R1-2002 Q1(g)

g) A neutron moving through heavy water strikes, head on, an isolated stationary deuteron.

(i) Assuming the mass m of the neutron is equal to half that of the deuteron, show that the ratio of the final speed of the deuteron, v_d, to the incident speed of the neutron, u_n, is (👌).

(ii) Determine the percentage of the initial kinetic energy acquired by the deuteron.

(iii) How many such collisions would be required to slow the neutron down from 10 Mev to 0.0l ev?

[16]

R1-2003 Q1(c)

c) A rocket, of constant mass 2.00×10^3 kg, is fired vertically upwards with constant acceleration. After one minute it reaches a height of 36.0 km and its engine is switched off. Assuming the rocket's mass and g remain constant, calculate:

(i) the initial acceleration of the rocket

(ii) the maximum height reached

(iii) the total time of flight

(iv) the work done by the rocket

Why is the assumption made unrealistic? [10]

R1-2003 Q1(g)

g) A puck of mass m, velocity v, coordinates (x,y), slides under gravity, without friction, on the smooth track shown in Figure 1.2.
Determine, or answer, the following:

(i) the acceleration f along the straight portion of the track
(ii) the total energy E of the puck when located at (x,y)
(iii) comment on the resultant acceleration at 0
(iv) if released from rest at $x = a$, determine its velocity at 0. [5]

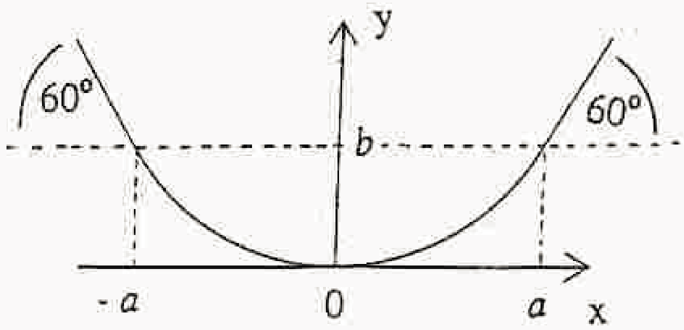

Figure 1.2

R1-2004 Q1(i)

i) A lady ice skater, mass 60 kg, is moving at 12 m s^{-1} in a straight line. She decelerates by standing on one skate, and comes to rest in 40 m. Neglecting air resistance, calculate:

(i) her deceleration
(ii) the coefficient of friction between the skate and the ice
(iii) her loss of kinetic energy
(iv) the maximum mass of ice melted [8]
The specific latent heat of melting of ice is 330 kJ kg^{-1}.

R1-2004 Q1(n)

n) During a thunder storm a student sets his stopwatch to zero at the time of a lightening strike. He records the time, t, of a subsequent lightening strike, from the same direction, and the time interval, Δt, between each strike and the following thunder clap. His results are given in the table below.

t /s	Δt /s
0	32.5
49.1	18.0

(i) Why does the lightening strike occur before the thunder clap?
(ii) Determine the speed u at which the storm is approaching.

Assume the speed of sound is 334 m s^{-1}. [6]

R1-2005 Q1(f)

f) A bullet leaves the 1.20 m barrel of a rifle at a horizontal speed of 310 m s^{-1}:

(i) Calculate the acceleration of the bullet in the barrel assuming it to be constant.
(ii) If the bullet emerges from the barrel after two complete rotations, estimate its final rotational speed in radians per second.
(iii) What advantage has a barrel that causes the bullet to rotate?
(iv) In practice the acceleration of the bullet is not constant. Sketch a graph of the expected variation, with distance, and explain the variation. [5]

R1-2005 Q1(h)

h) The acceleration, a, of a particle, velocity v, along a straight line can have the following forms:

(i) g
(ii) $g - kv$
(iii) $-\omega\sqrt{b^2\omega^2 - v^2}$,

g is the constant acceleration of free fall, v is the velocity, k, ω and b are constants. Sketch graphs, for each case, assuming $v = 0$ at time $t = 0$, of:

(1) a against v
(2) v against time, t. [8]

R1-2005 Q1(l)

Two identical elastic spheres, each of mass m, are at rest on a smooth table and touch each other. They are struck symmetrically by an identical sphere, but of mass M, having a velocity u, perpendicular to the line of centres of the two stationary spheres. The mass M comes to rest immediately after the collision.
Determine the ratio M/m.

[4]

R1-2006 Q1(m)

(m) A car starts from rest at time $t = 0$ and travels with constant acceleration a_1 for time t_1. From time t_1 to t_2 it travels with constant speed u. After t_2 a retarding acceleration is applied, of initial magnitude a_2, which decreases linearly to zero at time t_3 when the car comes to rest.

Sketch the following graphs:

(i) acceleration – time
(ii) velocity – time
(iii) distance – time

[3]

R1-2007 Q1(m)

(m) A 0.20 kg mass is attached to the lower end of a helical spring which is fixed at its upper end. The vertical spring is extended by 0.16 m when in equilibrium. Determine :

(i) the change in gravitational potential energy of the mass due to the spring's extension
(ii) the elastic energy stored in the spring
(iii) Why do the magnitudes of (i) and (ii) differ ?

The mass is pulled down a further distance of 0.08 m and released.

(iv) What is its kinetic energy when passing through the equilibrium position ?
(v) What is its period of oscillation ?
(vi) If the upper end of the spring is released, describe the motion of the mass and the spring.

[10]

R1-2008 Q1(f)

(f) A vehicle is travelling at 60 mph along a straight road, without slipping. What are the velocities at the 'compass points', N ,S , E , and W, of the rim of the wheel ? [7]

R1-2009 Q1(d)

(d) A man cycles to work, with the wind behind him , at 8.0 ms^{-1} and returns home, Against the wind, at 4.0 ms^{-1}. What is his average speed ?

[3]

R1-2009 Q1(k)

(k) Answer the following questions with an example where possible:

(i) Can a body to be accelerating while travelling at constant speed ?
(ii) Can a body have a constant velocity and a varying speed ?
(iii) If a body has zero velocity, can it be accelerating ?
(iv) Can a body be accelerating in a direction opposite to its velocity ?

[6]

R1-2010 Q1(l)

(l) A boat can travel at a speed of 3.0 ms^{-1} on a pond. A boatman wants to cross a river by the shortest path. In what direction should he row, with respect to the bank, if the speed of the water is 2.0 ms^{-1}.
Explain, using a diagram, which path he should take if the water speed is 4.0 ms^{-1}. [7]

R1-2011 Q1(i)

i) A sphere, mass M and speed u, collides elastically head-on with an identical sphere of mass m which is initially at rest. After the collision the masses M and m have respectively speeds, in the direction of u, of v and w.

(i) Prove or verify that $u + v = w$.

(ii) If $R = (u\text{-}v)/ u$, prove $R = mw/(Mu)$.

(iii) Express R in terms of M and m only.

[8]

R1-2012 Q1(d)

(d) A proton travelling with a velocity of 3.00×10^7 m s^{-1} collides with an oxygen nucleus, of mass 2.56×10^{-26} kg that is at rest, and is scattered through an angle of 90°. Calculate the velocity and direction of the oxygen nucleus using Newtonian mechanics.

[12]

R1-2013 Q1(m)

(m) A smooth flat horizontal turntable 4.0 m in diameter is rotating at 0.050 revs per second. A student at the centre of the turntable, and rotating with it, releases a smooth flat puck on the turntable 0.50 m from the edge. Describe the motion of the puck as seen by a stationary observer who is standing at the side of the turntable.

(i) How long does the puck remain on the turntable?

(ii) At what relative *velocity* would the student, at the centre of the turntable, see the puck leave the turntable?

[10]

R1-2004 Q2

a) A stone is dropped into a deep canyon. After 10.2 s it is heard to strike bottom. Estimate approximately:

(i) the depth of the canyon, h, neglecting the time taken by the sound wave to return to the top of the canyon

(ii) the time t_2 taken by the returning sound wave to reach the top of the canyon, assuming the speed of sound is 334 m s^{-1}

(iii) the accuracy of the result in (i)

[6]

b) If t_1 is the time taken for the stone to reach the bottom of the canyon and t_2 is the time for the sound wave produced to reach the top of the canyon:

(i) write down the equations that determine t_1 and t_2, neglecting air resistance

(ii) calculate the exact value of t_1

(iii) calculate the exact value of t_2

(iv) deduce the depth of the canyon

[10]

c) If the stone is initially thrown with velocity u horizontally into the canyon, what differences will arise in the answers to question (b)(i)?

[2]

d) If the stone is thrown vertically upwards with velocity u, how will this alter the answers to question (b)(i)?

[2]

R1-2004 Q8

a) Fast neutrons, mass m_1, with a speed $v_1 = 2.0 \times 10^7$ ms^{-1}, are slowed down in a nuclear reactor by elastic collisions with the nuclei of a moderator. Calculate the speed v of a neutron after a single, head on, collision with (i) a hydrogen nucleus in water and (ii) a carbon nucleus in graphite by first deriving v in the general case of a collision with a nucleus of mass m_2. These nuclei are initially stationary.

After many collisions with atoms of a moderator at room temperature, what energy will the neutrons attain? The masses involved are:

neutron 1.0087 u; hydrogen nucleus 1.0073 u; carbon nucleus 11.9934 u

[12]

b) The ballistic pendulum is a device used to measure the speed v of a bullet. It consists of a stationary heavy rectangular wooden block of mass M suspended by vertical strings from the corners of the upper horizontal face. When a bullet of mass m strikes the block horizontally it undergoes an inelastic collision and embeds itself in the block. The block swings upwards. If the block rises a height h, obtain an expression for the speed of the bullet assuming h is small and the block moves initially with a horizontal velocity.
Comment on the motion of the block during its upward swing.

[8]

R1-2006 Q7

(a) A projectile, mass m, is thrown vertically upwards with velocity v. Calculate:

(i) the maximum height, H, reached.
(ii) the time taken, T, to return to the ground.

[2]

(b) A horizontal wind exerts a horizontal force on the projectile of αmg, where α is a constant. The projectile has initial vertical and horizontal components of velocity v and u respectively; u being taken in the same direction as the wind.

(i) What is the resultant force on the mass?
(ii) Determine the horizontal range, R, of the projectile.
(iii) Sketch the trajectory, indicating any axis of symmetry and giving its direction.
(iv) Under what initial condition, with the wind present, will the trajectory be a straight line? Give the elevation of this trajectory.

[11]

(c) Determine the work done *on* the mass during its motion:

(i) from its initial position to the maximum height in the case of a straight line trajectory.
(ii) for the general trajectory, from launch to its return to the ground.

[7]

R1-2008 Q4(b)

(b)

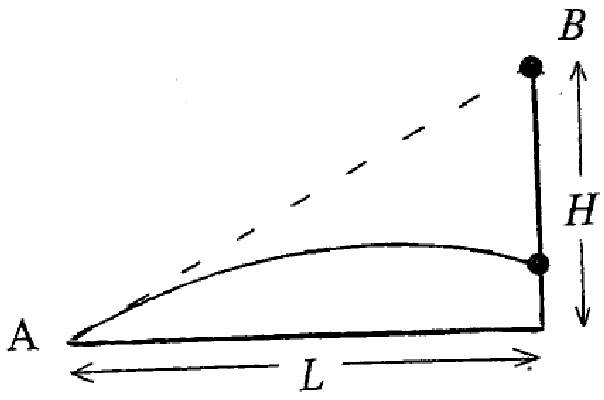

Figure 4.b

A marksman on the ground at A fires his rifle in the direction of a stationary clay pigeon located in a tower at B, height H, at a horizontal distance L from A, Figure 4b. At this instant the pigeon is released and falls vertically, under gravity. Verify that the bullet strikes the pigeon during its fall.

[12]

R1-2008 Q5(a)

(a)

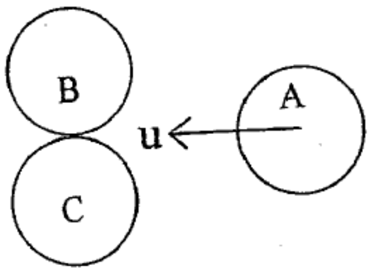

Figure 5.a

A sphere A travelling horizontally on a smooth table, with speed u, collides symmetrically, and elastically, with two stationary spheres, B and C, that are touching. All the spheres are identical and of mass m, Figure 5a . Determine the velocities of all the spheres after the collision.

C has a further collision with an identical sphere D , initially at rest and touching it. The centres of B,C and D lie on a straight line. Determine the outcome of this collision.

[12]

R1-2009 Q2

A spherical stone is dropped from the top of a cliff of height h at time $t = 0$. At the same moment another identical stone is thrown vertically upwards from the bottom of the cliff with a *positive* velocity u in the same vertical line as the first stone.

(a)

(i) After what time, T_c, will the stones collide ?

(ii) If the stones have equal speeds on collision, what is the value of u, and T_c ?

(iii) If the collision in (ii) is elastic, determine the time interval between the impacts of the stones on the ground.

[9]

(b)

(i) Sketch a fully *labelled* velocity – time graph for the motion of the two stones, on the same graph, using a full curve for the stone dropped from the cliff top and a dotted curve for the stone projected vertically upwards from the bottom of the cliff.

(ii) Sketch a fully *labelled* height– time graph for the two stones using the notation specified in (i).

[11]

R1-2011 Q4

a) A stone is projected with a speed u at a small angle α to the horizontal ground. It impacts on the ground at a distance d, having reached a maximum height h. At time t its velocity makes an angle θ with the horizontal.

Determine in terms of u and α:

(i) The time taken, T_g, to reach the ground and the distance d.
(ii) The maximum height, h, reached.
(iii) An expression for the radius of curvature of the trajectory, R, at height h.
(iv) Express R in terms of d and h.
(v) Sketch a graph of $\tan\theta$ against t, indicating the key points on the graph.
(vi) Deduce, from (v), that there are no pair of points on the stone's trajectory, with velocities that are perpendicular if α less than 45°.

[16]

b) A car, mass m, travels across a parabolic bridge of horizontal length d and maximum height h, the same values as in (a), at a constant speed v. Determine the reaction force, N, exerted by the bridge on the car at height h for any value of v. What advantage could be obtained by adding a spoiler to the car?

[4]

R1-2012 Q6

(a) A block of wood, mass M, rests on a smooth horizontal table. A gun is fired horizontally at the block and the bullet, mass m, passes through it, emerging with half its initial speed. Determine the fraction of the initial kinetic energy that is lost in the collusion.

[5]

(b) A particle, mass m, is placed at the top of a smooth sphere of radius a. The particle is disturbed and slides down the side gaining speed v at a vertical height z above the centre of the sphere. At what value of z will it leave the surface of the sphere?

[6]

(c) Figure 6.c shows two 45° wedges, the smaller wedge w has a horizontal top face. It can slide down the larger wedge W, which is on a horizontal table. All the surfaces are smooth. A mass m sits on the top face of the upper wedge. Describe qualitatively the motion of the system once it is released from rest.

[4]

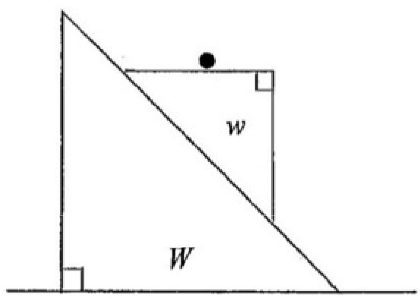

Figure 6.c

(d) Two trains are travelling away from a common station at speeds of u and $2u$, in directions that are at an angle 60° to each other. What is the *velocity* of the train with speed $2u$ relative to an observer in the other train?

[5]

R1-2013 Q6

Three small identical steel balls A, B, and C are suspended by vertical threads of equal length from a horizontal support, with their centres in a horizontal line and separated by a small gap. A is raised by a height h, with the thread taut, and released. All subsequent collisions are elastic.

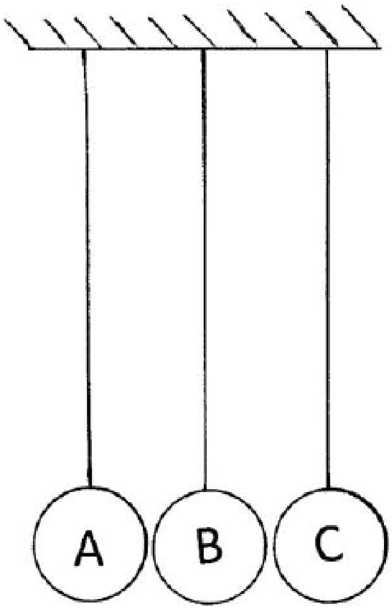

Figure 6.1

(i) When all the balls have mass M, determine the subsequent motion of the system and the height to which the centre of C is raised following its first collision.

[8]

(ii) When A has mass M, B has mass 2M and C has mass 3M, determine the height to which the centre of C is raised after its first collision.

[12]