GWANDA STATE UNIVERSITY

FACULTY OF ENGINEERING AND THE ENVIRONMENT

DEPARTMENT OF GEOMATICS AND SURVEYING

MECHANICS (EGS 1209)

Final Examination Paper

June 2025

EPOCH MINE CAMPUS

Time Allowed: **3 hours**
Total Marks: **100**
Examiner's Name: **Mr. V. D Muzenda**

INSTRUCTIONS

1. Answer **ALL** question in SECTION A.
2. Answer any **THREE** questions from SECTION B.
3. Use of calculators is permissible.

MARK ALLOCATION

Section A	**40**
Question A1	20
Question A2	20
Section B	**60**
Question B3	20
Question B4	20
Question B5	20
Question B6	20
Total Attainable	**100**

SECTION A **ANSWER ALL QUESTIONS IN THIS SECTION (40 Marks)**

Question A1

A1.1

A particle moves along the x axis. Its position varies with time according to the expression $x = -4t + 2t^2$, where x is in meters and t is in seconds. The position–time graph for this motion is shown in Fig A1.1 Notice that the particle moves in the negative x direction for the first second of motion, is momentarily at rest at the moment t =1 s, and moves in the positive x direction at times $t > 1s$.

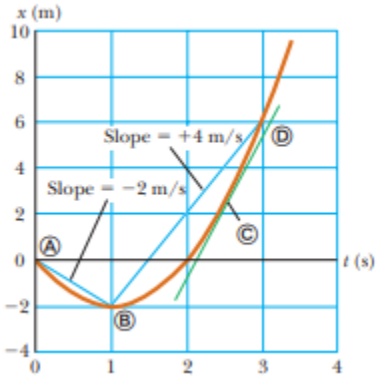


Fig A1.1

Determine the displacement of the particle in the time intervals t =0 to t =1 s and t =1 s to t =3 s. **[2]**

(i) Calculate the average velocity during these two time intervals**. [2]**

(ii) Find the instantaneous velocity of the particle at t = 2.**5s [1]**

(1b) The cables of suspension bridge are anchored into large standing blocks of concrete as shown in figure A1.2 (a). One of these blocks is shown on a larger scale in Figure A1.2 (b); it has a length of 30m and its cross section and density are uniform. The maximum force which the cable could

exert on this block is $5.5x10^8$ N for a particular bridge. The force acts in the direction shown so that its line of action is 26m from the point about which the block might be possibly rotate.

(i) Show in figure 1.2 (b) the forces which would be acting on the block if it is just about to rotate. **[1]**

(ii) Calculate the minimum mass of the block needed to prevent rotation when the force exerted by the cable has its maximum value**. [3]**

(iii) Show on a second sketch the forces which would be acting under normal operating conditions. **[1]**

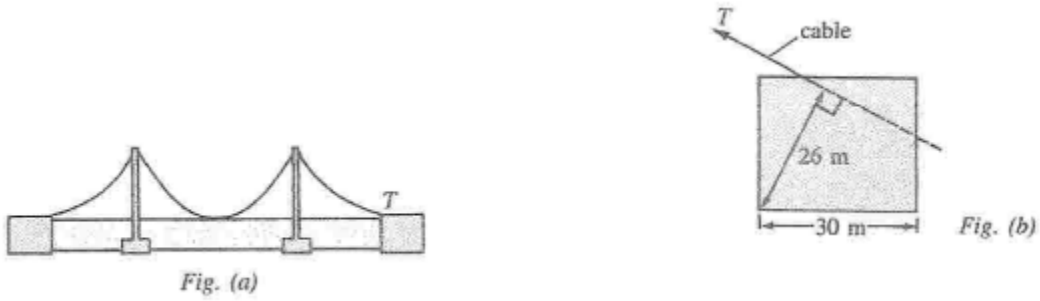
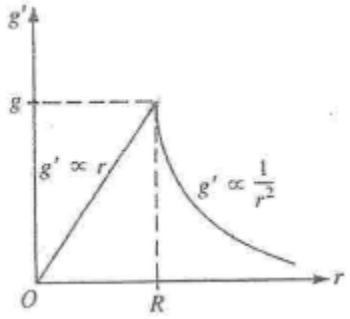


Fig.A1.2

1c) State and explain all the equations of motion. Derive all the equations showing all steps and required. [10]

Question A2

a) Show how gravity varies with distance from the center of the earth. Derive the equations. **[5]**



FigA1.3

(b) State Newton's laws of motion. **[3]**

(c) When the body moves through a fluid, a retarding force due to turbulence maybe experienced. In the case of a sphere of radius r moving with speed v through a stationary fluid of density ρ which is at rest, this force is given by $F = K\rho r^2 v^2$. Show that k is dimensionless. **[2]**

(d) By relating the retarding force to the transfer of momentum between the sphere and the fluid. Explain why F is proportional to r^2v^2 . When spherical raindrops fall through still air, all but the smallest experience a retarding force given by the equation above. It is found that drops of a given medium approach the ground with an approximately constant speed, which is independent of the height of the cloud in which they are formed. Explain this observation by reference to Newton's laws. Find an expression for this terminal speed v_t in terms of constant k, the radius r of the drop, its density ρ_w , the density ρ_A of the air and the acceleration of free fall g. (Neglect the buoyancy of the air). The terminal speed of a raindrop of radius 1 mm is approximately 7 ms^{-1}. In freak storms, hailstones with radii as large as 20mm may fall. Estimate the speed with which such stones strike the ground.

[Take the density of water as $1x10^3$ kgm^{-3} and the density of ice as $9x10^2$ kgm^{-3}] **[10]**

SECTION B (60 marks)

Answer ANY THREE questions from this section.

Question B3

A playful astronaut releases a bowling ball, of mass m 7.20 kg, into circular orbit about Earth at an altitude h of 350 km

(a) What is the mechanical energy E of the ball in its orbit? [2]

(b) What is the mechanical energy E_0 of the ball on the launch pad at the Kennedy Space Center (before launch)? From there to the orbit, what is the change 'E in the ball's mechanical energy? [3]

(c) A spaceship of mass $m = 4.50x10^3 kg$ is in a circular Earth orbit of radius r =8.00x10^6 m and period T=118.6 min when a thruster is fired in the forward direction to decrease the speed to 96.0% of the original speed. What is the period T of the resulting elliptical orbit (Fig. b1)? [10]

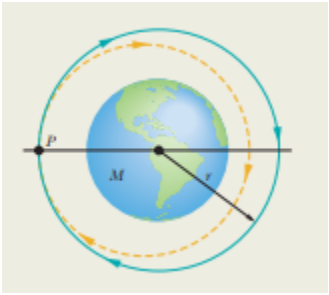


Fig B1

(d) Calculate the escape speed from the Earth for a 5 000-kg spacecraft and determine the kinetic energy it must have at the Earth's surface to move infinitely far away from the Earth. **[5]**

Question B4

(a) State the laws of conservation of momentum and energy **[4]**

(b) The Fig B2 (a) below shows a person bending over with his back horizontal to lift a load of 60N. The spine is considered as a rod pivoted at its base. The weight of the upper part of the body is 250N acting at the center of gravity G as shown by Fig B2(b).

Fig. (a)

Fig B2(a)

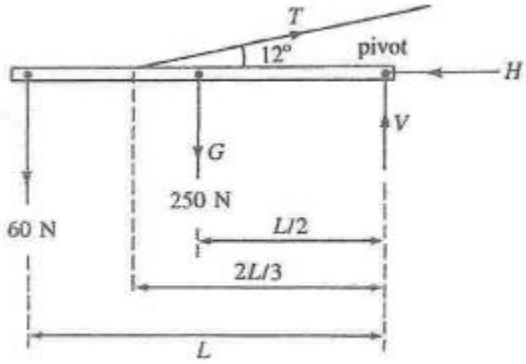


Fig. (b)

Fig B2(b)

Find

(i) The Tension T in his back muscle **[5]**

(ii) The horizontal compressional force H on the spine **[3]**

(iii) The vertical reaction v at the pivot **[3]**

(c) A ball is thrown vertically upwards from the ground with an initial velocity u. The time taken by the ball to reach the height h is t_1 . The ball then takes a further time of t_2 to return to the ground. Find (in terms of t_1, t_2 and g) the initial velocity u and the height h **[5]**

Question B5

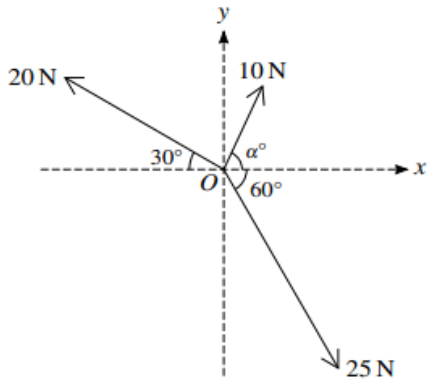


Figure B5.0

Three coplanar forces of magnitudes 10 N, 25 N and 20 N act at a point O in the directions shown in the diagram **Figure B5.0**

(a) Given that the component of the resultant force in the x-direction is zero, find α, and hence find the magnitude of the resultant force**. [4]**

(b) Given instead that α= 45 degrees, find the magnitude and direction of the resultant of the three forces. **[5]**

(c) A motorist whose car will not start seeks a tow from the second motorist. The towing vehicle accelerates slowly from rest with the tow-rope slack, when the rope becomes tight, the towed car starts to accelerate and towing vehicle moves with a constant speed of 0.8 m/s until the towed car of mass 1000 kg achieves the same speed.

i) What is the change of momentum of the towed car? **[2]**

ii) The average tension in the rope may be assumed to be 4000 N during the acceleration of the towed car. How far does the towed car travel from rest before it reaches the speed of 0.8m/s? **[3]**

iii) How does the towing vehicle travel this time? **[2]**

iv) The breaking strain of the tow-rope is 0.04. What must be the minimum unstretched length of the rope if the tow is accomplished without breaking of the rope? **[4]**

Question B6

a) A ball bearing is released from a height of 1m from a metal plate. Describe how you would determine the fractional decrease in the kinetic energy of the ball bearing after it hits the plate. What happens to different in kinetic energy? **[5]**

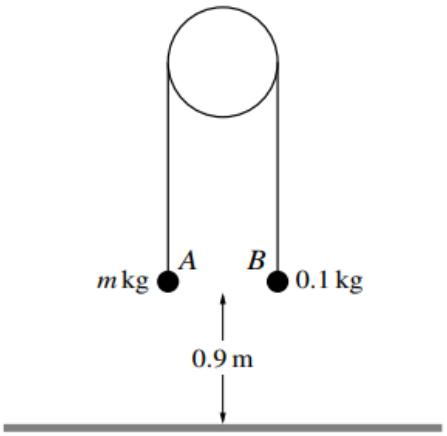
b) A neutron of mass m collides head-on with a carbon nucleus of mass 12m which was initially at rest. If the collision is elastic, find the ratio of the kinetic energy of the neutron after collision to its kinetic energy before collision. **[5]**

c) State any two ways in which heavy duty industrial machines can produce more work output in relation to the energy input **[2]**

d) Two particles A and B have masses m kg and 0.1 kg respectively, where m > 0.1. The particles are attached to the ends of a light inextensible string. The string passes over a fixed smooth pulley and the particles hang vertically below it. Both particles are at a height of 0.9 m above horizontal ground (**see Fig B6.1**). The system is released from rest, and while both particles are in motion the tension in the string is 1.5 N. Particle B does not reach the pulley.

i. Find m. **[4]**
ii. Find the speed at which A reaches the ground. **[4]**

Fig B6.1



End of Question Paper.

