NCERT Physics Question Paper (Class - 11)

:: Chapter 1 Physical World ::

Question 1.1 Some of the most profound statements on the nature of science have come from Albert Einstein, one of the greatest scientists of all time. What do you think did Einstein mean when he said : "The most incomprehensible thing about the world is that it is comprehensible"?

Question 1.2 "Every great physical theory starts as a heresy and ends as a dogma". Give some examples from the history of science of the validity of this incisive remark.

Question 1.3 "Politics is the art of the possible". Similarly, "Science is the art of the soluble". Explain this beautiful aphorism on the nature and practice of science.

Question 1.4 Though India now has a large base in science and technology, which is fast expanding, it is still a long way from realising its potential of becoming a world leader in science. Name some important factors, which in your view have hindered the advancement of science in India.

Question 1.5 No physicist has ever "seen" an electron. Yet, all physicists believe in the existence of electrons. An intelligent but superstitious man advances this analogy to argue that 'ghosts' exist even though no one has 'seen' one. How will you refute his argument ?

Question 1.6 The shells of crabs found around a particular coastal location in Japan seem mostly to resemble the legendary face of a Samurai. Given below are two explanations of this observed fact. Which of these strikes you as a scientific explanation ?
(a) A tragic sea accident several centuries ago drowned a young Samurai. As a tribute to his bravery, nature through its inscrutable ways immortalised his face by imprinting it on the crab shells in that area
(b) After the sea tragedy, fishermen in that area, in a gesture of honour to their dead hero, let free any crab shell caught by them which accidentally had a shape resembling the face of a Samurai. Consequently, the particular
shape of the crab shell survived longer and therefore in course of time the shape was genetically propagated. This is an example of evolution by artificial selection. [Note :This interesting illustration taken from Carl Sagan's 'The Cosmos' highlights the fact that often strange and inexplicable facts which on the first sight appear 'supernatural' actually turn out to have simple scientific explanations. Try to think out other examples of this kind].

Question 1.7 The industrial revolution in England and Western Europe more than two centuries ago was triggered by some key scientific and technological advances. What were these advances ?

Question 1.8 It is often said that the world is witnessing now a second industrial revolution, which will transform the society as radically as did the first. List some key contemporary areas of science and technology, which are responsible for this revolution.

Question 1.9 Write in about 1000 words a fiction piece based on your speculation on the science and technology of the twenty-second century.

Question 1.10 Attempt to formulate your 'moral' views on the practice of science. Imagine yourself stumbling upon a discovery, which has great academic interest but is certain to have nothing but dangerous consequences for the human society. How, if at all, will you resolve your dilemma ?

Question 1.11 Science, like any knowledge, can be put to good or bad use, depending on the user. Given below are some of the applications of science. Formulate your views on whether the particular application is good, bad or something that cannot be so clearly categorised :
(a) Mass vaccination against small pox to curb and finally eradicate this disease from the population. (This has already been successfully done in India).
(b) Television for eradication of illiteracy and for mass communication of news and ideas.

(c) Prenatal sex determination

(d) Computers for increase in work efficiency

(e) Putting artificial satellites into orbits around the Earth

(f) Development of nuclear weapons

(g) Development of new and powerful techniques of chemical and biological warfare).

(h) Purification of water for drinking

(i) Plastic surgery

(j) Cloning

Question 1.12 India has had a long and unbroken tradition of great scholarship — in mathematics, astronomy, linguistics, logic and ethics. Yet, in parallel with this, several superstitious and obscurantistic attitudes and practices flourished in our society and unfortunately continue even today — among many educated people too. How will you use your knowledge of science to develop strategies to counter these attitudes ?

Question 1.13 Though the law gives women equal status in India, many people hold unscientific views on a woman's innate nature, capacity and intelligence, and in practice give them a secondary status and role. Demolish this view using scientific arguments, and by quoting examples of great women in science and other spheres; and persuade yourself and others that, given equal opportunity, women are on par with men.

Question 1.14 "It is more important to have beauty in the equations of physics than to have them agree with experiments". The great British physicist P. A. M. Dirac held this view. Criticize this statement. Look out for some equations and results in this book which strike you as beautiful.

Question 1.15 Though the statement quoted above may be disputed, most physicists do have a feeling that the great laws of physics are at once simple and beautiful. Some of the notable physicists, besides Dirac, who have articulated this feeling, are : Einstein, Bohr, Heisenberg, Chandrasekhar and Feynman. You are urged to make special efforts toaccess to the general books and writings by these and other great masters of physics. (See the Bibliography at the end of this book.) Their writings are truly inspiring !

Question 1.16 Textbooks on science may give you a wrong impression that studying science is dry and all too serious and that scientists are absent-minded introverts who never laugh or grin. This image of science and scientists is patently false. Scientists, like any other group of humans, have their share of humorists, and many have led their lives with a great sense of fun and adventure, even as they seriously pursued their scientific work. Two great physicists of this genre are Gamow and Feynman. You will enjoy reading their books listed in the Bibliography.

:: Chapter 2 Units And Measurement ::

Question 2. 1 Fill in the blanks
(a) The volume of a cube of side 1 cm is equal to m3
(b) The surface area of a solid cylinder of radius 2. 0 cm and height 10.0 cm is equal to ...(mm)2
(c) A vehicle moving with a speed of 18 km h–1 covers....m in 1 s
(d) The relative density of lead is 11.3. Its density is ....g cm–3 or ....kg m–3.

Question 2. 2 Fill in the blanks by suitable conversion of units
(a) 1 kg m2 s–2 = ...g cm2 s–2
(b) 1 m = ... ly
(c) 3.0 m s–2 = ... km h–2
(d) G = 6.67 × 10–11 N m2 (kg)–2 = ... (cm)3 s–2 g–1.

Question 2. 3 A calorie is a unit of heat or energy and it equals about 4.2 J where 1J = 1 kg m2 s–2. Suppose we employ a system of units in which the unit of mass equals α kg, the unit of length equals β m, the unit of time is γ s. Show that a calorie has a magnitude 4.2 α–1 β –2 γ 2 in terms of the new units.

Question 2. 4 Explain this statement clearly : “To call a dimensional quantity ‘large’ or ‘small’ is meaningless without specifying a standard for comparison”. In view of this, reframe the following statements wherever necessary :
(a) atoms are very small objects
(b) a jet plane moves with great speed
(c) the mass of Jupiter is very large
(d) the air inside this room contains a large number of molecules
(e) a proton is much more massive than an electron
(f) the speed of sound is much smaller than the speed of light.

Question 2. 5 A new unit of length is chosen such that the speed of light in vacuum is unity. What is the distance between the Sun and the Earth in terms of the new unit if light takes 8 min and 20 s to cover this distance ?

Question 2. 6 Which of the following is the most precise device for measuring length :

(a) a vernier callipers with 20 divisions on the sliding scale

(b) a screw gauge of pitch 1 mm and 100 divisions on the circular scale

(c) an optical instrument that can measure length to within a wavelength of light ?

Question 2. 7 A student measures the thickness of a human hair by looking at it through a microscope of magnification 100. He makes 20 observations and finds that the average width of the hair in the field of view of the microscope is 3.5 mm. What is the estimate on the thickness of hair ?

Question 2. 8 Answer the following :

(a)You are given a thread and a metre scale. How will you estimate the diameter of the thread ?

(b)A screw gauge has a pitch of 1.0 mm and 200 divisions on the circular scale. Do you think it is possible to increase the accuracy of the screw gauge arbitrarily by increasing the number of divisions on the circular scale ?

(c) The mean diameter of a thin brass rod is to be measured by vernier callipers. Why is a set of 100 measurements of the diameter expected to yield a more reliable estimate than a set of 5 measurements only ?

Question 2. 9 The photograph of a house occupies an area of 1.75 cm2 on a 35 mm slide. The slide is projected on to a screen, and the area of the house on the screen is 1.55 m 2. What is the linear magnification of the projector-screen arrangement. 2.10 State the number of significant figures in the following :

(a) 0.007 m2

(b) 2. 64 × 1024 kg

(c) 0.2370 g cm–3

(d) 6.320 J

(e) 6.032 N m–2

(f) 0.0006032 m2

Question 2.11 The length, breadth and thickness of a rectangular sheet of metal are 4.234 m, 1.005 m, and 2. 01 cm respectively. Give the area and volume of the sheet to correct significant figures.

Question 2.12 The mass of a box measured by a grocer’s balance is 2. 300 kg. Two gold pieces of masses 20.15 g and 20.17 g are added to the box. What is (a) the total mass of the box, (b) the difference in the masses of the pieces to correct significant figures ?

Question 2.13 A physical quantity P is related to four observables a, b, c and d as follows : P = a3b2/ (c d) The percentage errors of measurement in a, b, c and d are 1%, 3%, 4% and 2%, respectively. What is the percentage error in the quantity P ? If the value of P calculated using the above relation turns out to be 3.763, to what value should you round off the result ?

Question 2. 14 A book with many printing errors contains four different formulas for the displacement y of a particle undergoing a certain periodic motion :
(a) y = a sin 2π t/T
(b) y = a sin vt
(c) y = (a/T) sin t/a
(d) y = (a 2) (sin 2πt / T + cos 2πt / T) (a = maximum displacement of the particle, v = speed of the particle. T = time-period of motion). Rule out the wrong formulas on dimensional grounds.

Question 2.15 A famous relation in physics relates 'moving mass' m to the 'rest mass' mo of a particle in terms of its speed v and the speed of light, c. (This relation first arose as a consequence of special relativity due to Albert Einstein). A boy recalls the relation almost correctly but forgets where to put the constant c. He writes : ( ) m m 1 v = 0 − 2 1/2. Guess where to put the missing c.

Question 2.16 The unit of length convenient on the atomic scale is known as an angstrom and is denoted by Å: 1 Å = 10–10 m. The size of a hydrogen atom is about 0.5 Å. What is the total atomic volume in m3 of a mole of hydrogen atoms ?

Question 2. 17 One mole of an ideal gas at standard temperature and pressure occupies 22.4 L (molar volume). What is the ratio of molar volume to the atomic volume of a mole of hydrogen ? (Take the size of hydrogen molecule to be about 1 Å). Why is this ratio so large ?

Question 2. 18 Explain this common observation clearly :
If you look out of the window of a fast moving train, the nearby trees, houses etc. seem to move rapidly in a direction opposite to the train's motion, but the distant objects (hill tops, the Moon, the stars etc.) seem to be stationary. (In fact, since you are aware that you are moving, these distant objects seem to move with you).

Question 2. 19 The principle of 'parallax' in section 2.3.1 is used in the determination of distances of very distant stars. The baseline AB is the line joining the Earth's two locations six months apart in its orbit around the Sun. That is, the baseline is about the diameter of the Earth's orbit ≈ 3 × 1011m.

However, even the nearest stars are so distant that with such a long baseline, they show parallax only of the order of 1” (second) of arc or so. A parsec is a convenient unit of length on the astronomical scale. It is the distance of an object that will show a parallax of 1” (second) of arc from opposite ends of a baseline equal to the distance from the Earth to the Sun. How much is a parsec in terms of metres ?

Question 2. 20 The nearest star to our solar system is 4.29 light years away. How much is this distance in terms of parsecs? How much parallax would this star (named Alpha Centauri) show when viewed from two locations of the Earth six months apart in its orbit around the Sun ?

Question 2. 21 Precise measurements of physical quantities are a need of science. For example, to ascertain the speed of an aircraft, one must have an accurate method to find its positions at closely separated instants of time. This was the actual motivation behind the discovery of radar in World War II. Think of different examples in modern science where precise measurements of length, time, mass etc. are needed. Also, wherever you can, give a quantitative idea of the precision needed.

Question 2. 22 Just as precise measurements are necessary in science, it is equally important to be able to make rough estimates of quantities using rudimentary ideas and common observations. Think of ways by which you can estimate the following (where an estimate is difficult to obtain, try to get an upper bound on the quantity) :
(a) the total mass of rain-bearing clouds over India during the Monsoon
(b) the mass of an elephant
(c) the wind speed during a storm
(d) the number of strands of hair on your head
(e) the number of air molecules in your classroom.

Question 2. 23 The Sun is a hot plasma (ionized matter) with its inner core at a temperature exceeding 107 K, and its outer surface at a temperature of about 6000 K. At these high temperatures, no substance remains in a solid or liquid phase. In what range do you expect the mass density of the Sun to be, in the range of densities of solids and liquids or gases ? Check if your guess is correct from the following data : mass of the Sun =2.0 × 1030 kg, radius of the Sun = 7.0 × 108 m.

Question 2. 24 When the planet Jupiter is at a distance of 824.7 million kilometers from the Earth, its angular diameter is measured to be 35.72” of arc. Calculate the diameter of Jupiter. Additional Exercises

Question 2. 25 A man walking briskly in rain with speed v must slant his umbrella forward making an angle θ with the vertical. A student derives the following relation between θ and v : tan θ = v and checks that the relation has a correct limit: as v → 0, θ →0, as expected. (We are assuming there is no strong wind and that the rain falls vertically for a stationary man). Do you think this relation can be correct ? If not, guess the correct relation.

Question 2. 26 It is claimed that two cesium clocks, if allowed to run for 100 years, free from any disturbance, may differ by only about 0.02 s. What does this imply for the accuracy of the standard cesium clock in measuring a time-interval of 1 s ?

Question 2. 27 Estimate the average mass density of a sodium atom assuming its size to be about 2. 5 Å. (Use the known values of Avogadro's number and the atomic mass of sodium). Compare it with the density of sodium in its crystalline phase :

970 kg m–3. Are the two densities of the same order of magnitude ? If so, why ?

Question 2. 28 The unit of length convenient on the nuclear scale is a fermi : 1 f = 10–15 m. Nuclear sizes obey roughly the following empirical relation : r = r0 A1/3 where r is the radius of the nucleus, A its mass number, and ro is a constant equal to about, 1.2 f. Show that the rule implies that nuclear mass density is nearly constant for different nuclei. Estimate the mass density of sodium nucleus. Compare it with the average mass density of a sodium atom obtained in Exercise. 2. 27.

Question 2. 29 A LASER is a source of very intense, monochromatic, and unidirectional beam of light. These properties of a laser light can be exploited to measure long distances. The distance of the Moon from the Earth has been already determined very precisely using a laser as a source of light. A laser light beamed at the Moon takes 2. 56 s toreturn after reflection at the Moon's surface. How much is the radius of the lunar orbit around the Earth ?

Question 2. 30 A SONAR (sound navigation and ranging) uses ultrasonic waves to detect and locate objects under water. In a submarine equipped with a SONAR the time delay between generation of a probe wave and the reception of its echo after reflection from an enemy submarine is found to be 77.0 s. What is the distance of the enemy submarine? (Speed of sound in water = 1450 m s–1).

Question 2. 31 The farthest objects in our Universe discovered by modern astronomers are so distant that light emitted by them takes billions of years to reach the Earth. These objects (known as quasars) have many puzzling features, which have not yet been satisfactorily explained. What is the distance in km of a quasar from which light takes 3.0 billion years to reach us ?

Question 2. 32 It is a well known fact that during a total solar eclipse the disk of the moon almost completely covers the disk of the Sun. From this fact and from the information you can gather from examples 2. 3 and 2. 4, determine the approximate diameter of the moon.

Question 2. 33 A great physicist of this century (P.A.M. Dirac) loved playing with numerical values of Fundamental constants of nature. This led him to an interesting observation. Dirac found that from the basic constants of atomic physics (c, e, mass of electron, mass of proton) and the gravitational constant G, he could arrive at a number with the dimension of time. Further, it was a very large number, its magnitude being close to the present estimate on the age of the universe (~15 billion years). From the table of fundamental constants in this book, try to see if you too can construct this number (or any other interesting number you can think of). If its coincidence with the age of the universe were significant, what would this imply for the constancy of fundamental constants ?

:: Chapter 3 Motion In A Straight Line ::

Question 3.1 In which of the following examples of motion, can the body be considered approximately a point object:

(a) a railway carriage moving without jerks between two stations.

(b) a monkey sitting on top of a man cycling smoothly on a circular track.

(c) a spinning cricket ball that turns sharply on hitting the ground.

(d) a tumbling beaker that has slipped off the edge of a table.

Question 3.2 The position-time (x-t) graphs for two children A and B returning from their school O to their homes P and Q respectively are shown in Fig.

Question 3.19 Choose the correct entries in the brackets below ;

(a) (A/B) lives closer to the school than (B/A)

(b) (A/B) starts from the school earlier than (B/A)

(c) (A/B) walks faster than (B/A)

(d) A and B reach home at the (same/different) time

(e) (A/B) overtakes (B/A) on the road (once/twice).

Question 3.3 A woman starts from her home at 9.00 am, walks with a speed of 5 km h–1 on a straight road up to her office 2.5 km away, stays at the office up to 5.00 pm, and returns home by an auto with a speed of 25 km h–1. Choose suitable scales and plot the x-t graph of her motion.

Question 3.4 A drunkard walking in a narrow lane takes 5 steps forward and 3 steps backward, followed again by 5 steps forward and 3 steps backward, and so on. Each step is 1 m long and requires 1 s. Plot the x-t graph of his motion. Determine graphically and otherwise how long the drunkard takes to fall in a pit 13 m away from the start.

Question 3.5 A jet airplane travelling at the speed of 500 km h–1 ejects its products of combustion at the speed of 1500 km h–1 relative to the jet plane. What is the speed of the latter with respect to an observer on the ground ?

Question 3.6 A car moving along a straight highway with speed of 126 km h–1 is brought to a stop within a distance of 200 m. What is the retardation of the car (assumed uniform), and how long does it take for the car to stop ?

Question 3.7 Two trains A and B of length 400 m each are moving on two parallel tracks with a uniform speed of 72 km h–1 in the same direction, with A ahead of B. The driver of B decides to overtake A and accelerates by 1 m s–2. If after 50 s, the guard of B just brushes past the driver of A, what was the original distance between them ?

Question 3.8 On a two-lane road, car A is travelling with a speed of 36 km h–1. Two cars B and C approach car A in opposite directions with a speed of 54 km h–1 each. At a certain instant, when the distance AB is equal to AC, both being 1 km, B decides to overtake A before C does. What minimum acceleration of car B is required to avoid an accident ?

Question 3.9 Two towns A and B are connected by a regular bus service with a bus leaving in either direction every T minutes. A man cycling with a speed of 20 km h–1 in the direction A to B notices that a bus goes past him every 18 min in the direction of his motion, and every 6 min in the opposite direction. What is the period T of the bus service and with what speed (assumed constant) do the buses ply on the road?

Question 3.10 A player throws a ball upwards with an initial speed of 29.4 m s–1.
(a) What is the direction of acceleration during the upward motion of the ball ?

(b) What are the velocity and acceleration of the ball at the highest point of its motion ?
(c) Choose the x = 0 m and t = 0 s to be the location and time of the ball at its highest point, vertically downward direction to be the positive direction of x-axis, and give the signs of position, velocity and acceleration of the ball during its upward, and downward motion.
(d) To what height does the ball rise and after how long does the ball return to the player's hands ? (Take g = 9.8 m s–2 and neglect air resistance).

Question 3.11 Read each statement below carefully and state with reasons and examples, if it is true or false ; A particle in one-dimensional motion
(a) with zero speed at an instant may have non-zero acceleration at that instant
(b) with zero speed may have non-zero velocity,
(c) with constant speed must have zero acceleration,
(d) with positive value of acceleration must be speeding up.

Question 3.12 A ball is dropped from a height of 90 m on a floor. At each collision with the floor, the ball loses one tenth of its speed. Plot the speed-time graph of its motion between t = 0 to 12 s.

Question 3.13 Explain clearly, with examples, the distinction between :
(a) magnitude of displacement (sometimes called distance) over an interval of time, and the total length of path covered by a particle over the same interval; (b) magnitude of average velocity over an interval of time, and the average speed over the same interval. [Average speed of a particle over an interval of time is defined as the total path length divided by the time interval]. Show in both (a) and (b) that the second quantity is either greater than or equal to the first. When is the equality sign true ? [For simplicity, consider one-dimensional motion only].

Question 3.14 A man walks on a straight road from his home to a market 2.5 km away with a speed of 5 km h–1. Finding the market closed, he instantly turns and walks back home with a speed of 7.5 km h–1. What is the (a) magnitude of average velocity, and (b) average speed of the man over the interval of time
(i) 0 to 30 min,
(ii) 0 to 50 min,
(iii) 0 to 40 min ?
[Note: You will appreciate from this exercise why it is better to define average speed as total path length divided by time, and not as magnitude of average velocity. You would not like to tell the tired man on his return home that his average speed was zero !]

Question 3.15 In Exercises 3.13 and 3.14, we have carefully distinguished between average speed and magnitude of average velocity. No such distinction is necessary when we consider instantaneous speed and magnitude of velocity. The instantaneous speed is always equal to the magnitude of instantaneous velocity. Why ?

Question 3.16 Look at the graphs (a) to (d) (Fig. 3.20) carefully and state, with reasons, which of these cannot possibly represent one-dimensional motion of a particle.

Question 3.17 Figure3.21 shows the x-t plot of one-dimensional motion of a particle. Is it correct to say from the graph that the particle moves in a straight line for $t < 0$ and on a parabolic path for $t > 0$? If not, suggest a suitable physical context for this graph.

Question 3.18 A police van moving on a highway with a speed of 30 km h–1 fires a bullet at a thief's car speeding away in the same direction with a speed of 192 km h–1. If the muzzle speed of the bullet is 150 m s–1, with what speed does the bullet hit the thief's car ?
(Note: Obtain that speed which is relevant for damaging the thief's car).

Question 3.19 Suggest a suitable physical situation for each of the following graphs (Fig 3.22):

Question 3.20 Figure3.23 gives the x-t plot of a particle executing one-dimensional simple harmonic motion. (You will learn about this motion in more detail in Chapter14). Give the signs of position, velocity and acceleration variables of the particle at t = 0.3 s, 1.2 s, – 1.2 s. Fig.

Question 3.21 Figure 3.24 gives the x-t plot of a particle in one-dimensional motion. Three different equal intervals of time are shown. In which interval is the average speed greatest, and in which is it the least ? Give the sign of average velocity for each interval.

Question 3.22 Figure 3.25 gives a speed-time graph of a particle in motion along a constant direction. Three equal intervals of time are shown. In which interval is the average acceleration greatest in magnitude ? In which interval is the average speed greatest ? Choosing the positive direction as the constant direction of motion, give the signs of v and a in the three intervals. What are the accelerations at the points A, B, C and D ?

Question 3.23 A three-wheeler starts from rest, accelerates uniformly with 1 m s–2 on a straight road for 10 s, and then moves with uniform velocity. Plot the distance covered by the vehicle during the nth second (n = 1,2,3….) versus n. What do you expect this plot to be during accelerated motion

: a straight line or a parabola ?

Question 3.24 A boy standing on a stationary lift (open from above) throws a ball upwards with the maximum initial speed he can, equal to 49 m s–1. How much time does the ball take to return to his hands? If the lift starts moving up with a uniform speed of 5 m s-1 and the boy again throws the ball up with the maximum speed he can, how long does the ball take to return to his hands ?

Question 3.25 On a long horizontally moving belt (Fig.3.26), a child runs to and fro with a speed 9 km h–1 (with respect to the belt) between his father and mother located 50 m apart on the moving belt. The belt moves with a speed of 4 km h–1. For an observer on a stationary platform outside, what is the
(a) speed of the child running in the direction of motion of the belt ?.
(b) speed of the child running opposite to the direction of motion of the belt ?
(c) time taken by the child in (a) and (b) ? Which of the answers alter if motion is viewed by one of the parents ?

Question 3.26 Two stones are thrown up simultaneously from the edge of a cliff 200 m high with initial speeds of 15 m s–1 and 30 m s–1. Verify that the graph shown in Fig.

Question 3.27 correctly represents the time variation of the relative position of the second stone with respect to the first. Neglect air resistance and assume that the stones do not rebound after hitting the ground. Take g = 10 m s–2. Give the equations for the linear and curved parts of the plot.3.27 The speed-time graph of a particle moving along a fixed direction is shown in Fig. 3.28. Obtain the distance traversed by the particle between
(a) t = 0 s to 10 s, (b) t = 2 s to 6 s. Fig.3.28 What is the average speed of the particle over the intervals in (a) and (b) ?

Question 3.28 The velocity-time graph of a particle in one-dimensional motion is shown in Fig.3..29 : Fig

Question 3.29 Which of the following formulae are correct for describing the motion of the particle over the time-interval t 1 to t 2 :
(a) x(t2) = x(t1) + v (t1) (t2 – t1) +(½) a (t2 – t1)2
(b) v(t2) = v(t1) + a (t2 – t1)
(c) vaverage = (x(t2) – x(t1))/(t2 – t1)
(d) aaverage = (v(t2) – v(t1))/(t2 – t1)

(e) x(t2) = x(t1) + vaverage (t2 – t1) + (½) aaverage (t2 – t1)2 (f) x(t2) – x(t1) = area under the v-t curve bounded by the t-axis and the dotted line shown.

:: Chapter 4 Motion In A Plane ::

Question 4.1 State, for each of the following physical quantities, if it is a scalar or a vector : volume, mass, speed, acceleration, density, number of moles, velocity, angular frequency, displacement, angular velocity.

Question 4.2 Pick out the two scalar quantities in the following list : force, angular momentum, work, current, linear momentum,electric field, average velocity, magnetic moment, relative velocity.

Question 4.3 Pick out the only vector quantity in the following list : Temperature, pressure, impulse, time, power, total path length, energy, gravitational potential, coefficient of friction, charge.

Question 4.4 State with reasons, whether the following algebraic operations with scalar and vector physical quantities are meaningful :
(a) adding any two scalars,
(b) adding a scalar to a vector of the same dimensions ,
(c) multiplying any vector by any scalar,
(d) multiplying any two scalars,
(e) adding any two vectors,
(f) adding a component of a vector to the same vector.

Question 4.5 Read each statement below carefully and state with reasons, if it is true or false :
(a) The magnitude of a vector is always a scalar,
(b) each component of a vector is always a scalar,
(c) the total path length is always equal to the magnitude of the displacement vector of a particle. (
d) the average speed of a particle (defined as total path length divided by the time taken to cover the path) is either greater or equal to the magnitude of average velocity of the particle over the same interval of time,
(e) Three vectors not lying in a plane can never add up to give a null vector.

Question 4.6 Establish the following vector inequalities geometrically or otherwise :
(a) |a+b| < |a| + |b|

(b) |a+b| > ||a| −|b||

(c) |a−b| < |a| + |b|

(d) |a−b| > ||a| − |b||

When does the equality sign above apply?

Question 4.7 Given a + b + c + d = 0, which of the following statements are correct :

(a) a, b, c, and d must each be a null vector,

(b) The magnitude of (a + c) equals the magnitude of (b + d),

(c) The magnitude of a can never be greater than the sum of the magnitudes of b, c, and d,

(d) b + c must lie in the plane of a and d if a and d are not collinear, and in the line of a and d, if they are collinear ?

Question 4.8 Three girls skating on a circular ice ground of radius 200 m start from a point P on the edge of the ground and reach a point Q diametrically opposite to P following different paths as shown in Fig. 4.20. What is the magnitude of the displacement vector for each ? For which girl is this equal to the actual length of path skate ?

Question 4.9 A cyclist starts from the centre O of a circular park of radius 1 km, reaches the edge P of the park, then cycles along the circumference, and returns to the centre along QO as shown in Fig. 4.21. If the round trip takes 10 min, what is the (a) net displacement, (b) average velocity, and (c) average speed of the cyclist ?

Question 4.10 On an open ground, a motorist follows a track that turns to his left by an angle of 600 after every 500 m. Starting from a given turn, specify the displacement of the motorist at the third, sixth and eighth turn. Compare the magnitude of the displacement with the total path length covered by the motorist in each case .

Question 4.11 A passenger arriving in a new town wishes to go from the station to a hotel located 10 km away on a straight road from the station. A dishonest cabman takes him along a circuitous path 23 km long and reaches the hotel in 28 min. What is (a) the average speed of the taxi, (b) the magnitude of average velocity ? Are the two equal ?

Question 4.12 Rain is falling vertically with a speed of 30 m s-1. A woman rides a bicycle with a speed of 10 m s-1 in the north to south direction. What is the direction in which she should hold her umbrella ?

Question 4.13 A man can swim with a speed of 4.0 km/h in still water. How long does he take to cross a river 1.0 km wide if the river flows steadily at 3.0 km/h and he makes his reaches the other bank ?

Question 4.14 In a harbour, wind is blowing at the speed of 72 km/h and the flag on the mast of a boat anchored in the harbour flutters along the N-E direction. If the boat starts moving at a speed of 51 km/h to the north, what is the direction of the flag on the mast of the boat ?

Question 4.15 The ceiling of a long hall is 25 m high. What is the maximum horizontal distance that a ball thrown with a speed of 40 m s-1 can go without hitting the ceiling of the hall ?

Question 4.16 A cricketer can throw a ball to a maximum horizontal distance of 100 m. How much high above the ground can the cricketer throw the same ball ?

Question 4.17 A stone tied to the end of a string 80 cm long is whirled in a horizontal circle with a constant speed. If the stone makes 14 revolutions in 25 s, what is the magnitude and direction of acceleration of the stone ?

Question 4.18 An aircraft executes a horizontal loop of radius 1.00 km with a steady speed of 900 km/h. Compare its centripetal acceleration with the acceleration due to gravity.

Question 4.19 Read each statement below carefully and state, with reasons, if it is true or false :
(a) The net acceleration of a particle in circular motion is always along the radius of the circle towards the centre
(b) The velocity vector of a particle at a point is always along the tangent to the path of the particle at that point
(c) The acceleration vector of a particle in uniform circular motion averaged over one cycle is a null vector

Question 4.20 The position of a particle is given by r = 3.0t ˆi − 2.0t 2 ˆj + 4.0 kˆ m where t is in seconds and the coefficients have the proper units for r to be in metres.
(a) Find the v and a of the particle?
(b) What is the magnitude and direction of velocity of the particle at t = 2.0 s ?

Question 4.21 A particle starts from the origin at t = 0 s with a velocity of 10.0 j m/s and moves in the x-y plane with a constant acceleration of + j) m s-2.

(a) At what time is the x- coordinate of the particle 16 m? What is the y-coordinate of the particle at that time?

(b) What is the speed of the particle at the time ?

Question 4.22 j are unit vectors along x- and y- axis respectively. What is the magnitude and direction of the vectors ij ? What are the com along the directions [You may use graphical method]

Question 4.23 For any arbitrary motion in space, which of the following relations are true :

(a) vaverage = (1/2) (v (t1) + v (t2))

(b) v average = [r(t2) - r(t1)] /(t2 – t1)

(c) v (t) = v (0) + a t

(d) r (t) = r (0) + v (0) t + (1/2) a t2

(e) a average =[v (t2) - v (t1)] /(t2 – t1)

(The ‘average’ stands for average of the quantity over the time interval t1 to t2)

Question 4.24 Read each statement below carefully and state, with reasons and examples, if it is true or false : A scalar quantity is one that

(a) is conserved in a process

(b) can never take negative values

(c) must be dimensionless

(d) does not vary from one point to another in space

(e) has the same value for observers with different orientations of axes.

Question 4.25 An aircraft is flying at a height of 3400 m above the ground. If the angle subtended at a ground observation point by the aircraft positions 10.0 s apart is 30°, what is the speed of the aircraft ?

Question 4.26 A vector has magnitude and direction. Does it have a location in space ? Can it vary with time ? Will two equal vectors a and b at different locations in space necessarily have identical physical effects ? Give examples in support of your answer.

Question 4.27 A vector has both magnitude and direction. Does it mean that anything that has magnitude and direction is necessarily a vector ? The rotation of a body can be specified by the direction of the axis of rotation, and the angle of rotation about the axis. Does that make any rotation a vector ?

Question 4.28 Can you associate vectors with (a) the length of a wire bent into a loop, (b) a plane area, (c) a sphere ? Explain.

Question 4.29 A bullet fired at an angle of 30° with the horizontal hits the ground 3.0 km away. By adjusting its angle of projection, can one hope to hit a target 5.0 km away ? Assume the muzzle speed to the fixed, and neglect air resistance.

Question 4.30 A fighter plane flying horizontally at an altitude of 1.5 km with speed 720 km/h passes directly overhead an anti-aircraft gun. At what angle from the vertical should the gun be fired for the shell with muzzle speed 600 m s-1 to hit the plane ? At what minimum altitude should the pilot fly the plane to avoid being hit ? (Take g = 10 m s-2).

Question 4.31 A cyclist is riding with a speed of 27 km/h. As he approaches a circular turn on the road of radius 80 m, he applies brakes and reduces his speed at the constant rate of 0.50 m/s every second. What is the magnitude and direction of the net acceleration of the cyclist on the circular turn ?

Question 4.32 (a) Show that for a projectile the angle between the velocity and the x-axis as a function of time is given by ( ) − ox 0y v v gt θ t = tan-1 (b) Shows that the projection angle θ0 for a projectile launched from the origin is given by 0 R 4h θ = tan-1 m where the symbols have their usual meaning

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:: Chapter 5 Laws Of Motion ::

Question 5.1 Give the magnitude and direction of the net force acting on (a) a drop of rain falling down with a constant speed, (b) a cork of mass 10 g floating on water, (c) a kite skillfully held stationary in the sky, (d) a car moving with a constant velocity of 30 km/h on a rough road, (e) a high-speed electron in space far from all material objects, and free of electric and magnetic fields.

Question 5.2 A pebble of mass 0.05 kg is thrown vertically upwards. Give the direction and magnitude of the net force on the pebble, (a) during its upward motion, (b) during its downward motion, (c) at the highest point where it is momentarily at rest. Do your answers change if the pebble was thrown at an angle of 45° with the horizontal direction? Ignore air resistance.

Question 5.3 Give the magnitude and direction of the net force acting on a stone of mass 0.1 kg,

(a) just after it is dropped from the window of a stationary train

(b) just after it is dropped from the window of a train running at a constant velocity of 36 km/h

(c) just after it is dropped from the window of a train accelerating with 1 m s-2

(d) lying on the floor of a train which is accelerating with 1 m s-2, the stone being at rest relative to the trainNeglect air resistance throughout.

Question 5.4 One end of a string of length l is connected to a particle of mass m and the other to a small peg on a smooth horizontal table. If the particle moves in a circle with speed v the net force on the particle (directed towards the centre) is :

(i) T

(ii) l mv T 2 −

(iii) l mv T + 2

(iv) 0 T is the tension in the string.

[Choose the correct alternative].

Question 5.5 A constant retarding force of 50 N is applied to a body of mass 20 kg moving initially with a speed of 15 m s-1. How long does the body take to stop ?

Question 5.6 A constant force acting on a body of mass 3.0 kg changes its speed from 2.0 m s-1 to 3.5 m s-1 in 25 s. The direction of the motion of the body remains unchanged. What is the magnitude and direction of the force ?

Question 5.7 A body of mass 5 kg is acted upon by two perpendicular forces 8 N and 6 N. Give the magnitude and direction of the acceleration of the body.

Question 5.8 The driver of a three-wheeler moving with a speed of 36 km/h sees a child standing in the middle of the road and brings his vehicle to rest in 4.0 s just in time to save the child. What is the average retarding force on the vehicle ? The mass of the three-wheeler is 400 kg and the mass of the driver is 65 kg.

Question 5.9 A rocket with a lift-off mass 20,000 kg is blasted upwards with an initial acceleration of5.0 m s-2. Calculate the initial thrust (force) of the blast.

Question 5.10 A body of mass 0.40 kg moving initially with a constant speed of 10 m s-1 to the north is subject to a constant force of 8.0 N directed towards the south for 30 s. Take the instant the force is applied to be t = 0, the position of the body at that time to be x = 0, and predict its position at t = –5 s, 25 s, 100 s.

Question 5.11 A truck starts from rest and accelerates uniformly at 2.0 m s-2. At t = 10 s, a stone is dropped by a person standing on the top of the truck (6 m high from the ground). What are the (a) velocity, and (b) acceleration of the stone at t = 11s ? (Neglect air resistance.)

Question 5.12 A bob of mass 0.1 kg hung from the ceiling of a room by a string 2 m long is set into oscillation. The speed of the bob at its mean position is 1 m s-1. What is the trajectory of the bob if the string is cut when the bob is (a) at one of its extreme positions, (b) at its mean position.

Question 5.13 A man of mass 70 kg stands on a weighing scale in a lift which is moving
(a) upwards with a uniform speed of 10 m s-1
(b) downwards with a uniform acceleration of 5 m s-2
(c) upwards with a uniform acceleration of 5 m s-2. What would be the readings on the scale in each case?
(d) What would be the reading if the lift mechanism failed and it hurtled down freely under gravity ?

Question 5.14 Figure 5.16 shows the position-time graph of a particle of mass 4 kg. What is the (a) force on the particle for $t < 0$, $t > 4$ s, $0 < t < 4$ s? (b) impulse at t = 0 and t = 4 s ? (Consider one-dimensional motion only).

Question 5.15 Two bodies of masses 10 kg and 20 kg respectively kept on a smooth, horizontal surface are tied to the ends of a light string. a horizontal force F = 600 N is applied to (i) A, (ii) B along the direction of string. What is the tension in thestring in each case?

Question 5.16 Two masses 8 kg and 12 kg are connected at the two ends of a light inextensible string that goes over a frictionless pulley. Find the acceleration of the masses, and the tension in the string when the masses are released.

Question 5.17 A nucleus is at rest in the laboratory frame of reference. Show that if it disintegrates into two smaller nuclei the products must move in opposite directions.

Question 5.18 Two billiard balls each of mass 0.05 kg moving in opposite directions with speed 6 m s-1 collide and rebound with the same speed. What is the impulse imparted to each ball due to the other ?

Question 5.19 A shell of mass 0.020 kg is fired by a gun of mass 100 kg. If the muzzle speed of the shell is 80 m s-1, what is the recoil speed of the gun ?

Question 5.20 A batsman deflects a ball by an angle of 45° without changing its initial speed which is equal to 54 km/h. What is the impulse imparted to the ball ? (Mass of the ball is 0.15 kg.)

Question 5.21 A stone of mass 0.25 kg tied to the end of a string is whirled round in a circle of radius 1.5 m with a speed of 40 rev./min in a horizontal plane. What is the tension in the string ? What is the maximum speed with which the stone can be whirled around if the string can withstand a maximum tension of 200 N ?

Question 5.22 If, in Exercise 5.21, the speed of the stone is increased beyond the maximum permissible value, and the string breaks suddenly, which of the following correctly describes the trajectory of the stone after the string breaks :
a) the stone moves radially outwards
(b) the stone flies off tangentially from the instant the string breaks
(c) the stone flies off at an angle with the tangent whose magnitude depends on the speed of the particle ?

Question 5.23 Explain why (a) a horse cannot pull a cart and run in empty space, (b) passengers are thrown forward from their seats when a speeding bus stops suddenly, (c) it is easier to pull a lawn mower than to push it, (d) a cricketer moves his hands backwards while holding a catch.
Additional Exercises

Question 5.24 Figure 5.17 shows the position-time graph of a body of mass 0.04 kg. Suggest a suitable physical context for this motion. What is the time between two consecutive impulses received by the body ? What is the magnitude of each impulse ?

Question 5.25 Figure 5.18 shows a man standing stationary with respect to a horizontal conveyor belt that is accelerating with 1 m s-2. What is the net force on the man? If the coefficient of static friction between the man’s shoes and the belt is 0.2, up to what acceleration of the belt can the man continue to be stationary relative to the belt ? (Mass of the man = 65 kg.)

Question 5.26 A stone of mass m tied to the end of a string revolves in a vertical circle of radius R. The net forces at the lowest and highest points of the circle directed vertically downwards are :[Choose the correct alternative] Lowest Point Highest Point

(a) mg – T1 mg + T2

(b) mg + T1 mg – T2

(c) mg + T1 – (m v 2 1) / R mg – T2 + (m v 2 1) / R (d) mg – T1 – (m v 2 1) / R mg + T2 + (m v 2 1) / R T1 and v1 denote the tension and speed at the lowest point. T2 and v2 denote corresponding values at the highest point.

Question 5.27 A helicopter of mass 1000 kg rises with a vertical acceleration of 15 m s-2. The crew and the passengers weigh 300 kg. Give the magnitude and direction of the (a) force on the floor by the crew and passengers, (b) action of the rotor of the helicopter on the surrounding air, (c) force on the helicopter due to the surrounding air.

Question 5.28 A stream of water flowing horizontally with a speed of 15 m s-1 gushes out of a tube of cross-sectional area 10-2 m2, and hits a vertical wall nearby. What is the force exerted on the wall by the impact of water, assuming it does not rebound ?

Question 5.29 Ten one-rupee coins are put on top of each other on a table. Each coin has a mass m. Give the magnitude and direction of (a) the force on the 7th coin (counted from the bottom) due to all the coins on its top, (b) the force on the 7th coin by the eighth coin, (c) the reaction of the 6th coin on the 7th coin.

Question 5.30 An aircraft executes a horizontal loop at a speed of 720 km/h with its wings banked at 15°. What is the radius of the loop ?

Question 5.31 A train runs along an unbanked circular track of radius 30 m at a speed of 54 km/h. The mass of the train is 106 kg. What provides the centripetal force required for this purpose — The engine or the rails ? What is the angle of banking required to prevent wearing out of the rail ?

Question 5.32 A block of mass 25 kg is raised by a 50 kg man in two different ways as shown in Fig. 5.19. What is the action on the floor by the man in the two cases ? If the floor yields to a normal force of 700 N, which mode should the man adopt to lift the block without the floor yielding ?

Question 5.33 A monkey of mass 40 kg climbs on a rope (Fig.5.20) which can stand a maximum tension of 600 N. In which of the following cases will the rope break: the monkey (a) climbs up with an acceleration of 6 m s-2 (b) climbs down with an acceleration of 4 m s-2 (c) climbs up with a uniform speed of 5 m s-1 (d) falls down the rope nearly freely under gravity? (Ignore the mass of the rope).

Question 5.34 Two bodies A and B of masses 5 kg and 10 kg in contact with each other rest on a table against a rigid wall (Fig. 5.21). The coefficient of friction between the bodies and the table is 0.15. A force of 200 N is applied horizontally to A. What are (a) the reaction of the partition (b) the action-reaction forces between A and B ? What happens when the wall is removed? Does the answer to (b) change, when the bodies are in motion? Ignore the difference between μs and μk.

Question 5.35 A block of mass 15 kg is placed on a long trolley. The coefficient of static friction between the block and the trolley is 0.18. The trolley accelerates from rest with 0.5 m s-2 for 20 s and then moves with uniform velocity. Discuss the motion of the block as viewed by (a) a stationary observer on the ground, (b) an observer moving with the trolley.

Question 5.36 The rear side of a truck is open and a box of 40 kg mass is placed 5 m away from the open end as shown in Fig.5.22. The coefficient of friction between the box and the surface below it is 0.15.On a straight road, the truck starts from rest and accelerates with 2 m s-2. At what distance from the starting point does the box fall off the truck? (Ignore the size of the box).

Question 5.37 A disc revolves with a speed of 33 1 3 rev/min, and has a radius of 15 cm. Two coins are placed at 4 cm and 14 cm away from the centre of the record. If the co-efficient of friction between the coins and the record is 0.15, which of the coins will revolve with the record ?

Question 5.38 You may have seen in a circus a motorcyclist driving in vertical loops inside a ‘deathwell’ (a hollow spherical chamber with holes, so the spectators can watch from outside). Explain clearly why the motorcyclist does not drop down when he is at the uppermost point, with no support from below. What is the minimum speed required at the uppermost position to perform a vertical loop if the radius of the chamber is 25 m ?

Question 5.39 A 70 kg man stands in contact against the inner wall of a hollow cylindrical drum of radius 3 m rotating about its vertical axis with 200 rev/min. The coefficient of friction between the wall and his clothing is 0.15.What is the minimum rotational speed of the cylinder to enable the man to remain stuck to the wall (without falling) when the floor is suddenly removed ?

Question 5.40 A thin circular loop of radius R rotates about its vertical diameter with an angular frequency ω. Show that a small bead on the wire loop remains at its lowermost point for ω ≤ g / R . What is the angle made by the radius vector joining the centre to the bead with the vertical downward direction for ω = 2g / R ? Neglect friction.

:: Chapter 6 Work, Energy And Power ::

Question 6.1 The sign of work done by a force on a body is important to understand. State carefully if the following quantities are positive or negative:
(a) work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket.
(b) work done by gravitational force in the above case,
(c) work done by friction on a body sliding down an inclined plane,
(d) work done by an applied force on a body moving on a rough horizontal plane with uniform velocity,
(e) work done by the resistive force of air on a vibrating pendulum in bringing it to rest.

Question 6.2 A body of mass 2 kg initially at rest moves under the action of an applied horizontal force of 7 N on a table with coefficient of kinetic friction = 0.1. Compute the (a) work done by the applied force in 10 s, (b) work done by friction in 10 s, (c) work done by the net force on the body in 10 s, (d) change in kinetic energy of the body in 10 s, and interpret your results.

Question 6.3 Given in Fig. 6.11 are examples of some potential energy functions in one dimension. The total energy of the particle is indicated by a cross on the ordinate axis. In each case, specify the regions, if any, in which the particle cannot be found for the given energy. Also, indicate the minimum total energy the particle must have in each case. Think of simple physical contexts for which these potential energy shapes are relevant.

Question 6.4 The potential energy function for a particle executing linear simple harmonic motion is given by V(x) = kx2/2, where k is the force constant of the oscillator. For k = 0.5 N m-1, the graph of V(x) versus x is shown in Fig6.12. Show that a particle of total energy 1 J moving under this potential must 'turn back' when it reaches x = ± 2 m.

Question 6.5 Answer the following :
(a) The casing of a rocket in flight burns up due to friction. At whose expense is the heat energy required for burning obtained? The rocket or the atmosphere?
(b) Comets move around the sun in highly elliptical orbits. The gravitational force on the comet due to the sun is not normal to the comet's velocity in general. Yet the work done by the gravitational force over every complete orbit of the comet is zero. Why ?
(c) An artificial satellite orbiting the earth in very thin atmosphere loses its energy gradually due to

dissipation against atmospheric resistance, however small. Why then does its speed increase progressively as it comes closer and closer to the earth ?
(d) In Fig. 6.13(i) the man walks 2 m carrying a mass of 15 kg on his hands. In Fig. 6.13(ii), he walks the same distance pulling the rope behind him. The rope goes over a pulley, and a mass of 15 kg hangs at its other end. In which case is the work done greater ?

Question 6.6 Underline the correct alternative :
(a) When a conservative force does positive work on a body, the potential energy of the body increases/decreases/remains unaltered.
(b) Work done by a body against friction always results in a loss of its kinetic/potential energy.
(c) The rate of change of total momentum of a many-particle system is proportional to the external force/sum of the internal forces on the system.
(d) In an inelastic collision of two bodies, the quantities which do not change after the collision are the total kinetic energy/total linear momentum/total energy of the system of two bodies.

Question 6.7 State if each of the following statements is true or false. Give reasons for your answer.
(a) In an elastic collision of two bodies, the momentum and energy of each body is conserved.
(b) Total energy of a system is always conserved, no matter what internal and external forces on the body are present.
(c) Work done in the motion of a body over a closed loop is zero for every force in nature.
(d) In an inelastic collision, the final kinetic energy is always less than the initial kinetic energy of the system.

Question 6.8 Answer carefully, with reasons :
(a) In an elastic collision of two billiard balls, is the total kinetic energy conserved during the short time of collision of the balls (i.e. when they are in contact) ?
(b) Is the total linear momentum conserved during the short time of an elastic collision of two balls?
(c) What are the answers to (a) and (b) for an inelastic collision ?
(d) If the potential energy of two billiard balls depends only on the separation distance between their centres, is the collision elastic or inelastic ? (Note, we are talking here of potential energy corresponding to the force during collision, not gravitational potential energy).

Question 6.9 A body is initially at rest. It undergoes one-dimensional motion with constant acceleration. The power delivered to it at time t is proportional to (i) t1/2 (ii) t (iii) t3/2 (iv) t2

Question 6.10 A body is moving unidirectionally under the influence of a source of constant power.

Its displacement in time t is proportional to (i) t1/2 (ii) t (iii) t3/2 (iv) t2

Question 6.11 A body constrained to move along the z-axis of a coordinate system is subject to a constant force F given by F = −ˆi + 2 ˆj + 3 kˆ N where ˆi, ˆj, kˆ are unit vectors along the x-, y- and z-axis of the system respectively. What is the work done by this force in moving the body a distance of 4 m along the z-axis ?

Question 6.12 An electron and a proton are detected in a cosmic ray experiment, the first with kinetic energy 10 keV, and the second with 100 keV. Which is faster, the electron or the proton ? Obtain the ratio of their speeds. (electron mass = 9.11× 10-31 kg, proton mass = 1.67×10–27 kg, 1 eV = 1.60 ×10–19 J).

Question 6.13 A rain drop of radius 2 mm falls from a height of 500 m above the ground. It falls with decreasing acceleration (due to viscous resistance of the air) until at half its original height, it attains its maximum (terminal) speed, and moves with uniform speed thereafter. What is the work done by the gravitational force on the drop in the first and second half of its journey ? What is the work done by the resistive force in the entire journey if its speed on reaching the ground is 10 m s–1 ?

Question 6.14 A molecule in a gas container hits a horizontal wall with speed 200 m s–1 and angle 30° with the normal, and rebounds with the same speed. Is momentum conserved in the collision ? Is the collision elastic or inelastic ?

Question 6.15 A pump on the ground floor of a building can pump up water to fill a tank of volume 30 m3 in 15 min. If the tank is 40 m above the ground, and the efficiency of the pump is 30%, how much electric power is consumed by the ump ?

Question 6.16 Two identical ball bearings in contact with each other and resting on a frictionless table are hit head-on by another ball bearing of the same mass moving initially with a speed V. If the collision is elastic, which of the following (Fig. 6.14) is a possible result after collision ?

Question 6.17 The bob A of a pendulum released from 30o to the vertical hits another bob B of the same mass at rest on a table as shown in Fig. 6.15. How high does the bob A rise after the collision ? Neglect the size of the bobs and assume the collision to be elastic.

Question 6.18 The bob of a pendulum is released from a horizontal position. If the length of the pendulum is 1.5 m, what is the speed with which the bob arrives at the lowermost point, given that it dissipated 5% of its initial energy against air resistance ?

Question 6.19 A trolley of mass 300 kg carrying a sandbag of 25 kg is moving uniformly with a speed of 27 km/h on a frictionless track. After a while, sand starts leaking out of a hole on the floor of the trolley at the rate of 0.05 kg s–1. What is the speed of the trolley after the entire sand bag is empty ?

Question 6.20 A body of mass 0.5 kg travels in a straight line with velocity v =a x3/2 where a = 5 m–1/2 s–1. What is the work done by the net force during its displacement from x = 0 to x = 2 m ?

Question 6.21 The blades of a windmill sweep out a circle of area A. (a) If the wind flows at a velocity v perpendicular to the circle, what is the mass of the air passing through it in time t ? (b) What is the kinetic energy of the air ? (c) Assume that the windmill converts 25% of the wind's energy into electrical energy, and that A = 30 m2, v = 36 km/h and the density of air is 1.2 kg m–3. What is the electrical power produced ?

Question 6.22 A person trying to lose weight (dieter) lifts a 10 kg mass, one thousand times, to a height of 0.5 m each time. Assume that the potential energy lost each time she lowers the mass is dissipated. (a) How much work does she do against the gravitational force ? (b) Fat supplies 3.8 × 107J of energy per kilogram which is converted to mechanical energy with a 20% efficiency rate. How much fat will the dieter use up?

Question 6.23 A family uses 8 kW of power. (a) Direct solar energy is incident on the horizontal surface at an average rate of 200 W per square meter. If 20% of this energy can be converted to useful electrical energy, how large an area is needed to supply 8 kW? (b) Compare this area to that of the roof of a typical house. Additional Exercises

Question 6.24 A bullet of mass 0.012 kg and horizontal speed 70 m s–1 strikes a block of wood of mass 0.4 kg and instantly comes to rest with respect to the block. The block is suspended from the ceiling by means of thin wires. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block.

Question 6.25 Two inclined frictionless tracks, one gradual and the other steep meet at A from where two stones are allowed to slide down from rest, one on each track (Fig. 6.16). Will the stones reach the bottom at the same time? Will they reach there with the same speed? Explain. Given θ1 = 300, θ2 = 600, and h = 10 m, what are the speeds and times taken by the two stones ?

Question 6.26 A 1 kg block situated on a rough incline is connected to a spring of spring constant 100 N m–1 as shown in Fig.6.17. The block is released from rest with the spring in the unstretched position. The block moves 10 cm down the incline before coming to rest. Find the coefficient of friction between the block and the incline. Assume that the spring has a negligible mass and the pulley is frictionless.

Question 6.27 A bolt of mass 0.3 kg falls from the ceiling of an elevator moving down with an uniform speed of 7 m s–1. It hits the floor of the elevator (length of the elevator = 3 m) and does not rebound. What is the heat produced by the impact ? Would your answer be different if the elevator were stationary ?

Question 6.28 A trolley of mass 200 kg moves with a uniform speed of 36 km/h on a frictionless track. A child of mass 20 kg runs on the trolley from one end to the other (10 m away) with a speed of 4 m s–1 relative to the trolley in a direction opposite to the its motion, and jumps out of the trolley. What is the final speed of the trolley ? How much has the trolley moved from the time the child begins to run ?

Question 6.29 Which of the following potential energy curves in Fig. 6.18 cannot possibly describe the elastic collision of two billiard balls ? Here r is the distance between centres of the balls.

:: Chapter 7 Systems of Particles and Rotational Motion ::

Question 7.1 Give the location of the centre of mass of a (i) sphere, (ii) cylinder, (iii) ring, and (iv) cube, each of uniform mass density. Does the centre of mass of a body necessarily lie inside the body ?

Question 7.2 In the HC1 molecule, the separation between the nuclei of the two atoms is about 1.27 Å (1 Å = 10-10 m). Find the approximate location of the CM of the molecule, given that a chlorine atom is about 35.5 times as massive as a hydrogen atom and nearly all the mass of an atom is concentrated in its nucleus.

Question 7.3 A child sits stationary at one end of a long trolley moving uniformly with a speed V on a smooth horizontal floor. If the child gets up and runs about on the trolley in any manner, what is the speed of the CM of the (trolley + child) system ?

Question 7.4 Show that the area of the triangle contained between the vectors a and b is one half of the magnitude of a × b.

Question 7.5 Show that a.(b × c) is equal in magnitude to the volume of the parallelepiped formed on the three vectors , a, b and c.

Question 7.6 Find the components along the x, y, z axes of the angular momentum l of a particle, whose position vector is r with components x, y, z and momentum is p with components px, py and pz. Show that if the particle moves only in the x-y plane the angular momentum has only a z-component.

Question 7.7 Two particles, each of mass m and speed v, travel in opposite directions along parallel lines separated by a distance d. Show that the vector angular momentum of the two particle system is the same whatever be the point about which the angular momentum is taken.

Question 7.8 A non-uniform bar of weight W is suspended at rest by two strings of negligible weight as shown in Fig.

Question 7.9. The angles made by the strings with the vertical are 36.9° and 53.1° respectively. The bar is 2 m long. Calculate the distance d of the centre of gravity of the bar from its left end.7.9 A car weighs 1800 kg. The distance between its front and back axles is 1.8 m. Its centre of gravity is 1.05 m behind the front axle. Determine the force exerted by the level ground on each front wheel and each back wheel.

Question 7.10 (a) Find the moment of inertia of a sphere about a tangent to the sphere, given the moment of inertia of the sphere about any of its diameters to be 2MR2/5, where M is the mass of the sphere and R is the radius of the sphere.
(b) Given the moment of inertia of a disc of mass M and radius R about any of its diameters to be MR2/4, find its moment of inertia about an axis normal to the disc and passing through a point on its edge.

Question 7.11 Torques of equal magnitude are applied to a hollow cylinder and a solid sphere, both having the same mass and radius. The cylinder is free to rotate about its standard axis of symmetry, and the sphere is free to rotate about an axis passing through its centre. Which of the two will acquire a greater angular speed after a given time.

Question 7.12 A solid cylinder of mass 20 kg rotates about its axis with angular speed 100 rad s-1. The radius of the cylinder is 0.25 m. What is the kinetic energy associated with the rotation of the cylinder? What is the magnitude of angular momentum of the cylinder about its axis?

Question 7.13 (a) A child stands at the centre of a turntable with his two arms outstretched. The turntable is set rotating with an angular speed of 40 rev/min. How much is the angular speed of the child if he folds his hands back and thereby reduces his moment of inertia to 2/5 times the initial value ? Assume that the turntable rotates without friction.
(b) Show that the child's new kinetic energy of rotation is more than the initial kinetic energy of rotation. How do you account for this increase in kinetic energy?

Question 7.14 A rope of negligible mass is wound round a hollow cylinder of mass 3 kg and radius 40 cm. What is the angular acceleration of the cylinder if the rope is pulled with a force of 30 N ? What is the linear acceleration of the rope ? Assume that there is no slipping.

Question 7.15 To maintain a rotor at a uniform angular speed or 200 rad s-1, an engine needs to transmit a torque of 180 N m. What is the power required by the engine ? (Note: uniform angular velocity in the absence of friction implies zero torque. In practice, applied torque is needed to counter frictional torque). Assume that the engine is 100% efficient.

Question 7.16 From a uniform disk of radius R, a circular hole of radius R/2 is cut out. The centre of the hole is at R/2 from the centre of the original disc. Locate the centre of gravity of the resulting flat body.

Question 7.17 A metre stick is balanced on a knife edge at its centre. When two coins, each of mass 5 g are put one on top of the other at the 12.0 cm mark, the stick is found to be balanced at 45.0 cm. What is the mass of the metre stick?

Question 7.18 A solid sphere rolls down two different inclined planes of the same heights but different angles of inclination.
(a) Will it reach the bottom with the same speed in each case?
(b) Will it take longer to roll down one plane than the other?
(c) If so, which one and why?

Question 7.19 A hoop of radius 2 m weighs 100 kg. It rolls along a horizontal floor so that its centre of mass has a speed of 20 cm/s. How much work has to be done to stop it?

Question 7.20 The oxygen molecule has a mass of 5.30 × 10-26 kg and a moment of inertia of 1.94×10-46 kg m2 about an axis through its centre perpendicular to the lines joining the two atoms. Suppose the mean speed of such a molecule in a gas is 500 m/s and that its kinetic energy of rotation is two thirds of its kinetic energy of translation. Find the average angular velocity of the molecule.

Question 7.21 A solid cylinder rolls up an inclined plane of angle of inclination 30° . At the bottom of the inclined plane the centre of mass of the cylinder has a speed of 5 m/s.
(a) How far will the cylinder go up the plane?
(b) How long will it take to return to the bottom? Additional Exercises

Question 7.22 As shown in Fig.7.40, the two sides of a step ladder BA and CA are 1.6 m long and hinged at A. A rope DE, 0.5 m is tied half way up. A weight 40 kg is suspended from a point F, 1.2 m from B along the ladder BA. Assuming the floor to be frictionless and neglecting the weight of the ladder, find the tension in the rope and forces exerted by the floor on the ladder. (Take g = 9.8 m/s2) (Hint: Consider the equilibrium of each side of the ladder separately.)

Question 7.23 A man stands on a rotating platform, with his arms stretched horizontally holding a 5 kg weight in each hand. The angular speed of the platform is 30 revolutions per minute. The man then brings his arms close to his body with the distance of each weight from the axis changing from 90cm to 20cm. The moment of inertia of the man together with the platform may be taken to be constant and equal to7.6 kg m2.
(a) What is his new angular speed? (Neglect friction.)
(b) Is kinetic energy conserved in the process? If not, from where does the change come about?

Question 7.24 A bullet of mass 10 g and speed 500 m/s is fired into a door and gets embedded exactly at the centre of the door. The door is 1.0 m wide and weighs 12 kg. It is hinged at one end and rotates about a vertical axis practically without friction. Find the angular speed of the door just after the bullet embeds into it. (Hint: The moment of inertia of the door about the vertical axis at one end is ML2/3.)

Question 7.25 Two discs of moments of inertia I1 and I2 about their respective axes (normal to the disc and passing through the centre), and rotating with angular speeds ω1 and ω2 are brought into contact face to face with their axes of rotation coincident.

(a) What is the angular speed of the two-disc system?

(b) Show that the kinetic energy of the combined system is less than the sum of the initial kinetic energies of the two discs. How do you account for this loss in energy? Take $\omega 1 \neq \omega 2$.

Question 7.26 (a) Prove the theorem of perpendicular axes. (Hint : Square of the distance of a point (x, y) in the x–y plane from an axis through the origin perpendicular to the plane is x2+y2). (b) Prove the theorem of parallel axes. (Hint : If the centre of mass is chosen to be the origin Σmi ri = 0).

Question 7.27 Prove the result that the velocity v of translation of a rolling body (like a ring, disc, cylinder or sphere) at the bottom of an inclined plane of a height h is given by ( ) 2 2 2 2 1 / gh v k R = + using dynamical consideration (i.e. by consideration of forces and torques). Note k is the radius of gyration of the body about its symmetry axis, and R is the radius of the body. The body starts from rest at the top of the plane.

Question 7.28 A disc rotating about its axis with angular speed ωo is placed lightly (without any translational push) on a perfectly frictionless table. The radius of the disc is R. What are the linear velocities of the points A, B and C on the disc shown in Fig.7.41? Will the disc roll in the direction indicated ?

Question 7.29 Explain why friction is necessary to make the disc in Fig. 7.41 roll in the direction indicated.

(a) Give the direction of frictional force at B, and the sense of frictional torque, before perfect rolling begins.

(b) What is the force of friction after perfect rolling begins ?

Question 7.30 A solid disc and a ring, both of radius 10 cm are placed on a horizontal table simultaneously, with initial angular speed equal to 10 π rad s-1. Which of the two will start to roll earlier ? The co-efficient of kinetic friction is μ k = 0.2.

Question 7.31 A cylinder of mass 10 kg and radius 15 cm is rolling perfectly on a plane of inclination 30o. The coefficient of static friction μs = 0.25.

(a) How much is the force of friction acting on the cylinder ?

(b) What is the work done against friction during rolling ?

(c) If the inclination θ of the plane is increased, at what value of θ does the cylinder begin to skid, and not roll perfectly ?

Question 7.32 Read each statement below carefully, and state, with reasons, if it is true or false

(a) During rolling, the force of friction acts in the same direction as the direction of motion of the CM of the body.

(b) The instantaneous speed of the point of contact during rolling is zero.

(c) The instantaneous acceleration of the point of contact during rolling is zero.

(d) For perfect rolling motion, work done against friction is zero.

(e) A wheel moving down a perfectly frictionless inclined plane will undergo slipping (not rolling) motion.

Question 7.33 Separation of Motion of a system of particles into motion of the centre of mass and motion about the centre of mass :

(a) Show p = pi +miV where pi is the momentum of the ith particle (of mass mi) and p i = mi v i. Note v i is the velocity of the ith particle relative to the centre of mass. Also, prove using the definition of the centre of mass 0 iΣ p′ =

(b) Show K = K +½MV 2 where K is the total kinetic energy of the system of particles, K′ is the total kinetic energy of the system when the particle velocities are taken with respect to the centre of mass and MV2/2 is the kinetic energy of the translation of the system as a whole (i.e. of the centre of mass motion of the system). The result has been used in Sec.7.14.

(c) Show L = L′ + R × MV where L = i i Σr × p′ is the angular momentum of the system about the centre of mass with velocities taken relative to the centre of mass. Remember – i i r = r R ; rest of the notation is thestandard notation used in the chapter. Note L′ and MR × V can be said to be angular momenta, respectively, about and of the centre of mass of the system of particles.

:: Chapter 8 Gravitation ::

Question 8.1 Answer the following :

(a) You can shield a charge from electrical forces by putting it inside a hollow conductor. Can you shield a body from the gravitational influence of nearby matter by putting it inside a hollow sphere or by some other means ?

(b) An astronaut inside a small space ship orbiting around the earth cannot detect gravity. If the space station orbiting around the earth has a large size, can he hope to detect gravity ?

(c) If you compare the gravitational force on the earth due to the sun to that due to the moon, you would find that the Sun's pull is greater than the moon's pull. (you can check this yourself using the data available in the succeeding exercises). However, the tidal effect of the moon's pull is greater than the tidal effect of sun. Why ?

Question 8.2 Choose the correct alternative :
(a) Acceleration due to gravity increases/decreases with increasing altitude.
(b) Acceleration due to gravity increases/decreases with increasing depth (assume the earth to be a sphere of uniform density).
(c) Acceleration due to gravity is independent of mass of the earth/mass of the body.
(d) The formula –G Mm(1/r2 – 1/r1) is more/less accurate than the formula mg(r2 – r1) for the difference of potential energy between two points r2 and r1 distance away from the centre of the earth.

Question 8.3 Suppose there existed a planet that went around the sun twice as fast as the earth. What would be its orbital size as compared to that of the earth ?

Question 8.4 Io, one of the satellites of Jupiter, has an orbital period of 1.769 days and the radius of the orbit is 4.22 × 108 m. Show that the mass of Jupiter is about one-thousandth that of the sun.

Question 8.5 Let us assume that our galaxy consists of 2.5 × 1011 stars each of one solar mass. How long will a star at a distance of 50,000 ly from the galactic centre take to complete one revolution ? Take the diameter of the Milky Way to be 105 ly.

Question 8.6 Choose the correct alternative:
(a) If the zero of potential energy is at infinity, the total energy of an orbiting satellite is negative of its kinetic/potential energy.
(b) The energy required to launch an orbiting satellite out of earth's gravitational influence is more/less than the energy required to project a stationary object at the same height (as the satellite) out of earth's influence.

Question 8.7 Does the escape speed of a body from the earth depend on
(a) the mass of the body
(b) the location from where it is projected
(c) the direction of projection
(d) the height of the location from where the body is launched?

Question 8.8 A comet orbits the sun in a highly elliptical orbit. Does the comet have a constant

(a) linear speed

(b) angular speed

(c) angular momentum

(d) kinetic energy

(e) potential energy

(f) total energy throughout its orbit? Neglect any mass loss of the comet when it comes very close to the Sun.

Question 8.9 Which of the following symptoms is likely to afflict an astronaut in space

(a) swollen feet,

(b) swollen face ,

(c) headache,

(d) orientational problem. In the following two exercises, choose the correct answer from among the given ones:

Question 8.10 The gravitational intensity at the centre of a hemispherical shell of uniform mass density has the direction indicated by the arrow (see Fig 8.12)

(i) a

(ii) b

(iii) c

(iv) 0

Question 8.11 For the above problem, the direction of the gravitational intensity at an arbitrary point P is indicated by the arrow (i) d, (ii) e, (iii) f, (iv) g.

Question 8.12 A rocket is fired from the earth towards the sun. At what distance from the earth's centre is the gravitational force on the rocket zero ? Mass of the sun = 2× 1030 kg, mass of the earth = 6× 1024 kg. Neglect the effect of other planets etc. (orbital radius = 1.5 × 1011 m).

Question 8.13 How will you 'weigh the sun', that is estimate its mass? The mean orbital radius of the earth around the sun is 1.5 × 108 km.

Question 8.14 A saturn year is 29.5 times the earth year. How far is the saturn from the sun if the earth is 1.50 × 108 km away from the sun ?

Question 8.15 A body weighs 63 N on the surface of the earth. What is the gravitational force on it due to the earth at a height equal to half the radius of the earth ?

Question 8.16 Assuming the earth to be a sphere of uniform mass density, how much would a body weigh half way down to the centre of the earth if it weighed 250 N on the surface ?

Question 8.17 A rocket is fired vertically with a speed of 5 km s-1 from the earth's surface. How far from the earth does the rocket go before returning to the earth ? Mass of the earth = 6.0 × 1024 kg; mean radius of the earth = 6.4 × 106 m; G = 6.67 × 10–11 N m2 kg–2.

Question 8.18 The escape speed of a projectile on the earth's surface is 11.2 km s–1. A body is projected out with thrice this speed. What is the speed of the body far away from the earth? Ignore the presence of the sun and other planets.

Question 8.19 A satellite orbits the earth at a height of 400 km above the surface. How much energy must be expended to rocket the satellite out of the earth's gravitational influence? Mass of the satellite = 200 kg; mass of the earth = 6.0× 1024 kg; radius of the earth = 6.4 × 106 m; G = 6.67 × 10–11 N m2 kg–2.

Question 8.20 Two stars each of one solar mass (= 2× 1030 kg) are approaching each other for a head on collision. When they are a distance 109 km, their speeds are negligible. What is the speed with which they collide ? The radius of each star is 104 km. Assume the stars to remain undistorted until they collide. (Use the known value of G).

Question 8.21 Two heavy spheres each of mass 100 kg and radius 0.10 m are placed 1.0 m apart on a horizontal table. What is the gravitational force and potential at the mid point of the line joining the centres of the spheres ? Is an object placed at that point in equilibrium? If so, is the equilibrium stable or unstable ? Additional Exercises

Question 8.22 As you have learnt in the text, a geostationary satellite orbits the earth at a height of nearly 36,000 km from the surface of the earth. What is the potential due to earth's gravity at the site of this satellite ? (Take the potential energy at infinity to be zero). Mass of the earth = 6.0× 1024 kg, radius = 6400 km.

Question 8.23 A star 2.5 times the mass of the sun and collapsed to a size of 12 km rotates with a speed of 1.2 rev. per second. (Extremely compact stars of this kind are known as neutron stars.

Certain stellar objects called pulsars belong to this category). Will an object placed on its equator remain stuck to its surface due to gravity ? (mass of the sun = 2× 1030 kg).

Question 8.24 A spaceship is stationed on Mars. How much energy must be expended on the spaceship to launch it out of the solar system ? Mass of the space ship = 1000 kg; mass of the sun = 2× 1030 kg; mass of mars = 6.4× 1023 kg; radius of mars = 3395 km; radius of the orbit of mars = 2.28 × 108 km; G = 6.67× 10-11 N m2 kg–2.

Question 8.25 A rocket is fired 'vertically' from the surface of mars with a speed of 2 km s–1. If 20% of its initial energy is lost due to martian atmospheric resistance, how far will the rocket go from the surface of mars before returning to it ? Mass of mars = 6.4× 1023 kg; radius of mars = 3395 km; G = 6.67× 10-11 N m2 kg–2.

:: Chapter 9 Mechanical Properties Of Solids ::

Question 9.1 A steel wire of length 4.7 m and cross-sectional area 3.0 × 10-5 m2 stretches by the same amount as a copper wire of length 3.5 m and cross-sectional area of 4.0 × 10–5 m2 under a given load. What is the ratio of the Young's modulus of steel to that of copper?

Question 9.2 Figure 9.11 shows the strain-stress curve for a given material. What are (a) Young's modulus and (b) approximate yield strength for this material?

Question 9.3 The stress-strain graphs for materials A and B are shown in Fig. 9.12.The graphs are drawn to the same scale. (a) Which of the materials has the greater Young's modulus? (b) Which of the two is the stronger material?

Question 9.4 Read the following two statements below carefully and state, with reasons, if it is true or false. (a) The Young's modulus of rubber is greater than that of steel; (b) The stretching of a coil is determined by its shear modulus.

Question 9.5 Two wires of diameter 0.25 cm, one made of steel and the other made of brass are loaded as shown in Fig. 9.13. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. Compute the elongations of the steel and the brass wires.

Question 9.6 The edge of an aluminium cube is 10 cm long. One face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is then attached to the opposite face of the cube. The shear modulus of aluminium is 25 GPa. What is the vertical deflection of this face?

Question 9.7 Four identical hollow cylindrical columns of mild steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 and 60 cm respectively. Assuming the load distribution to be uniform, calculate the compressional strain of each column.

Question 9.8 A piece of copper having a rectangular cross-section of 15.2 mm × 19.1 mm is pulled in tension with 44,500 N force, producing only elastic deformation. Calculate the resulting strain?

Question 9.9 A steel cable with a radius of 1.5 cm supports a chairlift at a ski area. If the maximum stress is not to exceed 108 N m–2, what is the maximum load the cable can support ?

Question 9.10 A rigid bar of mass 15 kg is supported symmetrically by three wires each 2.0 m long. Those at each end are of copper and the middle one is of iron. Determine the ratios of their diameters if each is to have the same tension.

Question 9.11 A 14.5 kg mass, fastened to the end of a steel wire of unstretched length 1.0 m, is whirled in a vertical circle with an angular velocity of 2 rev/s at the bottom of the circle. The cross-sectional area of the wire is 0.065 cm2. Calculate the elongation of the wire when the mass is at the lowest point of its path.

Question 9.12 Compute the bulk modulus of water from the following data: Initial volume = 100.0 litre, Pressure increase = 100.0 atm (1 atm = 1.013 × 105 Pa), Final volume = 100.5 litre. Compare the bulk modulus of water with that of air (at constant temperature). Explain in simple terms why the ratio is so large.

Question 9.13 What is the density of water at a depth where pressure is 80.0 atm, given that its density at the surface is 1.03 × 103 kg m–3?

Question 9.14 Compute the fractional change in volume of a glass slab, when subjected to a hydraulic pressure of 10 atm.

Question 9.15 Determine the volume contraction of a solid copper cube, 10 cm on an edge, when subjected to a hydraulic pressure of 7.0 × 106 Pa.

Question 9.16 How much should the pressure on a litre of water be changed to compress it by 0.10%? Additional Exercises

Question 9.17 Anvils made of single crystals of diamond, with the shape as shown in Fig.9.14, are used to investigate behaviour of materials under very high pressures. Flat faces at the narrow end of the anvil have a diameter of 0.50 mm, and the wide ends are subjected to a compressional force of 50,000 N. What is the pressure at the tip of the anvil?

Question 9.18 A rod of length 1.05 m having negligible mass is supported at its ends by two wires of steel (wire A) and aluminium (wire B) of equal lengths as shown in Fig9.15. The cross-sectional areas of wires A and B are 1.0 mm2 and 2.0 mm2, respectively. At what point along the rod should a mass m be suspended in order to produce (a) equal stresses and (b) equal strains in both steel and aluminium wires.

Question 9.19 A mild steel wire of length 1.0 m and cross-sectional area 0.50 × 10-2 cm2 is stretched, well within its elastic limit, horizontally between two pillars. A mass of 100 g is suspended from the mid-point of the wire. Calculate the depression at the midpoint.

Question 9.20 Two strips of metal are riveted together at their ends by four rivets, each of diameter 6.0 mm. What is the maximum tension that can be exerted by the riveted strip if the shearing stress on the rivet is not to exceed 6.9 × 107 Pa? Assume that each rivet is to carry one quarter of the load.

Question 9.21 The Marina trench is located in the Pacific Ocean, and at one place it is nearly eleven km beneath the surface of water. The water pressure at the bottom of the trench is about 1.1 × 108 Pa. A steel ball of initial volume 0.32 m3 is dropped into the ocean and falls to the bottom of the trench. What is the change in the volume of the ball when it reaches to the bottom?

:: Chapter 10 Mechanical Properties Of Fluids ::

Question 10.1 Explain why (a) The blood pressure in humans is greater at the feet than at the brain (b) Atmospheric pressure at a height of about 6 km decreases to nearly half of its value at the sea level, though the height of the atmosphere is more than 100 km (c) Hydrostatic pressure is a scalar quantity even though pressure is force divided by area.

Question 10.2 Explain why (a) The angle of contact of mercury with glass is obtuse, while that of water with glass is acute. (b) Water on a clean glass surface tends to spread out while mercury on the same surface tends to form drops. (Put differently, water wets glass while mercury does not.) (c) Surface tension of a liquid is independent of the area of the surface (d) Water with detergent disolved in it should have small angles of contact. (e) A drop of liquid under no external forces is always spherical in shape

Question 10.3 Fill in the blanks using the word(s) from the list appended with each statement:

(a) Surface tension of liquids generally . . . with temperatures (increases / decreases)

(b) Viscosity of gases . .. with temperature, whereas viscosity of liquids . . . with temperature (increases / decreases) (c) For solids with elastic modulus of rigidity, the shearing force is proportional to . . . , while for fluids it is proportional to . .. (shear strain / rate of shear strain)

(d) For a fluid in a steady flow, the increase in flow speed at a constriction follows (conservation of mass / Bernoulli’s principle)

(e) For the model of a plane in a wind tunnel, turbulence occurs at a ... speed for turbulence for an actual plane (greater / smaller)

Question 10.4 Explain why

(a) To keep a piece of paper horizontal, you should blow over, not under, it

(b) When we try to close a water tap with our fingers, fast jets of water gush through the openings between our fingers (c) The size of the needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection

(d) A fluid flowing out of a small hole in a vessel results in a backward thrust on the vessel

(e) A spinning cricket ball in air does not follow a parabolic trajectory

Question 10.5 A 50 kg girl wearing high heel shoes balances on a single heel. The heel is circular with a diameter 1.0 cm. What is the pressure exerted by the heel on the horizontal floor ?

Question 10.6 Toricelli’s barometer used mercury. Pascal duplicated it using French wine of density 984 kg m–3. Determine the height of the wine column for normal atmospheric pressure.

Question 10.7 A vertical off-shore structure is built to withstand a maximum stress of 109 Pa. Is the structure suitable for putting up on top of an oil well in the ocean ? Take the depth of the ocean to be roughly 3 km, and ignore ocean currents.

Question 10.8 A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000 kg.

The area of cross-section of the piston carrying the load is 425 cm2. What maximum pressure would the smaller piston have to bear ?

Question 10.9 A U-tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10.0 cm of water in one arm and 12.5 cm of spirit in the other. What is the specific gravity of spirit ?

Question 10.10 In the previous problem, if 15.0 cm of water and spirit each are further poured into the respective arms of the tube, what is the difference in the levels of mercury in the two arms ? (Specific gravity of mercury = 13.6)

Question 10.11 Can Bernoulli's equation be used to describe the flow of water through a rapid in a river ? Explain.

Question 10.12 Does it matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation ? Explain.

Question 10.13 Glycerine flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerine collected per second at one end is 4.0 × 10–3 kg s–1, what is the pressure difference between the two ends of the tube ? (Density of glycerine = 1.3 × 103 kg m–3 and viscosity of glycerine = 0.83 Pa s). [You may also like to check if the assumption of laminar flow in the tube is correct].

Question 10.14 In a test experiment on a model aeroplane in a wind tunnel, the flow speeds on the upper and lower surfaces of the wing are 70 m s–1and 63 m s-1 respectively. What is the lift on the wing if its area is 2.5 m2 ? Take the density of air to be 1.3 kg m–3.

Question 10.15 Figures10.23(a) and (b) refer to the steady flow of a (non-viscous) liquid. Which of the two figures is incorrect ? Why ?

Question 10.16 The cylindrical tube of a spray pump has a cross-section of 8.0 cm2 one end of which has 40 fine holes each of diameter 1.0 mm. If the liquid flow inside the tube is 1.5 m min–1, what is the speed of ejection of the liquid through the holes ?

Question 10.17 A U-shaped wire is dipped in a soap solution, and removed. The thin soap film formed between the wire and the light slider supports a weight of 1.5 × 10–2 N (which includes the small weight of the slider). The length of the slider is 30 cm. What is the surface tension of the film ?

Question 10.18 Figure 10.24 (a) shows a thin liquid film supporting a small weight = 4.5 × 10–2 N. What is the weight supported by a film of the same liquid at the same temperature in Fig. (b) and (c) ? Explain your answer physically

Question 10.19 What is the pressure inside the drop of mercury of radius 3.00 mm at room temperature ? Surface tension of mercury at that temperature (20 °C) is 4.65 × 10–1 N m–1. The atmospheric pressure is 1.01 × 105 Pa. Also give the excess pressure inside the drop.

Question 10.20 What is the excess pressure inside a bubble of soap solution of radius 5.00 mm, given that the surface tension of soap solution at the temperature (20 °C) is 2.50 × 10–2 N m–1 ? If an air bubble of the same dimension were formed at depth of 40.0 cm inside a container containing the soap solution (of relative density 1.20), what would be the pressure inside the bubble ? (1 atmospheric pressure is 1.01 × 105 Pa). Additional Exercises

Question 10.21 A tank with a square base of area 1.0 m2 is divided by a vertical partition in the middle. The bottom of the partition has a small-hinged door of area 20 cm2. The tank is filled with water in one compartment, and an acid (of relative density 1.7) in the other, both to a height of 4.0 m. compute the force necessary to keep the door close.

Question 10.22 A manometer reads the pressure of a gas in an enclosure as shown in Fig. 10.25 (a) When a pump removes some of the gas, the manometer reads as in Fig. 10.25 (b) The liquid used in the manometers is mercury and the atmospheric pressure is 76 cm of mercury. (a) Give the absolute and gauge pressure of the gas in the enclosure for cases (a) and (b), in units of cm of mercury. (b) How would the levels change in case (b) if 13.6 cm of water (immiscible with mercury) are poured into the right limb of the manometer ? (Ignore the small change in the volume of the gas).

Question 10.23 Two vessels have the same base area but different shapes. The first vessel takes twice the volume of water that the second vessel requires to fill upto a particular common height. Is the force exerted by the water on the base of the vessel the same in the two cases ? If so, why do the vessels filled with water to that same height give different readings on a weighing scale ?

Question 10.24 During blood transfusion the needle is inserted in a vein where the gauge pressure is 2000 Pa. At what height must the blood container be placed so that blood may just enter the vein ? [Use the density of whole blood from Table 10.1].

Question 10.25 In deriving Bernoulli's equation, we equated the work done on the fluid in the tube to its change in the potential and kinetic energy.
(a) What is the largest average velocity of blood flow in an artery of diameter 2 × 10–3 m if the flow must remain laminar ?
(b) Do the dissipative forces become more important as the fluid velocity increases ? Discuss qualitatively.

Question 10.26 (a) What is the largest average velocity of blood flow in an artery of radius 2×10–3m if the flow must remain lanimar?
(b) What is the corresponding flow rate ? (Take viscosity of blood to be 2.084 × 10–3 Pa s).

Question 10.27 A plane is in level flight at constant speed and each of its two wings has an area of 25 m2. If the speed of the air is 180 km/h over the lower wing and 234 km/h over the upper wing surface, determine the plane's mass. (Take air density to be 1 kg m–3).

Question 10.28 In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius 2.0 × 10–5 m and density 1.2 × 103 kg m–3. Take the viscosity of air at the temperature of the experiment to be 1.8 × 10–5 Pa s. How much is the viscous force on the drop at that speed ? Neglect buoyancy of the drop due to air.

Question 10.29 Mercury has an angle of contact equal to 140° with soda lime glass. A narrow tube of radius 1.00 mm made of this glass is dipped in a trough containing mercury. By what amount does the mercury dip down in the tube relative to the liquid surface outside ? Surface tension of mercury at the temperature of the experiment is 0.465 N m–1. Density of mercury = 13.6 × 103 kg m–3.

Question 10.30 Two narrow bores of diameters 3.0 mm and 6.0 mm are joined together to form a U-tube open at both ends. If the U-tube contains water, what is the difference in its levels in the two limbs of the tube ? Surface tension of water at the temperature of the experiment is 7.3 × 10–2 N m–1. Take the angle of contact to be zero and density of water to be 1.0 × 103 kg m–3 (g = 9.8 m s–2

:: Chapter 11 Thermal Properties of Matter ::

Question 11.1 The triple points of neon and carbon dioxide are 24.57 K and 216.55 K respectively. Express these temperatures on the Celsius and Fahrenheit scales.

Question 11.2 Two absolute scales A and B have triple points of water defined to be 200 A and 350 B. What is the relation between TA and TB ?

Question 11.3 The electrical resistance in ohms of a certain thermometer varies with temperature according to the approximate law :

R = Ro [1 + α (T – To)] The resistance is 101.6 Ω at the triple-point of water 273.16 K, and 165.5 Ω at the normal melting point of lead (600.5 K). What is the temperature when the resistance is 123.4 Ω ?

Question 11.4 Answer the following :

(a) The triple-point of water is a standard fixed point in modern thermometry. Why ? What is wrong in taking the melting point of ice and the boiling point of water as standard fixed points (as was originally done in the Celsius scale) ?

(b) There were two fixed points in the original Celsius scale as mentioned above which were assigned the number 0 °C and 100 °C respectively. On the absolute scale, one of the fixed points is the triple-point of water, which on the Kelvin absolute scale is assigned the number 273.16 K. What is the other fixed point on this (Kelvin) scale ?

(c) The absolute temperature (Kelvin scale) T is related to the temperature tc on the Celsius scale by tc = T – 273.15 Why do we have 273.15 in this relation, and not 273.16 ?

(d) What is the temperature of the triple-point of water on an absolute scale whose unit interval size is equal to that of the Fahrenheit scale ?

Question 11.5 Two ideal gas thermometers A and B use oxygen and hydrogen respectively. The following observations are made : Temperature Pressure Pressure thermometer A thermometer B Triple-point of water 1.250 × 105 Pa 0.200 × 105 Pa Normal melting point 1.797 × 105 Pa 0.287 × 105 Pa of sulphur (a) What is the absolute temperature of normal melting point of sulphur as read by thermometers A and B ? (b) What do you think is the reason behind the slight difference in answers of thermometers A and B ? (The thermometers are not faulty). What further procedure is needed in the experiment to reduce the discrepancy between the two readings ?

Question 11.6 A steel tape 1m long is correctly calibrated for a temperature of 27.0 °C. The length of a steel rod measured by this tape is found to be 63.0 cm on a hot day when the temperature is 45.0 °C. What is the actual length of the steel rod on that day ? What is the length of the same steel rod on a day when the temperature is 27.0 °C ? Coefficient of linear expansion of steel = 1.20 × 10–5 K–1 .

Question 11.7 A large steel wheel is to be fitted on to a shaft of the same material. At 27 °C, the outer diameter of the shaft is 8.70 cm and the diameter of the central hole in the wheel is 8.69 cm. The shaft is cooled using 'dry ice'. At what temperature of the shaft does the wheel slip on the shaft? Assume coefficient of linear expansion of the steel to be constant over the required temperature range : αsteel = 1.20 × 10–5 K–1.

Question 11.8 A hole is drilled in a copper sheet. The diameter of the hole is 4.24 cm at 27.0 °C. What is the change in the diameter of the hole when the sheet is heated to 227 °C? Coefficient of linear expansion of copper = 1.70 × 10–5 K–1.

Question 11.9 A brass wire 1.8 m long at 27 °C is held taut with little tension between two rigid supports. If the wire is cooled to a temperature of –39 °C, what is the tension developed in the wire, if its diameter is 2.0 mm ? Co-efficient of linear expansion of brass = 2.0 × 10–5 K–1; Young's modulus of brass = 0.91 × 1011 Pa.

Question 11.10 A brass rod of length 50 cm and diameter 3.0 mm is joined to a steel rod of the same length and diameter. What is the change in length of the combined rod at 250 °C, if the original lengths are at 40.0 °C? Is there a 'thermal stress' developed at the junction ? The ends of the rod are free to expand (Co-efficient of linear expansion of brass = 2.0 × 10–5 K–1, steel = 1.2 × 10–5 K–1).

Question 11.11 The coefficient of volume expansion of glycerin is 49 × 10–5 K–1. What is the fractional change in its density for a 30 °C rise in temperature ?

Question 11.12 A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8.0 kg. How much is the rise in temperature of the block in 2.5 minutes, assuming 50% of power is used up in heating the machine itself or lost to the surroundings. Specific heat of aluminium = 0.91 J g–1 K–1.

Question 11.13 A copper block of mass 2.5 kg is heated in a furnace to a temperature of 500 °C and then placed on a large ice block. What is the maximum amount of ice that can melt? (Specific heat of copper = 0.39 J g–1 K–1; heat of fusion of water = 335 J g–1).

Question 11.14 In an experiment on the specific heat of a metal, a 0.20 kg block of the metal at 150 °C is dropped in a copper calorimeter (of water equivalent 0.025 kg) containing 150 cm3 of water at

27 °C. The final temperature is 40 °C. Compute the specific heat of the metal. If heat losses to the surroundings are not negligible, is your answer greater or smaller than the actual value for specific heat of the metal ?

Question 11.15 Given below are observations on molar specific heats at room temperature of some common gases. Gas Molar specific heat (Cv) (cal mo1–1 K–1) Hydrogen 4.87 Nitrogen 4.97 Oxygen 5.02 Nitric oxide 4.99 Carbon monoxide 5.01 Chlorine 6.17 The measured molar specific heats of these gases are markedly different from those for monatomic gases. Typically, molar specific heat of a monatomic gas is 2.92 cal/mol K. Explain this difference. What can you infer from the somewhat larger (than the rest) value for chlorine ?

Question 11.16 Answer the following questions based on the P-T phase diagram of carbon dioxide:
(a) At what temperature and pressure can the solid, liquid and vapour phases of CO2 co-exist in equilibrium ?
(b) What is the effect of decrease of pressure on the fusion and boiling point of CO2 ?
(c) What are the critical temperature and pressure for CO2 ? What is their significance ?
(d) Is CO2 solid, liquid or gas at (a) –70 °C under 1 atm, (b) –60 °C under 10 atm, (c) 15 °C under 56 atm ?

Question 11.17 Answer the following questions based on the P – T phase diagram of CO2:
(a) CO2 at 1 atm pressure and temperature – 60 °C is compressed isothermally. Does it go through a liquid phase ?
(b) What happens when CO2 at 4 atm pressure is cooled from room temperature at constant pressure ?
(c) Describe qualitatively the changes in a given mass of solid CO2 at 10 atm pressure and temperature –65 °C as it is heated up to room temperature at constant pressure.
(d) CO2 is heated to a temperature 70 °C and compressed isothermally. What changes in its properties do you expect to observe ?

Question 11.18 A child running a temperature of 101°F is given an antipyrin (i.e. a medicine that lowers fever) which causes an increase in the rate of evaporation of sweat from his body. If the fever is brought down to 98 °F in 20 min, what is the average rate of extra evaporation caused, by the drug. Assume the evaporation mechanism to be the only way by which heat is lost. The mass of the child is 30 kg. The specific heat of human body is approximately the same as that of water, and latent heat of evaporation of water at that temperature is about 580 cal g–1.

Question 11.19 A 'thermacole' icebox is a cheap and efficient method for storing small quantities of cooked food in summer in particular. A cubical icebox of side 30 cm has a thickness of 5.0 cm. If 4.0 kg of ice is put in the box, estimate the amount of ice remaining after 6 h. The outside temperature is 45 °C, and co-efficient of thermal conductivity of thermacole is 0.01 J s–1 m–1 K–1. [Heat of fusion of water = 335 × 103 J kg–1]

Question 11.20 A brass boiler has a base area of 0.15 m2 and thickness 1.0 cm. It boils water at the rate of 6.0 kg/min when placed on a gas stove. Estimate the temperature of the part of the flame in contact with the boiler. Thermal conductivity of brass = 109 J s–1 m–1 K–1 ; Heat of vaporisation of water = 2256 × 103 J kg–1.

Question 11.21 Explain why :
(a) a body with large reflectivity is a poor emitter
(b) a brass tumbler feels much colder than a wooden tray on a chilly day
(c) an optical pyrometer (for measuring high temperatures) calibrated for an ideal black body radiation gives too low a value for the temperature of a red hot iron piece in the open, but gives a correct value for the temperature when the same piece is in the furnace
(d) the earth without its atmosphere would be inhospitably cold
(e) heating systems based on circulation of steam are more efficient in warming a building than those based on circulation of hot water

Question 11.22 A body cools from 80 °C to 50 °C in 5 minutes. Calculate the time it takes to cool from 60 °C to 30 °C. The temperature of the surroundings is 20 °C.

:: Chapter 12 Thermodynamics ::

Question 12.1 A geyser heats water flowing at the rate of 3.0 litres per minute from 27 °C to 77 °C. If the geyser operates on a gas burner, what is the rate of consumption of the fuel if its heat of combustion is 4.0 × 104 J/g ?
Question 12.2 What amount of heat must be supplied to 2.0 × 10–2 kg of nitrogen (at room temperature) to raise its temperature by 45 °C at constant pressure ? (Molecular mass of N2 = 28; R = 8.3 J mol–1 K–1.)

Question 12.3 Explain why

(a) Two bodies at different temperatures T1 and T2 if brought in thermal contact do not necessarily settle to the mean temperature (T1 + T2)/2.
(b) The coolant in a chemical or a nuclear plant (i.e., the liquid used to prevent the different parts of a plant from getting too hot) should have high specific heat.
(c) Air pressure in a car tyre increases during driving.
(d) The climate of a harbour town is more temperate than that of a town in a desert at the same latitude.

Question 12.4 A cylinder with a movable piston contains 3 moles of hydrogen at standard temperature and pressure. The walls of the cylinder are made of a heat insulator, and the piston is insulated by having a pile of sand on it. By what factor does the pressure of the gas increase if the gas is compressed to half its original volume ?

Question 12.5 In changing the state of a gas adiabatically from an equilibrium state A to another equilibrium state B, an amount of work equal to 22.3 J is done on the system. If the gas is taken from state A to B via a process in which the net heat absorbed by the system is 9.35 cal, how much is the net work done by the system in the latter case ? (Take 1 cal = 4.19 J)

Question 12.6 Two cylinders A and B of equal capacity are connected to each other via a stopcock. A contains a gas at standard temperature and pressure. B is completely evacuated. The entire system is thermally insulated. The stopcock is suddenly opened. Answer the following :
(a) What is the final pressure of the gas in A and B ?
(b) What is the change in internal energy of the gas ?
(c) What is the change in the temperature of the gas ?
(d) Do the intermediate states of the system (before settling to the final equilibrium state) lie on its P-V-T surface ?

Question 12.7 A steam engine delivers 5.4×108J of work per minute and services 3.6 × 109J of heat per minute from its boiler. What is the efficiency of the engine? How much heat is wasted per minute?

Question 12.8 An electric heater supplies heat to a system at a rate of 100W. If system performs work at a rate of 75 joules per second. At what rate is the internal energy increasing?

Question 12.9 A thermodynamic system is taken from an original state to an intermediate state by the linear process shown in Fig. (12.13) Its volume is then reduced to the original value from E to F by an isobaric process. Calculate the total work done by the gas from D to E to F

Question 12.10 A refrigerator is to maintain eatables kept inside at 90C. If room temperature is 360C, calculate the coefficient of performance .

:: Chapter 13 Kinetic Theory ::

Question 13.1 Estimate the fraction of molecular volume to the actual volume occupied by oxygen gas at STP. Take the diameter of an oxygen molecule to be 3 Å.

Question 13.2 Molar volume is the volume occupied by 1 mol of any (ideal) gas at standard temperature and pressure (STP : 1 atmospheric pressure, 0 °C). Show that it is 22.4 litres.

Question 13.3 Figure13.8 shows plot of PV/T versus P for 1.00×10–3 kg of oxygen gas at two different temperatures.

(a) What does the dotted plot signify?

(b) Which is true: T1 > T2 or T1 < T2?

(c) What is the value of PV/T where the curves meet on the y-axis?

(d) If we obtained similar plots for 1.00×10–3 kg of hydrogen, would we get the same value of PV/T at the point where the curves meet on the y-axis? If not, what mass of hydrogen yields the same value of PV/T (for low pressurehigh temperature region of the plot) (Molecular mass of H2 = 2.02 u, of O2 = 32.0 u, R = 8.31 J mo1–1 K–1.)

Question 13.4 An oxygen cylinder of volume 30 litres has an initial gauge pressure of 15 atm and a temperature of 27 °C. After some oxygen is withdrawn from the cylinder, the gauge pressure drops to 11 atm and its temperature drops to 17 °C. Estimate the mass of oxygen taken out of the cylinder (R = 8.31 J mol–1 K–1, molecular mass of O2 = 32 u).

Question 13.5 An air bubble of volume 1.0 cm3 rises from the bottom of a lake 40 m deep at a temperature of 12 °C. To what volume does it grow when it reaches the surface, which is at a temperature of 35 °C ?

Question 13.6 Estimate the total number of air molecules (inclusive of oxygen, nitrogen, water vapour and other constituents) in a room of capacity 25.0 m3 at a temperature of 27 °C and 1 atm pressure.

Question 13.7 Estimate the average thermal energy of a helium atom at (i) room temperature (27 °C), (ii) the temperature on the surface of the Sun (6000 K), (iii) the temperature of 10 million kelvin (the typical core temperature in the case of a star).

Question 13.8 Three vessels of equal capacity have gases at the same temperature and pressure. The first vessel contains neon (monatomic), the second contains chlorine (diatomic), and the third contains uranium hexafluoride (polyatomic). Do the vessels contain equal number of respective molecules ? Is the root mean square speed of molecules the same in the three cases? If not, in which case is vrms the largest ?

Question 13.9 At what temperature is the root mean square speed of an atom in an argon gas cylinder equal to the rms speed of a helium gas atom at – 20 °C ? (atomic mass of Ar = 39.9 u, of He = 4.0 u).

Question 13.10 Estimate the mean free path and collision frequency of a nitrogen molecule in a cylinder containing nitrogen at 2.0 atm and temperature 17 0C. Take the radius of a nitrogen molecule to be roughly 1.0 Å. Compare the collision time with the time the molecule moves freely between two successive collisions (Molecular mass of N2 = 28.0 u).

Question 13.11 A metre long narrow bore held horizontally (and closed at one end) contains a 76 cm long mercury thread, which traps a 15 cm column of air. What happens if the tube is held vertically with the open end at the bottom ?

Question 13.12 From a certain apparatus, the diffusion rate of hydrogen has an average value of 28.7 cm3 s–1. The diffusion of another gas under the same conditions is measured to have an average rate of 7.2 cm3 s–1. Identify the gas. [Hint : Use Graham's law of diffusion: R1/R2 = (M2 /M1)1/2, where R1, R2 are diffusion rates of gases 1 and 2, and M1 and M2 their respective molecular masses. The law is a simple consequence of kinetic theory.]

Question 13.13 A gas in equilibrium has uniform density and pressure throughout its volume. This is strictly true only if there are no external influences. A gas column under gravity, for example, does not have uniform density (and pressure). As you might expect, its density decreases with height. The precise dependence is given by the so-called law of atmospheres n2 = n1 exp [-mg (h2 – h1)/ kBT] where n2, n1 refer to number density at heights h2 and h1 respectively. Use this relation to derive the equation for sedimentation equilibrium of a suspension in a liquid column: n2 = n1 exp [-mg NA (ρ - P′) (h2 –h1)/ (ρ RT)] where ρ is the density of the suspended particle, and ρ’ that of surrounding medium. [NA is Avogadro’s number, and R the universal gas constant.] [Hint : Use Archimedes principle to find the apparent weight of the suspended particle.]

Question 13.14 Given below are densities of some solids and liquids. Give rough estimates of the size of their atoms : [Hint : Assume the atoms to be ‘tightly packed’ in a solid or liquid phase, and use the known value of Avogadro’s number. You should, however, not take the actual numbers you obtain for various atomic sizes too literally. Because of the crudeness of the tight packing approximation, the results only indicate that atomic sizes are in the range of a few Å].

:: Chapter 14 Oscillations ::

Question 14.1 Which of the following examples represent periodic motion?
(a) A swimmer completing one (return) trip from one bank of a river to the other and back.
(b) A freely suspended bar magnet displaced from its N-S direction and released.
(c) A hydrogen molecule rotating about its center of mass.
(d) An arrow released from a bow.

Question 14.2 Which of the following examples represent (nearly) simple harmonic motion and which represent periodic but not simple harmonic motion?
(a) the rotation of earth about its axis.
(b) motion of an oscillating mercury column in a U-tube.
(c) motion of a ball bearing inside a smooth curved bowl, when released from a point slightly above the lower most point.
(d) general vibrations of a polyatomic molecule about its equilibrium position.

Question 14.3 Figure 14.27 depicts four x-t plots for linear motion of a particle. Which of the plots represent periodic motion? What is the period of motion (in case of periodic motion) ?

Question 14.4 Which of the following functions of time represent
(a) simple harmonic (b) periodic but not simple harmonic, and (c) non-periodic motion? Give period for each case of periodic motion (ω is any positive constant):
(a) sin ωt – cos ωt
(b) sin3 ωt
(c) 3 cos (π/4 – 2ωt)

(d) cos ωt + cos 3ωt + cos 5ωt

(e) exp (–ω2t2)

(f) 1 + ωt + ω2t2

Question 14.5 A particle is in linear simple harmonic motion between two points, A and B, 10 cm apart. Take the direction from A to B as the positive direction and give the signs of velocity, acceleration and force on the particle when it is

(a) at the end A (b) at the end B (c) at the mid-point of AB going towards A (d) at 2 cm away from B going towards A

(e) at 3 cm away from A going towards B and (f) at 4 cm away from B going towards A.

Question 14.6 Which of the following relationships between the acceleration a and the displacement x of a particle involve simple harmonic motion?

(a) a = 0.7x

(b) a = –200x2

(c) a = –10x

(d) a = 100x3

Question 14.7 The motion of a particle executing simple harmonic motion is described by the displacement function, x(t) = A cos (ωt + φ). If the initial (t = 0) position of the particle is 1 cm and its initial velocity is ω cm/s, what are its amplitude and initial phase angle ? The angular frequency of the particle is π s–1. If instead of the cosine function, we choose the sine function to describe the SHM : x = B sin (ωt + α), what are the amplitude and initial phase of the particle with the above initial conditions.

Question 14.8 A spring balance has a scale that reads from 0 to 50 kg. The length of the scale is 20 cm. A body suspended from this balance, when displaced and released, oscillates with a period of 0.6 s. What is the weight of the body ?

Question 14.9 A spring having with a spring constant 1200 N m–1 is mounted on a horizontal table as shown in Fig. 14.28. A mass of 3 kg is attached to the free end of the spring. The mass is then pulled sideways to a distance of 2.0 cm and released. Fig.14.28 Determine (i) the frequency of oscillations, (ii) maximum acceleration of the mass, and (iii) the maximum speed of the mass.

Question 14.10 In Exercise 14.9, let us take the position of mass when the spring is unstreched as x = 0, and the direction from left to right as the positive direction of x-axis. Give x as a function of time t for the oscillating mass if at the moment we start the stopwatch ($t = 0$), the mass is (a) at the mean position, (b) at the maximum stretched position, and (c) at the maximum compressed position. In what way do these functions for SHM differ from each other, in frequency, in amplitude or the initial phase?

Question 14.11 Figures 14.29 correspond to two circular motions. The radius of the circle, the period of revolution, the initial position, and the sense of revolution (i.e. clockwise or anti-clockwise) are indicated on each figure. Obtain the corresponding simple harmonic motions of the x-projection of the radius vector of the revolving particle P, in each case.

Question 14.12 Plot the corresponding reference circle for each of the following simple harmonic motions. Indicate the initial ($t = 0$) position of the particle, the radius of the circle, and the angular speed of the rotating particle. For simplicity, the sense of rotation may be fixed to be anticlockwise in every case: (x is in cm and t is in s).

(a) $x = -2 \sin (3t + \pi/3)$

(b) $x = \cos (\pi/6 - t)$

(c) $x = 3 \sin (2\pi t + \pi/4)$

(d) $x = 2 \cos \pi t$

Question 14.13 Figure 14.30 (a) shows a spring of force constant k clamped rigidly at one end and a mass m attached to its free end. A force F applied at the free end stretches the spring. Figure 14.30 (b) shows the same spring with both ends free and attached to a mass m at either end. Each end of the spring in Fig. 14.30(b) is stretched by the same force F. (a) What is the maximum extension of the spring in the two cases ? (b) If the mass in Fig. (a) and the two masses in Fig. (b) are released, what is the period of oscillation in each case ?

Question 14.14 The piston in the cylinder head of a locomotive has a stroke (twice the amplitude) of 1.0 m. If the piston moves with simple harmonic motion with an angular frequency of 200 rad/min, what is its maximum speed ?

Question 14.15 The acceleration due to gravity on the surface of moon is 1.7 m s^{-2}. What is the time period of a simple pendulum on the surface of moon if its time period on the surface of earth is 3.5 s ? (g on the surface of earth is 9.8 m s^{-2})

Question 14.16 Answer the following questions :

(a) Time period of a particle in SHM depends on the force constant k and mass m of the particle: T m k = 2π . A simple pendulum executes SHM approximately. Why then is the time period of a pendulum independent of the mass of the pendulum?
(b) The motion of a simple pendulum is approximately simple harmonic for small angle oscillations. For larger angles of oscillation, a more involved analysis shows that T is greater than 2π l g . Think of a qualitative argument to appreciate this result.
(c) A man with a wristwatch on his hand falls from the top of a tower. Does the watch give correct time during the free fall ?
(d) What is the frequency of oscillation of a simple pendulum mounted in a cabin that is freely falling under gravity ?

Question 14.17 A simple pendulum of length l and having a bob of mass M is suspended in a car. The car is moving on a circular track of radius R with a uniform speed v. If the pendulum makes small oscillations in a radial direction about its equilibrium position, what will be its time period ?

Question 14.18 A cylindrical piece of cork of density of base area A and height h floats in a liquid of density ρl. The cork is depressed slightly and then released. Show that the cork oscillates up and down simple harmonically with a period T h g 1 = 2π ρ ρ where ρ is the density of cork. (Ignore damping due to viscosity of the liquid).

Question 14.19 One end of a U-tube containing mercury is connected to a suction pump and the other end to atmosphere. A small pressure difference is maintained between the two columns. Show that, when the suction pump is removed, the column of mercury in the U-tube executes simple harmonic motion. Additional Exercises

Question 14.20 An air chamber of volume V has a neck area of cross section a into which a ball of mass m just fits and can move up and down without any friction (Fig 14.33). Show that when the ball is pressed down a little and released , it executes SHM. Obtain an expression for the time period of oscillations assuming pressure-volume variations of air to be isothermal [see Fig 14.33].

Question 14.21 You are riding in an automobile of mass 3000 kg. Assuming that you are examining the oscillation characteristics of its suspension system. The suspension sags 15 cm when the entire automobile is placed on it. Also, the amplitude of oscillation decreases by 50% during one complete oscillation. Estimate the values of (a) the spring constant k and (b) the damping constant b for the spring and shock absorber system of one wheel, assuming that each wheel supports 750 kg.

Question 14.22 Show that for a particle in linear SHM the average kinetic energy over a period of oscillation equals the average potential energy over the same period.

Question 14.23 A circular disc of mass 10 kg is suspended by a wire attached to its centre. The wire is twisted by rotating the disc and released. The period of torsional oscillations is found to be 1.5 s. The radius of the disc is 15 cm. Determine the torsional spring constant of the wire. (Torsional spring constant α is defined by the relation $J = -\alpha \theta$, where J is the restoring couple and θ the angle of twist).

Question 14.24 A body describes simple harmonic motion with an amplitude of 5 cm and a period of 0.2 s. Find the acceleration and velocity of the body when the displacement is (a) 5 cm, (b) 3 cm, (c) 0 cm.

Question 14.25 A mass attached to a spring is free to oscillate, with angular velocity ω, in a horizontal plane without friction or damping. It is pulled to a distance x0 and pushed towards the centre with a velocity v0 at time t = 0. Determine the amplitude of the resulting oscillations in terms of the parameters ω, x0 and v0. [Hint : Start with the equation $x = a \cos(\omega t+\theta)$ and note that the initial velocity is negative.]

:: Chapter 15 Waves ::

Question 15. 1 A string of mass 2.50 kg is under a tension of 200 N. The length of the stretched string is 20.0 m. If the transverse jerk is struck at one end of the string, how long does the disturbance take to reach the other end?

Question 15. 2 A stone dropped from the top of a tower of height 300 m high splashes into the water of a pond near the base of the tower. When is the splash heard at the top given that the speed of sound in air is 340 m s–1 ? (g = 9.8 m s–2)

Question 15. 3 A steel wire has a length of 12.0 m and a mass of 2.10 kg. What should be the tension in the wire so that speed of a transverse wave on the wire equals the speed of sound in dry air at 20 °C = 343 m s–1.

Question 15. 4 Use the formula v P = γ ρ to explain why the speed of sound in air (a) is independent of pressure, (b) increases with temperature, (c) increases with humidity.

Question 15. 5 You have learnt that a travelling wave in one dimension is represented by a function y = f (x, t) where x and t must appear in the combination x – v t or x + v t, i.e. y = f (x ± v t). Is the converse true? Examine if the following functions for y can possibly represent a travelling wave :

(a) (x – vt)2

(b) log [(x + vt)/x0]

(c) 1/(x + vt)

Question 15. 6 A bat emits ultrasonic sound of frequency 1000 kHz in air. If the sound meets a water surface, what is the wavelength of (a) the reflected sound, (b) the transmitted sound? Speed of sound in air is 340 m s –1 and in water 1486 m s–1.

Question 15. 7 A hospital uses an ultrasonic scanner to locate tumours in a tissue. What is the wavelength of sound in the tissue in which the speed of sound is 1.7 km s–1 ? The operating frequency of the scanner is 4.2 MHz.

Question 15. 8 A transverse harmonic wave on a string is described by y(x, t) = 3.0 sin (36 t + 0.018 x + π/4) where x and y are in cm and t in s. The positive direction of x is from left to right.

(a) Is this a travelling wave or a stationary wave ? If it is travelling, what are the speed and direction of its propagation ?

(b) What are its amplitude and frequency ?

(c) What is the initial phase at the origin ?

(d) What is the least distance between two successive crests in the wave ?

Question 15. 9 For the wave described in Exercise 15. 8, plot the displacement (y) versus (t) graphs for x = 0, 2 and 4 cm. What are the shapes of these graphs? In which aspects does the oscillatory motion in travelling wave differ from one point to another: amplitude, frequency or phase ?

Question 15. 10 For the travelling harmonic wave y(x, t) = 2.0 cos 2π (10t – 0.0080 x + 0.35) where x and y are in cm and t in s. Calculate the phase difference between oscillatory motion of two points separated by a distance of (a) 4 m, (b) 0.5 m, (c) λ/2, (d) 3λ/4 WAVES 389

Question 15. 11 The transverse displacement of a string (clamped at its both ends) is given by y(x, t) = 0.06 sin 2 3 x cos (120 πt) where x and y are in m and t in s. The length of the string is 1.5 m and its mass is 3.0 ×10–2 kg. Answer the following :

(a) Does the function represent a travelling wave or a stationary wave?

(b) Interpret the wave as a superposition of two waves travelling in opposite directions. What is the wavelength, frequency, and speed of each wave ?

(c) Determine the tension in the string.

Question 15. 12 (i) For the wave on a string described in Exercise 15.11, do all the points on the string oscillate with the same (a) frequency, (b) phase, (c) amplitude? Explain your answers. (ii) What is the amplitude of a point 0.375 m away from one end?

Question 15. 13 Given below are some functions of x and t to represent the displacement (transverse or longitudinal) of an elastic wave. State which of these represent (i) a travelling wave, (ii) a stationary wave or (iii) none at all:

(a) y = 2 cos (3x) sin (10t)

(b) y = 2 x − vt

(c) y = 3 sin (5x – 0.5t) + 4 cos (5x – 0.5t)

(d) y = cos x sin t + cos 2x sin 2t

Question 15. 14 A wire stretched between two rigid supports vibrates in its fundamental mode with a frequency of 45 Hz. The mass of the wire is 3.5 × 10–2 kg and its linear mass density is 4.0 × 10–2 kg m–1. What is (a) the speed of a transverse wave on the string, and (b) the tension in the string?

Question 15. 15 A metre-long tube open at one end, with a movable piston at the other end, shows resonance with a fixed frequency source (a tuning fork of frequency 340 Hz) when the tube length is 25.5 cm or 79.3 cm. Estimate the speed of sound in air at the temperature of the experiment. The edge effects may be neglected.

Question 15. 16 A steel rod 100 cm long is clamped at its middle. The fundamental frequency of longitudinal vibrations of the rod are given to be 2.53 kHz. What is the speed of sound in steel?

Question 15. 17 A pipe 20 cm long is closed at one end. Which harmonic mode of the pipe is resonantly excited by a 430 Hz source ? Will the same source be in resonance with the pipe if both ends are open? (speed of sound in air is 340 m s–1).

Question 15. 18 Two sitar strings A and B playing the note ‘Ga’ are slightly out of tune and produce beats of frequency 6 Hz. The tension in the string A is slightly reduced and the beat frequency is found to reduce to 3 Hz. If the original frequency of A is 324 Hz, what is the frequency of B?

Question 15. 19 Explain why (or how):
(a) in a sound wave, a displacement node is a pressure antinode and vice versa
(b) bats can ascertain distances, directions, nature, and sizes of the obstacles without any "eyes"
(c) a violin note and sitar note may have the same frequency, yet we can distinguish between the two notes
(d) solids can support both longitudinal and transverse waves, but only longitudinal waves can propagate in gases
(e) the shape of a pulse gets distorted during propagation in a dispersive medium. 390

Question 15. 20 A train, standing at the outer signal of a railway station blows a whistle of frequency 400 Hz in still air. (i) What is the frequency of the whistle for a platform observer when the train (a) approaches the platform with a speed of 10 m s–1, (b) recedes from the platform with a speed of 10 m s–1? (ii) What is the speed of sound in each case ? The speed of sound in still air can be taken as 340 m s–1.

Question 15. 21 A train, standing in a station-yard, blows a whistle of frequency 400 Hz in still air. The wind starts blowing in the direction from the yard to the station with at a speed of 10 m s–1. What are the frequency, wavelength, and speed of sound for an observer standing on the station's platform? Is the situation exactly identical to the case when the air is still and the observer runs towards the yard at a speed of 10 m s–1? The speed of sound in still air can be taken as 340 m s–1
Additional Exercises

Question 15. 22 A travelling harmonic wave on a string is described by y(x, t) = 7.5 sin (0.0050x +12t + π/4) (a)what are the displacement and velocity of oscillation of a point at x = 1 cm, and t = 1 s? Is this velocity equal to the velocity of wave propagation? (b)Locate the points of the string which have the same transverse displacements and velocity as the x = 1 cm point at t = 2 s, 5 s and 11 s.

Question 15. 23 A narrow sound pulse (for example, a short pip by a whistle) is sent across a medium. (a) Does the pulse have a definite (i) frequency, (ii) wavelength, (iii) speed of propagation? (b) If the pulse rate is 1 after every 20 s, (that is the whistle is blown for a split of second after every 20 s), is the frequency of the note produced by the whistle equal to 1/20 or 0.05 Hz ?

Question 15. 24 One end of a long string of linear mass density 8.0 × 10–3 kg m–1 is connected to an electrically driven tuning fork of frequency 256 Hz. The other end passes over a pulley and is tied to a pan containing a mass of 90 kg. The pulley end absorbs all the incoming energy so that reflected waves at this end have negligible amplitude. At t = 0, the left end (fork end) of the string x = 0 has zero transverse displacement (y = 0) and is moving along positive y-direction. The amplitude of the wave is 5.0 cm. Write down the transverse displacement y as function of x and t that describes the wave on the string.

Question 15. 25 A SONAR system fixed in a submarine operates at a frequency 40.0 kHz. An enemy submarine moves towards the SONAR with a speed of 360 km h–1. What is the frequency of sound reflected by the submarine ? Take the speed of sound in water to be 1450 m s–1.

Question 15. 26 Earthquakes generate sound waves inside the earth. Unlike a gas, the earth can experience both transverse (S) and longitudinal (P) sound waves. Typically the speed of S wave is about 4.0 km s–1, and that of P wave is 8.0 km s–1. A seismograph records P and S waves from an earthquake. The first P wave arrives 4 min before the first S wave. Assuming the waves travel in straight line, at what distance does the earthquake occur ?

Question 15. 27 A bat is flitting about in a cave, navigating via ultrasonic beeps. Assume that the sound emission frequency of the bat is 40 kHz. During one fast swoop directly toward a flat wall surface, the bat is moving at 0.03 times the speed of sound in air. What frequency does the bat hear reflected off the wall ?