UNIVERSITY OF FORT HARE

MECHANICS OF A PARTICLE
PHY 111

DEGREE EXAMINATIONS

JUNE

2025

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Time: 3 hours

Subject: PHY 111

Marks: 100

This paper consists of _ pages including the cover page

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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 and the formulae sheet appear at the end of the question paper

QUESTION 1 [20 MARKS]

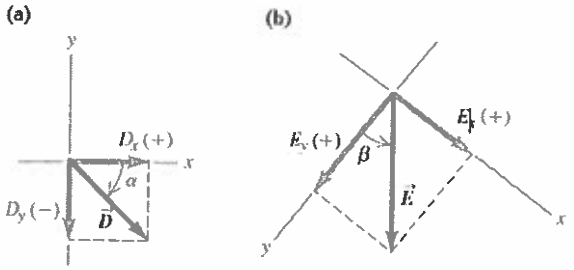
1.1. Define the following:

1.1.1. Frame of reference (2)

1.1.2. Free fall motion (2)

1.2. At $t = 10$ s, a particle is moving from left to right with a speed of 5.0 m/s. At $t = 20$ s, the particle is moving right to left with a speed of 8.0 m/s. Assuming the particle's acceleration is constant, determine its acceleration and initial velocity. (5)

1.3. Consider Figure 1. The magnitude of vector $D = 3.00\ m$ and the angle $\alpha = 45°$. The magnitude of vector $E = 4.50\ m$ and the angle $\beta = 37°$. Find the components of x and y of vectors $\vec{D}$ and $\vec{E}$ in Figure 1 (a and b).



(7)

Figure 1

1.4. Calculate the displacement and velocity at time equal to 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)

QUESTION 2 [20 MARKS]

2.1. Mention and explain any two common forces. (4)

2.2. Figure 2 shows a particle executing circular motion in a counterclockwise direction. As the particle moves on the circle, its position vector makes out the angle θ (angular position) with the x-axis. Show that the acceleration vector is given as; (5)

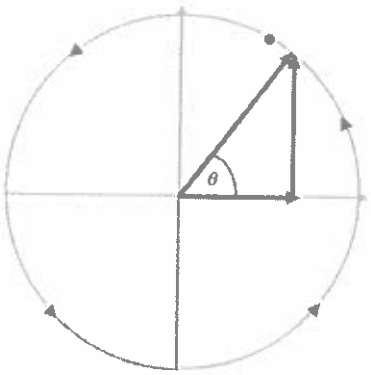


Figure 2

$$\vec{a}(t) = -\omega^2 \vec{r}(t)$$

2.3. A cyclist rides 5.0 km due east, then 10.0 km 20° west of north. From this point she rides 8.0 km due west. What is the final displacement from where the cyclist started? (5)

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? (6)

QUESTION 3 [20 MARKS]

3.1. State the following:

3.1.1. The conservation of energy principle (2)

3.1.2. Impulse-momentum 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 as shown in Figure 3. Derive the work-energy equation.

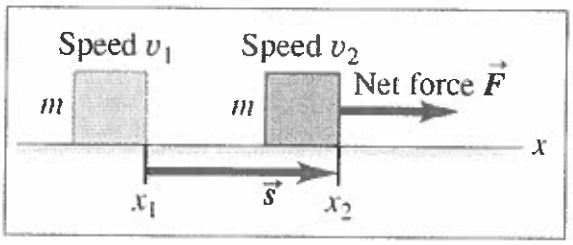


Figure 3 (6)

3.3. Train cars are coupled together by being bumped into one another as shown in Figure 4. 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 $(0.30 \text{ m/s})\hat{\imath}$, and the second having a mass of 1.10×10^5 kg and a velocity of $-(0.12 \text{ m/s})\hat{\imath}$. What is their final velocity?

Figure 4 (5)

3.4. How fast must a 3000-kg elephant move to have the same kinetic energy as a 65.0-kg sprinter running at10.0 m/s? (5)

QUESTION 4 [20 MARKS]

4.1. State the two conditions of static equilibrium in word and equation forms. (4)

4.2. Given that the change in potential energy (ΔU) is defined as the negative of the work done by the force associated with the potential energy. show that (6)

$$U = -\frac{GmM_E}{r}$$

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? (7)

QUESTION 5 [20 MARKS]

5.1. State the following:

5.1.1. Pascal's principle (2)

5.1.2. Buoyant force (2)

5.2. Consider an incompressible fluid flowing through a pipe that has a varying diameter and height, as shown in Figure 2 and show that the Bernoulli's equation is given as; (10)

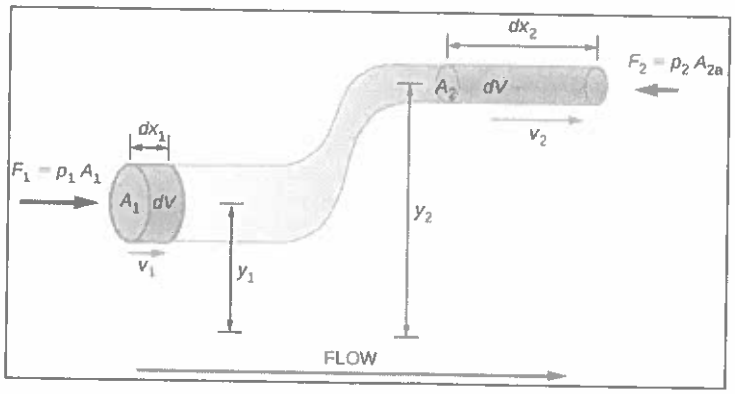


Figure 5.

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

5.3. 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? (6)

Formulae Sheet

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

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

$$E = -G\frac{mM_E}{2r};\ W_{grav} = Fs = F(y_1 - y_2) = mgy_1 - mgy_2;\ \ y_C = \frac{-2mg}{k};$$

$$p = p_0 + \frac{\rho Ahg}{A} = p_0 + \rho hg;\qquad A_1 v_1 = A_2 v_2;\qquad \eta = \frac{FL}{vA}$$

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

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

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

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	$6.67408 \times 10^{-11}\ N\ m^2\ Kg^{-2}$

Coulomb constant	$8.987 \times 10^9\ \mathrm{N \cdot m^2/C^2}$
Electron mass	$9.1 \times 10^{-31}\ \mathrm{kg}$
Elementary charge	$1.602 \times 10^{-19}\ \mathrm{C}$
Planck's constant	$6.626 \times 10^{-34}\ \mathrm{J \cdot s}$
Speed of light in vacuum	$2.997 \times 10^8\ \mathrm{m/s}$
Mass of Earth	$5.97 \times 10^{24}\ \mathrm{kg}$
Mass of the Moon	$7.36 \times 10^{22}\ \mathrm{kg}$
Mass of the Sun	$1.99 \times 10^{30}\ \mathrm{kg}$
Mass of Jupiter	$1.898 \times 10^{27}\ kg$
Radius of Earth	6,371.0088 km