# 100 LONG-FORM ADVANCED PHYSICS QUESTIONS

*Class XI | Revised topic set with Electrostatics*

Original, demanding practice questions inspired by the topic coverage and problem-solving style of Class XI physics textbooks, including S. Chand and Mastering Physics. These are not copied verbatim from either book. Each numbered question has parts A–C and Roman-numeral tasks. Unless stated otherwise, use g = 9.8 m $s^{-2}$, show complete working, use SI units, and draw labelled diagrams where useful.

## 1. Units, Dimensions and Error Analysis

### Question 1

**A.** Express the gravitational constant G in terms of the fundamental dimensions M, L and T.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

### Question 2

**A.** Using dimensional analysis, test whether the relation $T = 2\pi\sqrt{(l/g)}$ is dimensionally correct for a simple pendulum.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 3

**A.** The time period T of a small oscillation depends on mass m, length l and gravitational acceleration g. Use dimensional analysis to obtain a possible relation for T.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 4

**A.** A measured length is (12.40 ± 0.05) cm. Calculate the percentage error in the measurement.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 5

**A.** If $z = x^2y^3/\sqrt{w}$, and the percentage errors in x, y and w are 1%, 2% and 3% respectively, estimate the maximum percentage error in z.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 6

**A.** Convert 1 newton into dyne and 1 joule into erg.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 7

**A.** Determine the dimensions of (i) pressure, (ii) surface tension, and (iii) coefficient of viscosity.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 8

**A.** A quantity is calculated from $v = s/t$. If $s = (25.0 \pm 0.2)$ m and $t = (5.0 \pm 0.1)$ s, find v and its approximate maximum percentage error.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## Question 9

**A.** Show by dimensional analysis whether the expression $v^2 = u^2 + 2as$ is dimensionally consistent.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

### Question 10

**A.** The radius of a sphere is measured as (2.50 ± 0.02) cm. Estimate the percentage error in its calculated volume.

**(i)** (i) State the relevant physical quantities and their SI units. (ii) Express each quantity in fundamental dimensions.

**(ii)** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**B.** (i) Calculate the requested numerical result, showing substitutions and units. (ii) Estimate the uncertainty or percentage error where appropriate.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**C.** (i) Use dimensional reasoning to test the stated relation. (ii) Identify any dimensional inconsistency and explain what dimensional analysis cannot determine.

**(i)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

**(ii)** (i) State two assumptions made. (ii) Explain how an experimental measurement or graph could be used to check the result.

## 2. Motion in a Straight Line

### Question 11

**A.** A car starts from rest and accelerates uniformly at 2.4 m $s^{-2}$ for 8 s. Find its final speed and displacement.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 12

**A.** A body moving at 30 m $s^{-1}$ is uniformly retarded at 3 m $s^{-2}$. Find the time taken to stop and the stopping distance.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 13

**A.** A particle covers 18 m in the third second and 24 m in the fifth second under uniform acceleration. Determine its initial velocity and acceleration.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 14

**A.** A train increases its speed from 12 m $s^{-1}$ to 28 m $s^{-1}$ in 20 s. Calculate its acceleration and distance travelled.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 15

**A.** A stone is dropped from a tower and reaches the ground after 3.8 s. Find the tower height and impact speed. Take g = 9.8 m $s^{-2}$.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 16

**A.** A vehicle travels the first half of a journey at 20 m $s^{-1}$ and the second half at 30 m $s^{-1}$. Find its average speed for the whole journey.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 17

**A.** The position of a particle is $x = 4t^2 - 3t + 2$, where x is in metres and t in seconds. Find its velocity and acceleration at $t = 3$ s.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 18

**A.** A ball is thrown vertically upward at 24 m $s^{-1}$. Find the maximum height and total time before it returns to the launch point.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 19

**A.** A body covers 40 m in 4 s and 64 m in the next 4 s with constant acceleration. Find its initial velocity and acceleration.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## Question 20

**A.** A motorcyclist moving at 18 m $s^{-1}$ sees an obstacle 45 m ahead and brakes uniformly. Find the minimum retardation needed to stop before the obstacle.

**(i)** (i) Choose a suitable sign convention and list the known quantities. (ii) Draw or describe the velocity-time graph for the motion.

**(ii)** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**B.** (i) Calculate the relevant time, speed or distance. (ii) Check the answer using a second kinematic equation.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**C.** (i) Derive the required kinematic equation from the graph. (ii) Use it to find the requested displacement, velocity or acceleration.

**(i)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

**(ii)** (i) Explain how the answer changes if the acceleration is halved. (ii) State one limitation of the uniform-acceleration model.

## 3. Projectile Motion

### Question 21

**A.** A projectile is launched at 25 m $s^{-1}$ at 40° above the horizontal. Calculate its time of flight, maximum height and horizontal range.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

### Question 22

**A.** A ball is projected horizontally at 15 m $s^{-1}$ from a cliff 45 m high. Find the time to reach the ground and the horizontal distance travelled.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 23

**A.** A projectile has a range of 80 m when projected at 30° on level ground. Find its initial speed, taking g = 9.8 m $s^{-2}$.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 24

**A.** A stone is projected at 28 m $s^{-1}$ at 35°. Determine its velocity components after 2 s.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 25

**A.** A projectile passes through two points at the same height, 2.0 s apart. If its initial vertical component is 19.6 m $s^{-1}$, find the height of those points above the launch level.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 26

**A.** A football is kicked at 20 m $s^{-1}$ at 30°. A wall 12 m away is 2.5 m high. Determine whether the ball clears the wall.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 27

**A.** Show by calculation that the range of a projectile on level ground is the same for complementary projection angles when launch speed is unchanged.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 28

**A.** A projectile is fired from a platform 20 m above level ground at 18 m $s^{-1}$ and 25° above horizontal. Find the time until impact and horizontal range.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## Question 29

**A.** A ball must land 50 m away on level ground. Find two possible projection angles if its initial speed is 25 m $s^{-1}$.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

### Question 30

**A.** A projectile reaches a maximum height of 20 m. Determine its initial vertical speed and time to reach maximum height.

**(i)** (i) Resolve the initial velocity into horizontal and vertical components. (ii) Write the equations for horizontal and vertical motion.

**(ii)** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**B.** (i) Find the maximum height or range as applicable. (ii) Determine the velocity components at the specified time.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**C.** (i) Determine the time at the stated point or at impact. (ii) Calculate the horizontal displacement and vertical displacement.

**(i)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

**(ii)** (i) Sketch a labelled trajectory and show the velocity components. (ii) Explain which quantities remain constant and why.

## 4. Newton’s Laws of Motion

### Question 31

**A.** A 6 kg block is pulled along a smooth horizontal surface by a 24 N force. Find its acceleration and speed after 5 s from rest.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton’s second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 32

**A.** A 10 kg block rests on a rough horizontal surface with coefficient of friction 0.25. Find the minimum horizontal force needed to start moving it.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 33

**A.** Two masses of 4 kg and 6 kg are connected by a light string over a smooth pulley. Find the acceleration and string tension.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 34

**A.** A 5 kg body is pulled by a 30 N force at 30° above the horizontal on a smooth floor. Find its horizontal acceleration and normal reaction.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 35

**A.** A 1200 kg car rounds a flat curve of radius 50 m at 15 m $s^{-1}$. Calculate the frictional force needed to keep it on the curve.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 36

**A.** A lift of mass 500 kg accelerates upward at 1.5 m $s^{-2}$. Find the tension in its supporting cable.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 37

**A.** A 2 kg block on a smooth table is connected over a pulley to a hanging 3 kg mass. Find the acceleration and string tension.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 38

**A.** A 0.15 kg ball moving at 20 m $s^{-1}$ rebounds in the opposite direction at 12 m $s^{-1}$. If contact lasts 0.02 s, find the average force on the ball.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 39

**A.** A 60 kg person stands on a weighing scale in a lift accelerating downward at 2 m $s^{-2}$. Find the scale reading in newtons.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## Question 40

**A.** A 8 kg block is pushed with 50 N at 30° below the horizontal. If $\mu = 0.20$, calculate the friction and acceleration.

**(i)** (i) Draw a free-body diagram and label every force. (ii) Resolve forces along suitable axes.

**(ii)** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**B.** (i) Include friction, normal reaction or apparent weight where relevant. (ii) Calculate the resulting motion or force.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**C.** (i) Apply Newton's second law to calculate acceleration or tension. (ii) Check that the units and direction are consistent.

**(i)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

**(ii)** (i) State what changes if the surface is smooth or the acceleration reverses. (ii) Explain the physical meaning of the result.

## 6. Circular Motion

### Question 41

**A.** A car moves at 20 m $s^{-1}$ around a horizontal circular track of radius 80 m. Find its centripetal acceleration.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

### Question 42

**A.** A 0.25 kg stone is whirled in a horizontal circle of radius 0.8 m at 4 revolutions per second. Calculate its speed and centripetal force.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 43

**A.** A vehicle rounds a banked curve of radius 100 m at 20 m $s^{-1}$. Find the banking angle required if friction is negligible.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 44

**A.** A particle moves in a circle of radius 2 m with angular speed 6 rad $s^{-1}$. Find its linear speed and centripetal acceleration.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 45

**A.** A 0.4 kg mass is attached to a string of length 1.2 m and moves in a vertical circle. Find the minimum speed at the top for the string to remain just taut.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 46

**A.** A cyclist rounds a curve of radius 25 m. If the coefficient of friction between tyres and road is 0.4, find the maximum safe speed on a level road.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 47

**A.** A rotating wheel makes 120 revolutions in 30 s. Calculate its frequency, period and angular speed.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 48

**A.** A 2 kg object moves in a circle of radius 3 m at constant speed 9 m $s^{-1}$. Calculate the net force and the work done by this force over one complete revolution.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## Question 49

**A.** A particle's angular position is $\theta = 3t^2 + 2t$. Find its angular velocity and angular acceleration at $t = 4$ s.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

### Question 50

**A.** A conical pendulum has string length 1.5 m and makes an angle of 30° with the vertical. Find its angular speed and period.

**(i)** (i) Convert all quantities to SI units and identify the radius and speed/angular speed. (ii) Write the centripetal acceleration relation.

**(ii)** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**B.** (i) Determine the limiting condition, period or frequency where applicable. (ii) Substitute values carefully.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**C.** (i) Calculate the required centripetal force or angular quantity. (ii) Identify which real force provides the centripetal resultant.

**(i)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

**(ii)** (i) Explain how the result changes if speed is doubled. (ii) State the direction of acceleration and justify it.

## 7. Rotational Motion

### Question 51

**A.** A uniform solid cylinder of mass 8 kg and radius 0.20 m rotates at 12 rad $s^{-1}$. Calculate its moment of inertia and rotational kinetic energy.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 52

**A.** A torque of 15 N m acts on a wheel with moment of inertia 3 kg $m^2$. Find its angular acceleration.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 53

**A.** A uniform rod of mass 4 kg and length 2 m rotates about an axis through its centre and perpendicular to its length. Find its moment of inertia.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 54

**A.** A disc starts from rest and has angular acceleration 2.5 rad $s^{-2}$ for 6 s. Find its final angular speed and angular displacement.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 55

**A.** A flywheel of moment of inertia 5 kg $m^2$ rotates at 20 rad $s^{-1}$. A constant braking torque of 10 N m is applied. Find the stopping time and angular displacement before stopping.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 56

**A.** A solid sphere rolls without slipping down a vertical height of 1.8 m. Find its speed at the bottom.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 57

**A.** Two point masses of 2 kg and 3 kg are placed 0.5 m and 0.8 m from an axis respectively. Calculate the total moment of inertia about the axis.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 58

**A.** A tangential force of 25 N acts at the rim of a wheel of radius 0.4 m. If its moment of inertia is 2 kg $m^2$, find angular acceleration.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 59

**A.** A 3 kg uniform rod of length 1.2 m is pivoted at one end and released from horizontal. Find its initial angular acceleration.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## Question 60

**A.** A rotating body has angular momentum 18 kg $m^2$ $s^{-1}$ and moment of inertia 3 kg $m^2$. Find its angular speed and rotational kinetic energy.

**(i)** (i) Identify the axis of rotation and choose the correct moment-of-inertia expression. (ii) Calculate the moment of inertia or torque.

**(ii)** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**B.** (i) Calculate rotational kinetic energy or angular momentum. (ii) Check dimensional consistency.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**C.** (i) Apply $\tau = I\alpha$ or the rotational kinematic equations. (ii) Find angular acceleration, angular speed or displacement.

**(i)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

**(ii)** (i) Explain the effect of changing the axis or mass distribution. (ii) State any assumptions about the body and the applied torque.

## 8. Gravitation

### Question 61

**A.** Calculate the gravitational force between masses of 5 kg and 12 kg separated by 0.40 m.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

### Question 62

**A.** Find the acceleration due to gravity at a height equal to Earth's radius above its surface, given surface gravity g.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 63

**A.** A satellite orbits Earth at a radius $7.0 \times 10^6$ m from Earth's centre. Given GM = $3.986 \times 10^{14}$ $m^3\ s^{-2}$, calculate its orbital speed and period.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 64

**A.** Derive an expression for the escape speed from a planet of mass M and radius R, then calculate it for Earth using g = 9.8 m $s^{-2}$ and R = $6.4 \times 10^6$ m.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 65

**A.** Two masses attract each other with force F. Determine the new force if one mass is doubled and the separation is tripled.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 66

**A.** Calculate the gravitational potential at a point $2.0 \times 10^{7}$ m from Earth's centre, given GM = $3.986 \times 10^{14}$ $m^{3}\ s^{-2}$.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 67

**A.** A satellite has an orbital period of 90 minutes. If another satellite orbits the same planet at four times the orbital radius, find its period.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 68

**A.** Show how the value of g varies with depth d below Earth’s surface, assuming Earth has uniform density.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## Question 69

**A.** A planet has twice Earth's mass and twice Earth's radius. Find the ratio of its surface gravitational acceleration to Earth's.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

### Question 70

**A.** Find the minimum work needed to move a 100 kg payload from Earth's surface to a very large distance away, using $GM = 3.986 \times 10^{14}\ m^3\ s^{-2}$ and $R = 6.4 \times 10^6\ m$.

**(i)** (i) Draw a labelled diagram showing the centre of the planet and the relevant radius/distance. (ii) State the gravitational law or orbital relation needed.

**(ii)** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**B.** (i) Compare the result with the surface value or a second orbit where appropriate. (ii) Give the ratio clearly.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**C.** (i) Derive or select the appropriate expression before substituting values. (ii) Calculate the requested force, field, potential, speed or period.

**(i)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

**(ii)** (i) Explain the physical meaning of the sign or variation. (ii) State the assumptions made about the planet and orbit.

## 11. Oscillations and Waves

### Question 71

**A.** A mass of 0.50 kg is attached to a spring of force constant 200 $N\ m^{-1}$. Calculate the period and frequency of small oscillations.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 72

**A.** A simple pendulum has length 1.0 m. Find its period at a location where g = 9.8 m $s^{-2}$.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 73

**A.** An oscillator has amplitude 0.08 m and angular frequency 5 rad $s^{-1}$. Find its maximum speed and maximum acceleration.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 74

**A.** A wave has frequency 250 Hz and wavelength 1.2 m. Calculate its propagation speed.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 75

**A.** A string fixed at both ends has length 1.5 m and wave speed 120 m $s^{-1}$. Find its fundamental frequency and third-harmonic frequency.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

### Question 76

**A.** Two tuning forks of frequencies 256 Hz and 262 Hz sound together. Calculate the beat frequency.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## 9. Electrostatics

### Question 77

**A.** Two point charges +4.0 μC and −6.0 μC are separated by 0.30 m in air. Calculate the magnitude and direction of the electrostatic force between them.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 78

**A.** Charges +3.0 μC and +8.0 μC are separated by 0.40 m. A third charge is placed on the line joining them. Determine the position at which the net electric force on the third charge is zero.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 79

**A.** Three point charges are placed at the corners of an equilateral triangle of side 0.20 m: +2 μC, +2 μC and −3 μC. Calculate the resultant force on the −3 μC charge.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 80

**A.** Two identical small conducting spheres carry charges +8 μC and −2 μC. They are touched together and separated. Find the final charge on each sphere and explain charge conservation.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 81

**A.** A charge of +5 μC is placed at the origin. Calculate the electric field strength and direction at a point 0.25 m away.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 82

**A.** Two charges +4 μC and −4 μC are separated by 0.12 m. Calculate the electric field at the midpoint between them.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 83

**A.** At a point P, two perpendicular electric field components have magnitudes $3.0 \times 10^{4}\ \text{N C}^{-1}$ and $4.0 \times 10^{4}\ \text{N C}^{-1}$. Find the resultant field and its direction.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 84

**A.** A charge +2 μC is moved between two points with potential difference 150 V. Calculate the work done by the electric field and the change in electric potential energy.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 85

**A.** Calculate the electric potential at a point 0.20 m from a point charge of −7 μC in air.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 86

**A.** Charges +3 μC and +5 μC are separated by 0.50 m. Calculate the electric potential at the midpoint and the work needed to bring a +2 μC charge from infinity to that midpoint.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 87

**A.** An electron is released from rest in a uniform electric field of magnitude $2.0 \times 10^{4}$ N C$^{-1}$. Find the magnitude of its acceleration. Use $e = 1.60 \times 10^{-19}$ C and $m_e = 9.11 \times 10^{-31}$ kg.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 88

**A.** An oil drop carrying charge $-3.2 \times 10^{-19}$ C is suspended at rest in a vertical electric field. If its mass is $2.0 \times 10^{-15}$ kg, determine the magnitude and direction of the field.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 89

**A.** A parallel-plate capacitor has plate area 0.020 $\text{m}^2$ and separation 1.0 mm. Calculate its capacitance in air, taking $\varepsilon_0 = 8.85 \times 10^{-12}$ F $\text{m}^{-1}$.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 90

**A.** A 6 μF capacitor is connected to a 12 V battery. Find its charge and stored energy.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 91

**A.** Capacitors of 2 μF, 3 μF and 6 μF are connected in series across a 24 V supply. Calculate the equivalent capacitance, charge on each capacitor and voltage across each.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 92

**A.** Capacitors of 4 μF and 8 μF are connected in parallel across 10 V. Find the equivalent capacitance, total charge and energy stored in the combination.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 93

**A.** A 5 μF capacitor charged to 100 V is disconnected from the battery and connected in parallel to an uncharged 10 μF capacitor. Determine the final common voltage and the energy lost during redistribution.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 94

**A.** A dielectric of relative permittivity 4 completely fills a parallel-plate capacitor. Explain and calculate how its capacitance changes compared with air if the original capacitance is 2 μF.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 95

**A.** Derive the expression for the electric field between two large oppositely charged parallel plates, neglecting edge effects, and state the assumptions used.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 96

**A.** Using Coulomb's law, explain why the electrostatic force follows an inverse-square relation. Then calculate how the force changes when the separation is reduced to one-third of its original value.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 97

**A.** Four equal charges +q are placed at the corners of a square of side a. Determine the magnitude and direction of the resultant electric field at the centre.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 98

**A.** A uniformly charged ring has total charge Q and radius R. Write an expression for the electric field on its axis at distance x from the centre, and find where the field is maximum.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 99

**A.** An electric dipole consists of charges ±4 μC separated by 5.0 mm. Calculate its dipole moment and estimate the far-field electric field on its axial line at 0.20 m, using $E = (1/(4\pi\varepsilon_0))(2p/r^3)$.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

## Question 100

**A.** A charged particle enters a uniform electric field perpendicular to its initial velocity. Describe its path and derive an expression for its vertical deflection after travelling a horizontal distance L between plates.

**(i)** (i) Identify the oscillating system and write the governing relation. (ii) Express all values in SI units.

**(ii)** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**B.** (i) Sketch a labelled displacement-time or wave diagram. (ii) Mark the amplitude, wavelength, period or nodes as appropriate.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**C.** (i) Calculate the requested period, frequency, speed or amplitude-related quantity. (ii) Check the result using a second relation where possible.

**(i)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.

**(ii)** (i) Explain the physical meaning of the result. (ii) State how the answer changes if frequency, length or stiffness is changed.