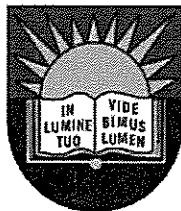


UNIVERSITY OF FORT HARE



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 the 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 of elements appear at end of the question paper

QUESTION 1 [20 Marks]

- 1.1. Define a frame of reference (2)
- 1.2. Name and discuss the five vector relations. (5)
- 1.3. Find the angle between vectors $\vec{A} = (-3.0\hat{i} - 4.0\hat{j})m$ and $\vec{B} = (-3.0\hat{i} + 4.0\hat{j})m$. (5)
- 1.4. A car is stopped at a traffic light. It then travels along a straight road so that its distance from the light is given by $x(t) = bt^2 - ct^3$, where $b = 2.40 m/s^2$ and $c = 0.12 m/s^3$. Calculate the instantaneous velocity of the car at $t = 0s$, $t = 5.0s$ and $t = 10.0s$. (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 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? (4)

- 2.3. 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)
- 2.4. A projectile is launched at an angle of 30° and lands 20 s later at the same height as it was launched.
- 2.4.1. What is the initial speed of the projectile? (3)
- 2.4.2. What is the maximum altitude? (3)
- 2.4.3. What is the range? (3)

[20]

QUESTION 3 [20 Marks]

- 3.1. State the following:
- 3.1.1. The law of conservation of momentum states. (2)
- 3.1.2. The conservation of energy principle state (2)
- 3.2. Consider two objects of masses m_1 and m_2 interacting; the force that object 2 applies to object 1 is equal in magnitude and opposite in direction to the force that object 1 applies on object 2. Show that

$$\frac{d}{dt}(\vec{p}_1 + \vec{p}_2) = 0 \quad (6)$$

- 3.3. Train cars are coupled together by being bumped into one another (Figure 1). Suppose two loaded train cars are moving toward one another, the first

having a mass of 1.50×10^5 kg and a velocity of $(0.30 \text{ m/s})\hat{i}$, and the second having a mass of 1.10×10^5 kg and a velocity of $-(0.12 \text{ m/s})\hat{i}$. What is their final velocity?

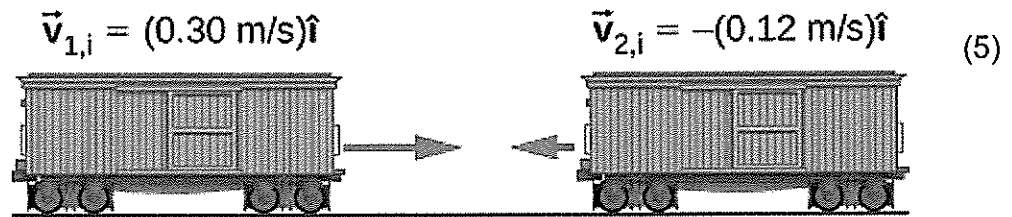


Figure 1

- 3.4. Calculate the average force a 60.0-kg sprinter exerts backward on the track to accelerate from 2.00 to 8.00 m/s in a distance of 25.0 m, if he encounters a headwind that exerts an average force of 30.0 N against him. (5)

[20]

QUESTION 4 [20 Marks]

- 4.1. State Kepler's second law (2)
- 4.2. Differentiate between center of mass and center of gravity. (5)
- 4.3. Evaluate the magnitude of gravitational force between two 5-kg spherical steel balls separated by a center-to-center distance of 15 cm. (3)
- 4.4. An average-sized asteroid located 5.0×10^7 km from Earth with mass 2.0×10^{13} kg is detected headed directly toward Earth with speed of 2.0 km/s. What will its speed be just before it hits our atmosphere? (10)

[20]

QUESTION 5 [20 marks]

- 5.1. Briefly describe the buoyant force. (4)
- 5.2. Consider an incompressible fluid flowing through a pipe that has a varying diameter and height, as shown in Figure 2.

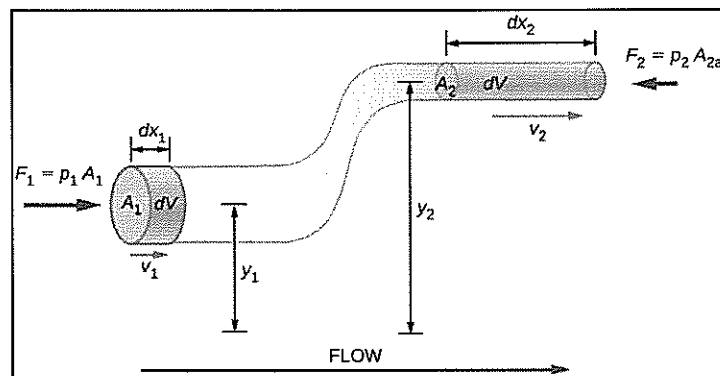


Figure 2.

Show that the Bernoulli's equation is given by

$$p_1 + \frac{1}{2} \rho v_1^2 + \rho g y_1 = p_2 + \frac{1}{2} \rho v_2^2 + \rho g y_2. \quad (8)$$

- 5.3. A trash compactor can compress its contents to 0.350 times their original volume. Neglecting the mass of air expelled, by what factor is the density of the rubbish increased? (4)
- 5.4. A dam in Figure 3 is used to hold back a river. The dam has a height $H = 12$ m and a width $W = 10$ m. Assume that the density of the water is $\rho = 1000$ kg/m³. Determine the net force on the dam. (4)

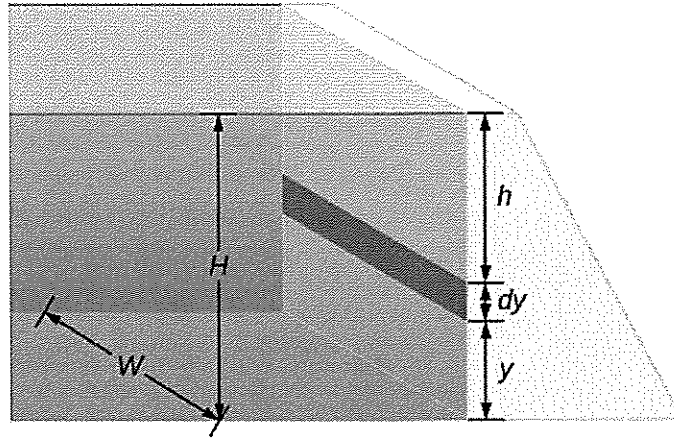


Figure 3

[20]

Formulae Sheet

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

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

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

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

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

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

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

Physical Constants	
Gravitational acceleration on Earth	9.81 m/s ²
Gravitational acceleration in Moon	1.625 m/s ²
Gravitational acceleration in Mars	3.72076 m/s ²
Gravitational acceleration in Jupiter	25.8 m/s ²
gravitational constant	6.67408 × 10 ⁻¹¹ N m ² Kg ⁻²
Coulomb constant	8.987 × 10 ⁹ N · m ² /C ²
Electron mass	9.1 × 10 ⁻³¹ kg
Elementary charge	1.602 × 10 ⁻¹⁹ C
Planck's constant	6.626 × 10 ⁻³⁴ J · s
Speed of light in vacuum	2.997 × 10 ⁸ m/s
Mass of Earth	5.97 × 10 ²⁴ kg
Mass of the Moon	7.36 × 10 ²² kg
Mass of the Sun	1.99 × 10 ³⁰ kg
Mass of Jupiter	1.898 × 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	
	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		