BINDURA UNIVERSITY OF SCIENCE EDUCATION

FACULTY OF SCIENCE

DEPARTMENT OF MATHEMATICS AND PHYSICS

Diploma Physics

PH007: Mechanics

JUN 2023

Duration: Three (3) hrs

Answer ALL parts of Section A and any THREE questions from section B. Section A carries 40 marks and each question of Section B carries 20 marks.

Section A

1.

a. Determine whether the following equation is dimensionally consistent: $v^2 = u^2 + 2as$, where u and v are the initial and final speeds, a is the acceleration and s is the distance travelled. [4]

b. The position of a particle moving along the x-axis varies with time according to the relation $x = t^3 - 12t + 20$, where x is in meters and t is in seconds.
   i. Determine the velocity and acceleration as a function of time. [4]
   ii. Find the time at which the velocity will be zero [2]

c. A ball is dropped from the top of a building. Find
   i. The acceleration [1]
   ii. The distance it falls in 2 seconds [3]
   iii. Its velocity after falling 15 m [3]
   iv. The time it takes to fall 25 m [3]

d. Define conservative and non conservative forces and give one example for each [4]

e. Given that $\boldsymbol{A} = 4\mathbf{i} - 2\mathbf{j} - \mathbf{k}$ and $\boldsymbol{B} = \mathbf{i} + 4\mathbf{j} - 4\mathbf{k}$. Determine
   i. The angle between **A** and **B** [3]
   ii. $\boldsymbol{A}.\boldsymbol{B}$ [3]
   iii. The magnitude of A [3]
   iv. $\boldsymbol{A} + \boldsymbol{B}$ **[2]**

f. A satellite orbits the earth at a height (from the surface) of 150 km, where the free fall acceleration is $9.8\ m/s^2$. Given that the radius of the earth is $6.4 \times 10^6 m$. Calculate the orbital speed and period of the satellite. [5]

Section B

2.

a. State Newton's laws of motion and give the corresponding mathematical form. [6]

b. A box of mass=10 kg is initially at rest on surface with coefficient of kinetic friction $\mu_k = 0.2$. The box is pulled horizontally by a force F=50 N that makes an angle of $\theta = 60^\circ$ with the horizontal. Calculate

i. the speed of the box after it moves a distance of 4 m. [6]

ii. The work done by the force over 4 m distance [3]

iii. what is the kinetic energy of the box at the distance of 4m [3]

iv. Explain why the answer in(ii) is different from the one in (iii) [2]

3.

a. A ball is thrown with an initial speed v of 30 m/s at an angle of 53.1° to the horizontal.

i. State two assumptions that are made when analysing projectile motion within the earth's atmosphere. [2]

ii. Find the x and y components of the velocity [2]

iii. Calculate the maximum height H and [3]

iv. the time taken to reach the maximum height [3]

b. A tram of 5000 kg, travelling at 15 m/s strikes a stationary 5000 kg tram and locks onto it. If the trams move together, what is the common speed after collision? [4]

c. A wheel accelerates form rest to an angular speed of 25 rad/s in 10 secs. Calculate the

i. Angular acceleration of the wheel [3]

ii. Tangential and radial acceleration of a point 10 cm form the centre [3]

4.

a. With the aid of a diagram, explain how a material would behave under a tensile force up to the breaking point, [10]

b. A small sphere of mass m=2 grams is released from rest in large vessel filled with oil. The sphere reaches a terminal speed $v_t = 3\ cm/s$.

i. Explain how the sphere reaches the terminal speed. [5]

ii. Given that the acceleration of the sphere at some point is 3.5 m/s^2, calculate the drag force on the object. [3]

iii. If the mass is increased while the volume of the ball is kept the same, explain how the forces acting on the sphere change. [2]

5.

a. State Newton's law of gravitation, and express it mathematically, defining all the quantities in the equation [5]

b. A 1000 kg satellite is to be placed in a circular orbit 300 km above the surface of the earth. The radius and mass of the earth are 6380 km and $5.97 \times 10^{24} kg$

i. If the satellite is to stay in orbit at that height, calculate the speed, period and centripetal acceleration. [9]

ii. How much work must be done to place the satellite at that height? [4]

iii. Explain why the gravitational potential is always negative [2]

6.

a. A spring of length 5 cm is compressed by a force of 10 N and its length reduces to 4 cm. Determine

i. the spring constant [2]

ii. energy stored in the spring when compressed to 4 cm [2]

b. Give any three uses of artificial satellites [3]

c. State two disadvantages of geostationary orbits [2]

a. A pendulum consists of a big sphere of mass m=30 kg hung from the end of a steel wire that has a length L =15 m, a cross-sectional area A=9×10^{-6} m^2, and Young's modulus Y =200×10^9 N/m^2. Calculate the

i. Tension force in the string [2]

ii. tensile stress on the wire [3]

iii. change in length. [4]

iv. tensile strain [2]

THE END