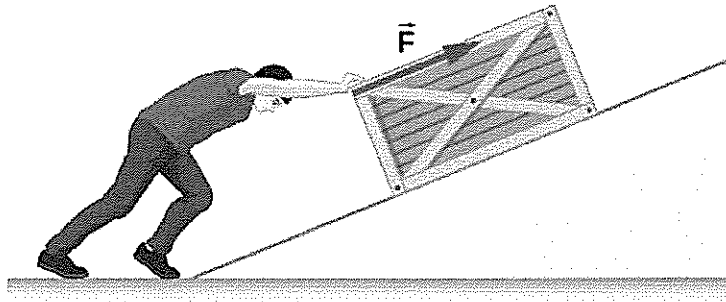


Figure 3

[20]

**QUESTION 4 [20 Marks]**

- 4.1. State Kepler's first law (2)
- 4.2. State the conditions of static equilibrium in words and in formulae. (4)
- 4.3. Show that the kinetic energy for a circular orbit is give as

$$K = G \frac{mM_E}{2r} \quad (5)$$

- 4.4. Determine the orbital radius of an Earth satellite having a period of 1.00 h? (4)
- 4.5. 4.5.1. Calculate the gravitational force exerted on a 4.20-kg baby by a 100-kg father 0.2 m away at birth. (2)
- 4.5.2. Calculate the force on the baby due to Jupiter if it is at its closest distance to Earth, some  $6.29 \times 10^{11}$  m away. (3)

[20]

**QUESTION 5 [20 Marks]**

5.1. State the following:

5.1.1. State Pascal's principle (2)

5.1.2. Archimedes' principle (2)

5.2. Consider an incompressible fluid flowing through a pipe that has a varying diameter and height, as shown in Figure 4.

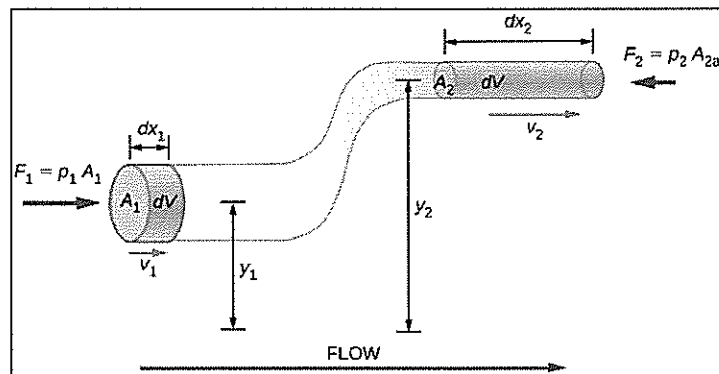


Figure 4.

Show that the Bernoulli's equation is given by (8)

$$p_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2.$$

5.3. What force must be exerted on the master cylinder of a hydraulic lift to support the weight of a 2000-kg car resting on a second cylinder? The master cylinder has a 2.00-cm diameter and the second cylinder has a 24.0-cm diameter. (3)

5.4. What is the pressure drop due to the Bernoulli Effect as water goes into a 3.00-cm-diameter nozzle from a 9.00-cm-diameter fire hose while carrying a flow of 40.0 L/s? (5)

**[20]**

## Formulae Sheet

$$x = x_0 + \vec{v}t; \quad \vec{v} = v_0 + at; \quad x = x_0 + v_0t + \frac{1}{2}at^2; \quad v^2 = v_0^2 + 2a(x - x_0);$$

$$a_c = \frac{v^2}{r}; \quad \vec{p} = m\vec{v}; \quad \vec{w} = m\vec{g}; \quad W = F \cdot s; \quad W = K_2 - K_1 = \Delta K; \quad T = 2\pi\sqrt{\frac{r^3}{GM_E}}; \quad E = -G\frac{mM_E}{2r}$$

$$W_{\text{grav}} = Fs = F(y_1 - y_2) = mgy_1 - mgy_2; \quad y_c = \frac{-2mg}{k};$$

$$p = p_0 + \frac{\rho Ahg}{A} = p_0 + \rho hg; \quad A_1v_1 = A_2v_2; \quad \eta = \frac{FL}{VA}$$

$$P = \frac{dW}{dt}; \quad \vec{j} = m\Delta\vec{v}; \quad \frac{1}{2}m_A v_{A1}^2 = \frac{1}{2}m_A v_{A2}^2 + \frac{1}{2}m_B v_{B2}^2;$$

$$m_A v_{A1} + m_B v_{B1} = m_A v_{A2} + m_B v_{B2}; \quad \vec{F}_{12} = G \frac{m_1 m_2}{r^2} \hat{r}_{12}; \quad v_{\text{orbit}} = \sqrt{\frac{GM_E}{r}}$$

$$v_{\text{esc}} = \sqrt{\frac{2GM}{R}}; \quad \frac{F_1}{A_1} = \frac{F_2}{A_2}; \quad \frac{V_{fl}}{V_{obj}} = \frac{m_{fl}/\rho_{fl}}{m_{obj}/\rho_{obj}}$$

Physical Constants	
Gravitational acceleration on Earth	9.81 m/s <sup>2</sup>
Gravitational acceleration in Moon	1.625 m/s <sup>2</sup>
Gravitational acceleration in Mars	3.72076 m/s <sup>2</sup>
Gravitational acceleration in Jupiter	25.8 m/s <sup>2</sup>
gravitational constant	6.67408 × 10 <sup>-11</sup> N m <sup>2</sup> Kg <sup>-2</sup>
Coulomb constant	8.987 × 10 <sup>9</sup> N · m <sup>2</sup> /C <sup>2</sup>
Electron mass	9.1 × 10 <sup>-31</sup> kg
Elementary charge	1.602 × 10 <sup>-19</sup> C
Planck's constant	6.626 × 10 <sup>-34</sup> J · s

Speed of light in vacuum	$2.997 \times 10^8$ m/s
Mass of Earth	$5.97 \times 10^{24}$ kg
Mass of the Moon	$7.36 \times 10^{22}$ kg
Mass of the Sun	$1.99 \times 10^{30}$ kg
Mass of Jupiter	$1.898 \times 10^{27}$ kg
Radius of Earth	6,371.0088 km

Group →	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period ↓	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																	2 He
2	3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	57 La	* 72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	89 Ac	* 104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Nh	114 Fl	115 Mc	116 Lv	117 Ts	118 Og
				* 58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu	
				* 90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr	