TOPIC 4 Dynamics

Newton's Laws of Motion

1 A force applied horizontally to a certain mass near the Earth's surface produces an acceleration a. If an equal force were applied to the same mass near the surface of the Moon, where the acceleration of free fall is one sixth of its value at the Earth's surface, the acceleration produced would be

A $a/36$
B $a/6$
C a
D $6a$
E $36a$

J76/II/4

2 A body of mass 3 kg is acted on by a force which varies as shown in Fig. 1. The momentum acquired is

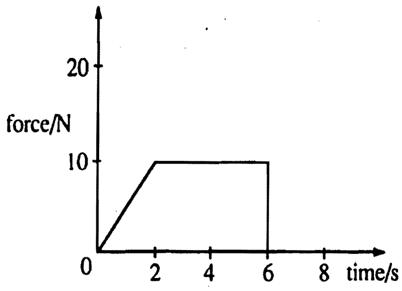


Fig. 1

A 0 N s
B 5 N s
C 30 N s
D 50 N s
E 60 N s

J76/II/6

3 A mass accelerates uniformly when the resultant force acting on it

A is zero.
B is constant but not zero.
C increases uniformly with respect to time.
D is proportional to the displacement of the mass from a fixed point.

J77/II/2; N82/II/3; N87/I/1; J90/I/1; J97/I/4

4 A body of mass 2 kg is moving on a horizontal surface with a speed of 1.41 m s^{-1} in a north-easterly direction. A force of 0.2 N acting in a westerly direction is applied to the body for 10 s. If friction is negligible, the body is then moving with a speed of

A 0.41 m s^{-1} in a north-easterly direction.
B 1.00 m s^{-1} in a northerly direction.
C 1.41 m s^{-1} in a north-westerly direction.
D 2.24 m s^{-1} in a direction 63.4° east of north.
E 2.41 m s^{-1} in a north-easterly direction.

J77/II/5

5 A mass hangs by a string from the ceiling of a carriage in a train and is just above a certain mark on the floor when the train is at rest. When the train is moving forward with constant velocity, the mass

A is behind the mark, so that the string is along the resultant of the forces due to the motion of the train and gravity.
B remains over the mark because the force due to the motion of the train is balanced by the reaction of the string on the support.
C oscillates with simple harmonic motion about its former position because of the unbalanced force due to the motion of the train.
D is behind the mark in a position in which the horizontal force exerted by the train on the mass is balanced by the horizontal component of the tension in the string.
E remains over the mark because the motion of the train produces no additional force on the mass.

J78/II/6; N86/I/2

6 Which one of the following pairs of forces is **not** a valid example of action and reaction to which Newton's third law of motion applies?

A the forces of repulsion between an atom in the surface of a table and an atom in the surface of a book resting on the table.
B the forces of repulsion experienced by each of two parallel wires carrying currents in opposite directions
C the forces of attraction experienced by each of two gas molecules passing near to each other
D the forces of attraction between an electron and a proton in a hydrogen atom
E the centripetal force keeping a satellite in orbit round the Earth and the weight of the satellite

N78/II/5; J82/II/4; J84/II/8; J87/I/4

7 In which one of the following situations does the person concerned experience 'weightlessness'? (Where necessary, neglect effects such as air resistance.)

A an astronaut propelled vertically in the first stage of his journey, with the rocket engines burning
B an astronaut in a Moon-lander vehicle as it uses retro-rockets to make a soft landing on the Moon
C an athlete clearing the bar in a high jump
D a parachutist descending at terminal velocity with the parachute fully open
E a diver equipped so that he remains at constant depth below the water surface without any effort on his part

N78/II/6

Questions 8 and 9 refer to the following information.

A tractor of mass 1000 kg pulls a trailer of mass 1000 kg. The total resistance to motion has a constant value of 4000 N. One quarter of this resistance acts on the trailer. At first, the acceleration of the tractor and trailer is 2 m s^{-2} but eventually they move at a constant speed of 6 m s^{-1}.

8 When the acceleration is 2 m s^{-2}, the force exerted on the tractor by the tow-bar is

A 1000 N
B 2000 N
C 3000 N
D 5000 N
E 8000 N

J80/II/2

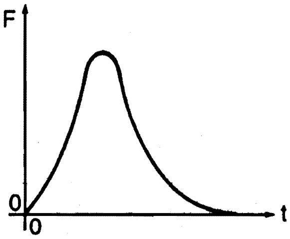
9 When the tractor and trailer are moving at a constant speed of 6 m s^{-1}, the force exerted on the tractor by the tow-bar is

A 0 N
B 1000 N
C 3000 N
D 4000 N
E 6000 N

J80/II/3

10 The graph below (Fig. 2) shows how the force F exerted on a body in collision with another body varies with time t.

Fig. 2

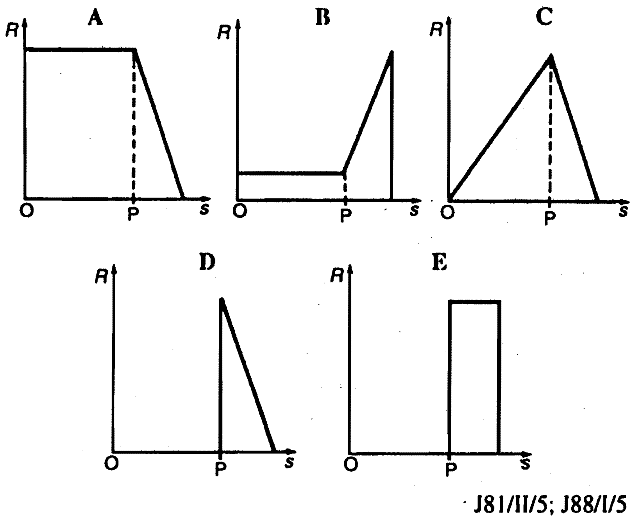


The area under the graph represents the body's change of

A acceleration.
B kinetic energy.
C momentum.
D potential energy.
E velocity.

J81/II/1

11 An object falls vertically through air at a constant velocity and then strikes soft ground in which it becomes embedded. Its deceleration during impact is constant. If P represents the point of impact, which of the following graphs best represents the variation of the total force *R* on the object with distance *s*?



J81/II/5; J88/I/5

12 A man is parachuting at constant speed towards the surface of the Earth. The force which, according to Newton's third law, makes an action-reaction pair with the gravitational force on the man is

A the tension in the harness of the parachute.
B the viscous force of the man and his parachute on the air.
C the gravitational force on the Earth due to the man.
D the viscous force of the air on the man and his parachute.
E the tension in the fabric of the parachute.

J81/II/6; N84/II/3

13 A body of mass 3 kg is acted on by a force which varies with time *t* as shown in Fig. 3 below.

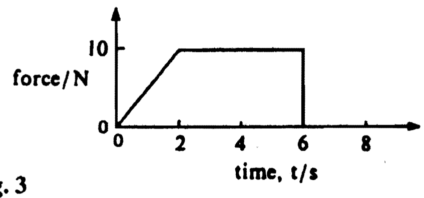


Fig. 3

What is the momentum of the body at time $t = 8$ s?

A 0 N s
B 10 N s
C 30 N s
D 50 N s
E 60 N s

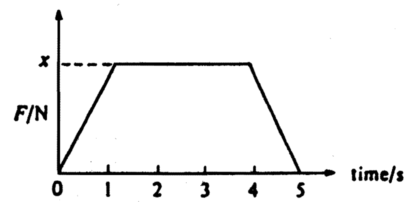
N82/II/2

14 A parachutist of mass 80 kg descends vertically at a constant velocity of 3.0 m s^{-1}. Taking the acceleration of free fall as 10 m s^{-2}, what is the net force acting on him?

A 800 N upwards
B zero
C 240 N downwards
D 360 N downwards
E 800 N downwards

J83/II/2

15 When a force, *F*, varying as shown below, is applied to a mass of 10 kg, the gain in momentum in 5 s is 40 kg m s^{-1}.



What is the value *x*?

A 4 B 8 C 10 D 15 E 50

N83/II/2

16 A helicopter of mass 3.0×10^3 kg rises vertically with a constant speed of 25 m s^{-1}. Taking the acceleration of free fall as 10 m s^{-2}, what resultant force acts on the helicopter?

A zero
B 3.0×10^4 N downwards
C 4.5×10^4 N upwards
D 7.5×10^4 N upwards
E 10.5×10^4 N upwards

N83/II/7

17 Two bodies P and Q, having masses M_P and M_Q respectively, exert forces on each other and have no other forces acting on them. The force acting on P is F, which gives P an acceleration a. Which of the following pairs is correct?

	magnitude of force on Q	*magnitude of acceleration of* Q
A	$\frac{M_Q}{M_P}F$	a
B	$\frac{M_P}{M_Q}F$	a
C	F	a
D	F	$\frac{M_P}{M_Q}a$
E	F	$\frac{M_Q}{M_P}a$

N86/I/3

18 A light spring has a mass of 0.20 kg suspended from its lower end. A second mass of 0.10 kg is suspended from the first by a thread. The arrangement is allowed to come into static equilibrium and then the thread is burned through. At this instant, what is the upward acceleration of the 0.20 kg mass? (Take g as 10 m s^{-2}.)

A zero
B 3.3 m s^{-2}
C 5.0 m s^{-2}
D 6.7 m s^{-2}
E 10 m s^{-2}

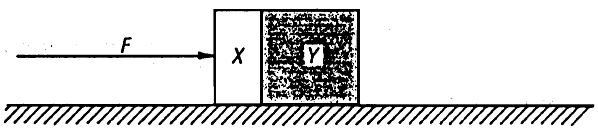
N87/I/5

19 When a force of 4 N acts on a mass of 2 kg for a time of 2 s, what is the rate of change of momentum?

A 1 kg m s^{-2}
B 2 kg m s^{-2}
C 4 kg m s^{-2}
D 8 kg m s^{-2}
E 16 kg m s^{-2}

J89/I/1

20 Two blocks, X and Y, of masses m and $2m$ respectively, are accelerated along a smooth horizontal surface by a force F applied to block X, as shown in the diagram.

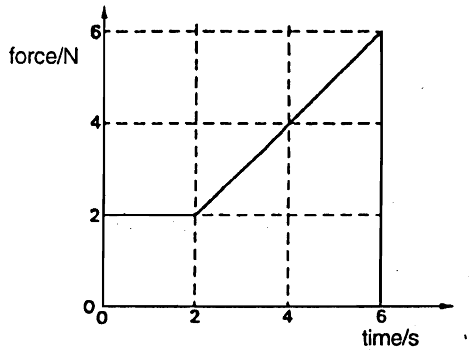


What is the magnitude of the force exerted by block Y on block X during this acceleration?

A O
B $\frac{F}{3}$
C $\frac{F}{2}$
D $\frac{2F}{3}$
E F

J90/I/2

21 The graph shows how the force acting on a body varies with time.



Assuming that the body is moving in a straight line, by how much does its momentum change?

A 40 kg ms^{-1}
B 36 kg ms^{-1}
C 20 kg ms^{-1}
D 16 kg ms^{-1}
E 10 kg ms^{-1}

N90/I/5

22 When a man is standing in an ascending lift, the magnitude of the force exerted on the man's feet by the floor is always

A equal to the magnitude of his weight.
B less than the magnitude of his weight.
C greater than it would be in a stationary lift.
D equal to what it would be in a stationary lift.
E equal to the magnitude of the force exerted on the lift floor by his feet.

N91/I/5

23 A raindrop of mass m is falling vertically through the air with a steady speed v. The raindrop experiences a retarding force kv due to the air, where k is a constant. The acceleration of free fall is g.

Which expression gives the kinetic energy of the raindrop?

A $\frac{mg}{k}$
B $\frac{mg^2}{2k^2}$
C $\frac{m^3g^2}{k^2}$
D $\frac{m^3g^2}{2k^2}$

J92/I/6; N96/I/7

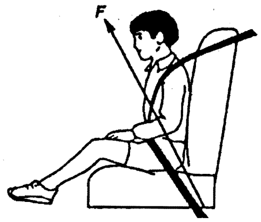
24 Newton's third law concerns the forces of interaction between two bodies.

Which of the following statements relating to the third law is **not** correct?

A The two forces must be of the same type.
B The two forces must act on different bodies.
C The two forces are always opposite in direction.
D The two forces are at all times equal in magnitude.
E The two forces are equal and opposite so the bodies are in equilibrium.

N93/I/3

25 A child (mass m) sits on a car seat which is accelerating horizontally at 0.50 g (where g is the acceleration of free fall).

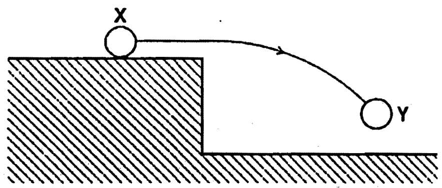


What is the magnitude of the total force F exerted by the car seat on the child?

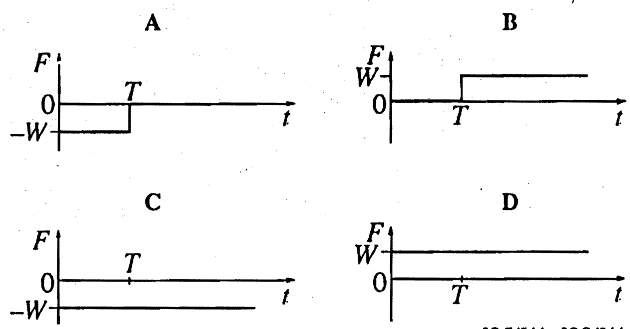
A 0.50 mg **B** 1.0 mg **C** 1.1 mg **D** 1.5 mg

J94/I/4

26 A ball of weight W slides along a smooth horizontal surface until it falls off the edge at time T.



Which graph represents how the resultant vertical force F, acting on the ball, varies with time t as the ball moves from position **X** to position **Y**?



J95/I/4; J98/I/4

27 An aircraft in level flight is moving with constant velocity relative to the ground.

The resultant force acting on the aircraft is equal to

A the weight of the aircraft.
B the resultant of the air resistance and the thrust of the engines.
C the resultant of the air resistance and the weight of the aircraft.
D zero.

N95/I/3

28 The rate of change of momentum of a body falling freely under gravity is equal to its

A impulse.
B kinetic energy.
C power.
D weight.

J96/I/4

29 Two instruments are used on the Earth to measure the mass of an object. A spring balance reads 600 g and a lever balance requires six 100 g discs to balance.

If these measurements were to be repeated on the Moon, where the gravitational field is $\frac{1}{6}$ of its value on Earth, which results would be expected?

	reading on spring balance	*number of* 100 g *discs required for balance on lever balance*
A	600 g	6
B	600 g	1
C	100 g	6
D	100 g	1

J98/I/2

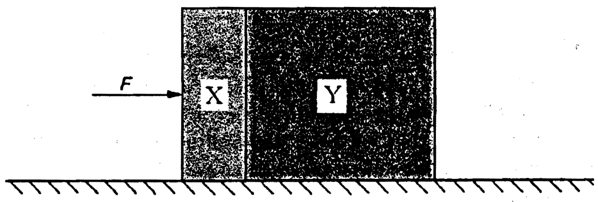
30 A crane has a maximum safe working load of 1.2×10^4 N and is used to lift a concrete block of mass 1000 kg.

What is the maximum safe upward acceleration of the block while being lifted?

A 0.83 ms^{-2} **C** 1.2 ms^{-2}
B 1.1 ms^{-2} **D** 2.2 ms^{-2}

J99/I/4

31 Two blocks X and Y, of masses m and 3 m respectively, are accelerated along a smooth horizontal surface by a force F applied to block X as shown.



What is the magnitude of the force exerted by block X on block Y during this acceleration?

A $\frac{F}{4}$ **B** $\frac{F}{3}$ **C** $\frac{F}{2}$ **D** $\frac{3F}{4}$

N99/I/4

32 A ball falls vertically and bounces on the ground.

The following statements are about the forces acting while the ball is in contact with the ground.

Which statement is correct?

A The force that the ball exerts on the ground is always equal to the weight of the ball.
B The force that the ball exerts on the ground is always equal in magnitude and opposite in direction to the force the ground exerts on the ball.
C The force that the ball exerts on the ground is always greater than the weight of the ball.
D The weight of the ball is always equal and opposite to the force that the ground exerts on the ball.

N2000/I/3

33 A space-research rocket stands vertically on its launching-pad. Prior to ignition, the mass of the rocket and its fuel is 1.9×10^3 kg. On ignition, gas is ejected from the rocket at a speed of 2.5×10^3 ms^{-1} relative to the rocket, and fuel is consumed at a constant rate of 7.4 kg s^{-1}. Find the thrust of the rocket and hence explain why there is an interval between ignition and lift-off.

(Acceleration of free fall, g = 10 ms^{-2}.) N76/I/1

34 In a tropical rainstorm, 40 mm of rain fell in one hour. Assuming that the raindrops struck an adequately drained roof normally with an average speed of 10 m s^{-1}, find the pressure exerted on the roof by the rain.

[Density of water = 1.0×10^3 kg m^{-3}.] N78/I/3

35 Describe the circumstances under which a body can be said to be *weightless*.

J79/I/1

36 A conveyor belt is used to transfer luggage at an airport. It consists of a horizontal endless belt running over driving rollers, moving at a constant speed of 1.5 m s^{-1}. To keep the belt moving when it is transporting luggage requires a greater driving force than for an empty belt. On average, the rate at which baggage is placed on one end of the belt and lifted off at the other end is 20 kg per second.

Why is an additional driving force required, and what is its value? N80/I/2

37 Some makes of car have, as a safety feature, regions at the front and rear which are designed to collapse on impact, but the shell of the passenger compartment is of rigid construction. Give a brief physical explanation of how this design may help to protect passengers from serious injury in the event of a collision. N85/II/2

38 A model helicopter of mass 5.0 kg rises with constant acceleration from rest to a height of 60 m in 10 s. Find the thrust exerted by the rotor blades during the ascent.

N86/II/1

39 *(a)* (i) Explain what is meant by the *linear momentum* of a body.

(ii) State how *force* is related to *linear momentum*. [4]

(b) In a safety test on a car, a dummy is firmly restrained in its seat by means of belts, as illustrated in Fig. 4.

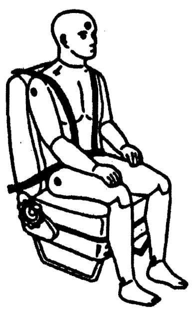


Fig. 4

The car suffers a head-on collision in which it is brought to rest from a speed of 14 m s^{-1} in 0.25 s. What is the average extra force in the neck of the dummy if its head has a mass of 3.0 kg and remains firmly attached to the body?

(c) Comment on whether this force is big enough to cause serious injury to a real driver. [2]

N90/II/1

40 *(a)* (i) What is meant by the *linear momentum* of a body?

(ii) State how the change in momentum of a freely moving body is related to the force acting on it. [2]

(b) A projectile of mass 3.2×10^{-2} kg is fired from a cylindrical barrel of cross-sectional area 2.8×10^{-4} m^2 by means of compressed gas. The variation with time t of the excess pressure p of the gas in the barrel above atmospheric pressure is shown in Fig. 5.

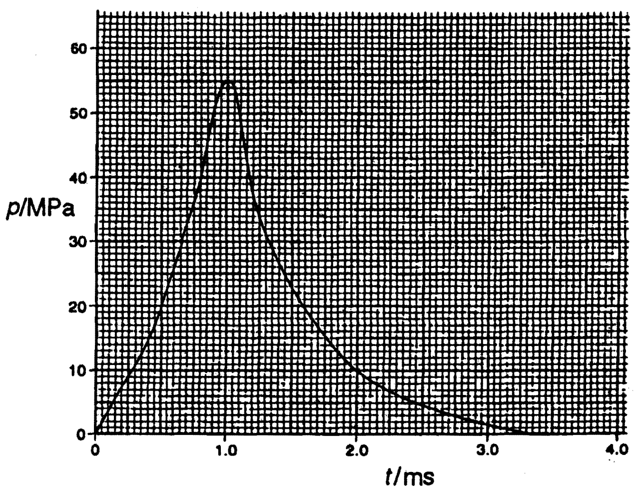


Fig. 5

Calculate

(i) the maximum force which the gas exerts on the projectile,

(ii) the acceleration of the projectile which would result from the force calculated in (i). [4]

(c) By reference to the area under the graph of Fig. 5, estimate the total change of momentum due to the compressed gas which is experienced by the projectile. [3]

(d) The speed of the projectile changes from zero to 270 m s^{-1} as it leaves the barrel. What is the change in momentum of the projectile? [1]

(e) Compare your answers to *(c)* and *(d)*, and comment. [2]

N94/II/1

41 Values of mass and velocity for a truck and for a car are given in the table below.

(a) Use these to calculate values for the momentum and kinetic energy of the truck and of the car. [6]

(b) Both vehicles are now subjected to a constant braking force of 2.0×10^4 N. From your values of momentum and kinetic energy, make calculations to determine

(i) the time taken for each vehicle to stop,

(ii) the distance taken for each vehicle to stop. [4]

	truck	car
mass	3000 kg	1000 kg
velocity	20 m s^{-1}	40 m s^{-1}
momentum		
kinetic energy		
stopping time		
stopping distance		

N95/II/1

42 A model rocket of initial mass 1.3 kg is fired vertically into the air. Its mass decreases at a constant rate of 0.23 kg s^{-1} as the fuel burns. The final mass of the rocket is 0.38 kg. The rocket rises to a height such that, during the flight, the gravitational field strength of the Earth may be considered to have the constant value of 9.8 N kg^{-1}.

(a) Calculate

(i) the initial weight of the rocket,

(ii) the final weight of the rocket,

(iii) the time taken for the fuel to be burned. [3]

(b) The variation with time t of the upward force on the rocket during the first 3 seconds after firing is shown in Fig. 6.

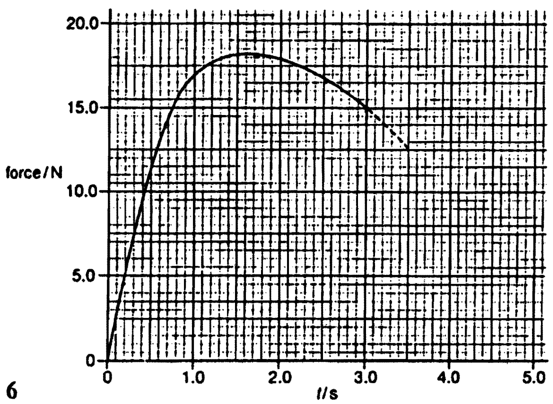


Fig. 6

(i) On Fig. 6, use the same scales to draw a line to represent the variation with time t of the total weight of the rocket during the first 5 seconds after firing.

(ii) Hence read off from Fig. 6 the time delay between firing the rocket and lift-off. [3]

(c) (i) Write down an equation to represent the relation between the resultant force F on a body, the time t for which the force acts and the change in momentum Δp of the body.

(ii) On Fig. 6, shade the area of the graph which represents the change in momentum of the rocket during the first 3 seconds after the rocket is fired. [3]

(d) The energy stored in the fuel is converted partly into kinetic energy of the rocket and thermal energy of the rocket. State two further forms of energy into which the energy of the fuel is converted. [2]

N96/II/1

Long Questions

43 State *Newton's laws of motion.*

Use the second and third laws to show that the momentum of a system of two colliding bodies remains constant, provided that no external forces act. N83/I/13 (part)

44 State Newton's laws of motion.

When a body moves through a fluid, a retarding force due to turbulence may be experienced. In the case of a sphere of radius r moving with speed v through a stationary fluid of density ρ which is at rest, this force is given by

$$F = k\rho r^2 v^2$$

where k is a constant.

(a) Show that the constant k is dimensionless.

(b) By relating the retarding force to the transfer of momentum between the sphere and the fluid, explain why F is proportional to $\rho r^2 v^2$.

When spherical raindrops fall through still air, all but the smallest experience a retarding force given by the equation above. It is found that drops of a given radius approach the ground with an approximately constant speed, which is independent of the height of the cloud in which they were formed. Explain this observation by reference to Newton's laws. Find an expression for this terminal speed v_t in terms of the constant k, the radius r of the drop, its density ρ_W, the density ρ_A of the air and the acceleration of free fall g. (Neglect the buoyancy of the air.)

The terminal speed of a raindrop of radius 1 mm is approximately 7 m s^{-1}. In freak storms, hailstones with radii as large as 20 mm may fall. Estimate the speed with which such stones strike the ground.

(Take the density of water as 1×10^3 kg m^{-3} and the density of ice as 9×10^2 kg m^{-3}.) J86/II/8

45 *(a)* Define the term *acceleration.* [2]

Use your definition to explain why it is that the velocity of a body may be in a different direction from its acceleration. [2]

(b) Discuss whether the resultant force on a body may or may not be in the same direction as its acceleration. [2]

(c) The moving head of an electronic printer has a mass of 0.20 kg and moves along the line of print in a jerky motion. After printing each character, the head accelerates sideways under a force of 10 N and then immediately decelerates to rest under a force of 30 N ready to print the next character. The characters are 2.5 mm apart.

(i) Sketch a graph to show how the velocity of the head of the printer varies with time. [2]

(ii) Calculate the time taken for the movement between characters. [6]

(iii) An additional time of 8.0 ms is required for the printing of each character. Find the maximum number of characters that can be printed each second. [2]

(iv) What physical problems might require the printer to run at a slower speed than the value you have calculated? What changes could be made to increase the printing speed? [6]

J88/II/8

46 *(a)* State *Newton's first law of motion* and show it leads to the concept of force. [2]

(b) Newton's second law states that "the rate of change of momentum of a body is proportional to the resultant force acting on it.".

Show how this law, together with a suitable definition of the unit of force, leads to the relationship

force = mass × acceleration

for a body of constant mass. [3]

(c) Together with these two laws, Newton's third law can be used to derive the principle of conservation of momentum. State the third law and show this derivation. [3]

(d) A ship of mass 12 000 000 kg is moving backwards with a velocity of 0.50 m s^{-1} towards a dockside. In order to stop the ship, the engines are ordered full ahead.

(i) Calculate the initial kinetic energy of the ship. [2]

(ii) Assuming that viscous effects are negligible, calculate the value of the constant force which must be exerted on the ship if it is to stop in a distance of 15 m. [3]

(iii) How long will it take the ship to stop under these conditions? Explain qualitatively how the result of this calculation would be affected by viscous forces. [5]

(iv) Explain how the law of conservation of momentum applies to this example. [4]

N88/II/8

47 In order to stop a car of mass 1500 kg travelling at 30 ms^{-1}, the driver applies his brakes so that F, the total stopping force, increases steadily to a maximum and then decreases to zero as shown in Fig. 7.

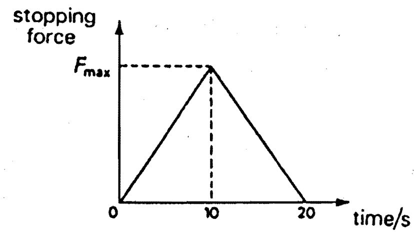


Fig. 7

(a) Calculate each of the following quantities:

(i) the momentum of the car when it is travelling at 30 m s^{-1},

(ii) the change in momentum between t = 0 and t = 10 s,

(iii) the kinetic energy at t = 0 and at t = 10 s,

(iv) the value of F_{max},

(v) the maximum negative acceleration of the car. [13]

(b) Draw sketch graphs to show the variation with time of

(i) the velocity,

(ii) the distance travelled. [7]

(c) Explain why this would seem to a passenger to be a more gentle stop than one in which the total time to stop was still 20 seconds but in which a constant force was applied throughout. [2]

N89/II/8

48 *(c)* A gun of effective barrel length 0.70 m and diameter 20 mm fires shot of mass 30 g with an exit velocity of 310 m s^{-1}. Assuming that the acceleration of the shot as it travels down the barrel is constant, calculate

(i) the acceleration of the shot,

(ii) the pressure in the barrel,

* (iii) the average power supplied to the shot. [7]

(d) The butt of such a gun is sometimes fitted with a thick rubber pad as shown in Fig. 8.

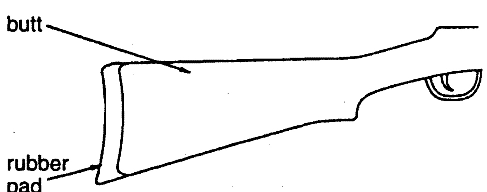


Fig. 8

Describe and explain how the pad will affect the recoil of the gun, as experienced by the shooter. [3]
J90/III/1 (part)

49 *(a)* Distinguish between the *mass* and the *weight* of a body. State the unit in which each is measured. [4]

(b) Show that

(i) the base units of the acceleration of free fall are the same as the base units of gravitational field strength,

(ii) the newton second is a unit of momentum. [4]

(c) In the United States, plans are under consideration for launching a satellite by use of a space gun. The satellite, of mass 2000 kg, accelerates uniformly along a tube of length 1200 m and reaches a speed of 8000 ms^{-1}.

Calculate

(i) the momentum of the satellite as it leaves the tube,

(ii) the time it takes to accelerate along the tube,

(iii) the force causing the acceleration,

(iv) the acceleration. [8]

(d) (i) It would be impossible to use the space gun in *(c)* for manned space flights. Suggest a reason.

(ii) It would be an advantage to site the gun on the Earth's equator pointing eastwards. Suggest a reason. [4]
N92/III/1

50 *(a)* What do you understand by

(i) the mass, (ii) the weight,

of a body? [3]

(b) A toy rocket consists of a plastic bottle which is partially filled with water. The space above the water contains compressed air, as shown in Fig. 9.

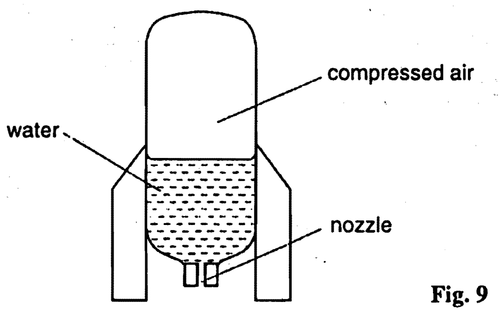


Fig. 9

At one instant during the flight of the rocket, water of density ρ is forced through the nozzle of radius r at speed v relative to the nozzle. Determine, in terms of ρ, r and v,

(i) the mass of water ejected per unit time from the nozzle,

(ii) the rate of change of momentum of the water.

Hence show that the accelerating force F acting on the rocket is given by the expression

$$F = \pi r^2 \rho v^2 - mg,$$

where m is the mass of the rocket and its contents at the instant considered. [6]

(c) The toy manufacturer recommends that the rocket should contain about 550 cm^3 of water before take-off. If the initial air pressure is 1.6×10^5 Pa, all of this water will be expelled and the pressure is just reduced to atmospheric pressure as the last of the water is expelled. However, on one flight, the initial volume of water was 750 cm^3 but the initial air pressure in the rocket was still 1.6×10^5 Pa. State, without calculation but with a reason, the effect of this increased volume of water on

(i) the initial thrust,

(ii) the initial resultant accelerating force,

(iii) the initial acceleration,

(iv) the final mass of the rocket and its contents,

(v) the maximum height reached. [11]
J96/III/1

51 The following data concern a tennis ball at a given instant just before it is struck by a tennis racket;

horizontal momentum of tennis ball = 2.4 N s,

kinetic energy of tennis ball = 45 J.

(a) Why is it correct to give the direction of the momentum but not of the kinetic energy? [1]

(b) Write down in terms of the mass m and the velocity v of a body, expressions for

(i) the momentum,

(ii) the kinetic energy. [2]

(c) Use your answer to *(b)* to help you to calculate the mass and the velocity of the tennis ball. [4]

(d) When the racket hits the ball it strikes it with a constant force of 60 N in a direction opposite to its momentum, bringing it to rest momentarily. Calculate

(i) the time the tennis ball takes to stop,

(ii) the distance the tennis ball travels while stopping. [4]

(e) The force of 60 N then continues to act on the tennis ball for a further 0.060 s. Calculate

(i) the new momentum of the ball,

(ii) the new velocity of the ball. [3]

(f) Calculate the increase in kinetic energy of the ball for the whole time that the force is applied to it and hence deduce the mean power being delivered to the ball while it is in contact with the racket. [4]

(g) Suggest why, in practice, it is impossible for a constant force to be applied to the ball. [2]
J97/III/1

52 A cyclist travels down an inclined road without pedalling. The angle that the road makes with the horizontal is 6.8°, as shown in Fig. 10.

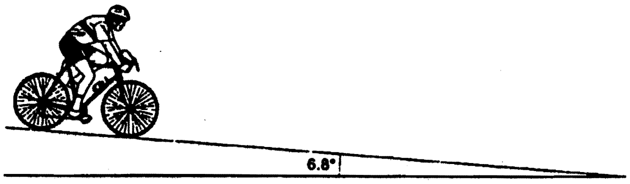


Fig. 10

The cyclist and cycle have a combined weight of 760 N.

(a) Show that the component of the weight of the cyclist and cycle down the slope is 90 N. [1]

(b) The variation with time t of the velocity v of the cyclist down the slope is illustrated in Fig. 11.

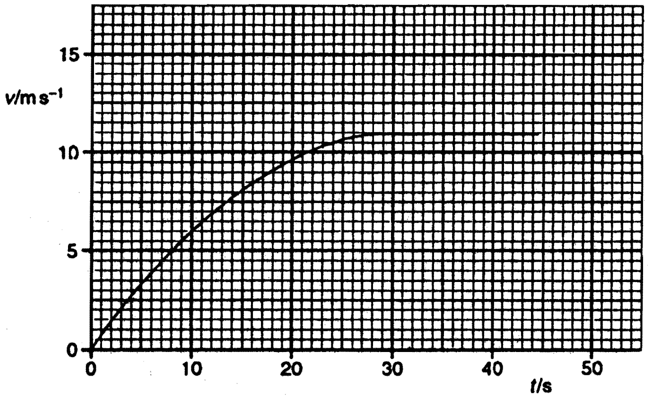


Fig. 11

The cyclist reaches a constant velocity after 30 s.

(i) Use Fig. 11 to determine

1. the maximum velocity of the cyclist,
2. the initial acceleration of the cyclist,
3. the total distance travelled before reaching constant velocity. [7]

(ii) 1. Use your answer to *(b)*(i)2 to calculate the accelerating force acting on the cycle and cyclist at time $t = 0$.

2. Hence determine the resistive force acting on the cycle and cyclist at time $t = 0$. [2]

(iii) State the magnitude of the total resistive force acting on the cycle and cyclist at time $t = 30$ s. [1]

(iv) Suggest why the total resistive force has changed between time $t = 0$ and time $t = 30$ s. [2]

(c) The cycle is serviced in order to reduce friction and then the journey down the slope is repeated. State and explain what change, if any, will occur in the maximum velocity of the cycle down the slope. [3]

(d) Having descended the slope, the cyclist travels along a horizontal straight section of road at a speed of 7.0 m s^{-1}. When the brakes are applied, the cyclist takes 3.5 s to come to rest.

(i) Calculate the average force opposing motion during the time that the brakes are applied, assuming the cyclist is not pedalling.

(ii) Comment on whether the brakes are efficient enough to bring the cycle to a halt when on the inclined road. [4]

J98/III/1

Conservation of Linear Momentum

53 A particle hits a massive wall normally and at speed u. Which one of the following groups of three statements may apply if the collision is *inelastic*?

A The particle returns along its original path with speed u; the principle of conservation of momentum applies; kinetic energy is conserved.

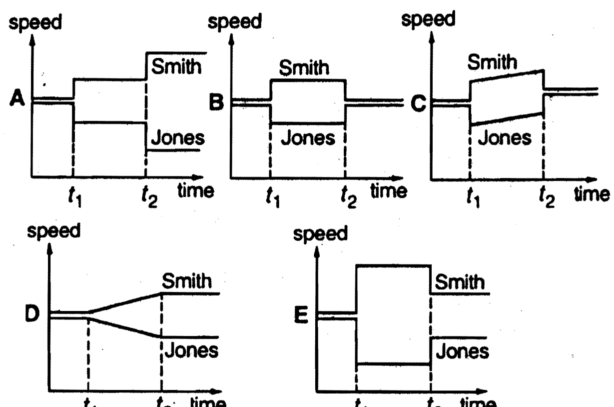
B The particle returns along its original path with speed < u; the principle of conservation of momentum applies; kinetic energy is conserved.

C The particle returns along its original path with speed < u; the principle of conservation of momentum does **not** apply; kinetic energy is **not** conserved.

D The particle does not rebound; the principle of conservation of momentum applies; kinetic energy is **not** conserved.

E The particle does not rebound; the principle of conservation of momentum does **not** apply; kinetic energy is **not** conserved. J76/II/2; N83/II/3

54 Smith and Jones are skating on ice (assumed frictionless) so that they are moving with equal speeds s in the same straight line. Smith is skating backwards facing Jones. Smith throws a ball to Jones at time t_1 and receives it back at time t_2. Assuming that the time of flight of the ball is negligible, which one of the sketches below gives the correct speed-time relationship for the two skaters?



N76/II/3

55 A neutron is in head-on elastic collision with a stationary nitrogen nucleus. The mass of a nitrogen nucleus is 14 times that of a neutron.

The neutron's velocity after the collision is

A less in magnitude than its initial velocity.
B less in magnitude than the final velocity of the nitrogen atom.
C equal in magnitude to its initial velocity but in the opposite direction.
D greater in magnitude than its initial velocity.
E zero. N77/II/1; J93/I/4

56 Particles X (of mass 4 units) and Y (of mass 9 units) move directly towards each other, collide and then separate. If Δv_x is the change of velocity of X and Δv_y, is the change of velocity of Y, the magnitude of the ratio $\Delta v_x / \Delta v_y$ is

A 9/4 B 3/2 C 1 D 2/3 E 4/9
J78/II/3

57 Which statement is correct with reference to perfectly elastic collisions between two bodies?

A Total kinetic energy is conserved; total momentum may decrease but cannot increase.
B Neither total momentum nor total kinetic energy need be conserved but total energy must be conserved.
C Total momentum and total energy are conserved but total kinetic energy may be changed into some other form of energy.
D Total kinetic energy and total energy are both conserved but total momentum is conserved only if the two bodies have equal masses.
E Total momentum, total kinetic energy and total energy are all conserved. N78/II/1; J83/II/4; N92/I/4

58 During the First World War, the German army fired millions of shells in a westerly direction and the Allied armies fired even more shells in an easterly direction. If the masses and speeds of the shells fired were, on average, the same for both sides, the ultimate effect on the momentum of the Earth was

A zero.
B a small increase in its angular momentum.
C a small decrease in its angular momentum.
D a small decrease in its linear momentum.
E a transfer of a small amount of its linear momentum into angular momentum. J79/II/2

59 A stationery uranium nucleus of mass 238 units disintegrates by the emission of an α-particle of mass 4 units.
The ratio

$$\frac{\text{kinetic energy of the α-particle}}{\text{kinetic energy of the recoiling daughter nucleus}}$$

is

A 4/238
B 4/234
C 234/4
D 238/4
E $(234/4)^2$
J79/II/3

60 A neutron moving with an initial velocity u has a head-on elastic collision with a stationary proton. After the collision, the velocity of the neutron is v and that of the proton is w. Taking the masses of the neutron and proton to be equal, which one of the following statements is *wrong*?

A Conservation of momentum shows that $u = v + w$.
B Conservation of energy shows that $u^2 = v^2 + w^2$.
C The momentum and energy equations taken together imply that the speed of the proton after the collision is the same as that of the neutron before the collision.
D The fact that the collision is elastic implies that the proton and the neutron move off in opposite directions with equal speeds.
E The momentum and energy equations taken together imply that the neutron remains at rest after the collision. J81/II/3

61 A particle X (of mass 4 units) and a particle Y (of mass 2 units) move directly towards each other, collide and then separate. If Δv_X is the change of velocity of X and Δv_Y is the change of velocity of Y, what is the magnitude of the ratio $\Delta v_X/\Delta v_Y$?

A $\frac{1}{2}$
B $1/\sqrt{2}$
C 1
D $\sqrt{2}$
E 2 J82/II/5

62 A stationary thoron nucleus (A = 200, Z = 90) emits an alpha particle with kinetic energy E_α. Which is the kinetic energy of the recoiling nucleus?

A $\dfrac{E_\alpha}{108}$
B $\dfrac{E_\alpha}{110}$
C $\dfrac{E_\alpha}{54}$
D $\dfrac{E_\alpha}{55}$
E E_α
J84/II/37

63 A particle Q moving with kinetic energy E and momentum p makes a head-on collision with an identical particle R which is initially at rest but free to move. The particles stick together. Which of the following correctly represents the kinetic energy of the particle Q and the system as a whole, and the magnitude of the momentum of Q and the system as a whole, after this collision?

	kinetic energy		momentum	
	of Q	of system	of Q	of system
A	0	0	0	0
B	0	E	0	p
C	$E/4$	$E/2$	$p/4$	$p/2$
D	$E/4$	$E/2$	$p/2$	p
E	E	E	$p/2$	p

N84/II/4

64 Two bodies P and Q, of equal mass, travelling towards one another on a level frictionless track at speeds u and v respectively, make an elastic collision.

At some instant during the collision P is brought momentarily to rest. What is the speed of Q at that instant?

A zero
B $v - u$
C $2(v - u)$
D $\frac{1}{2}(v - u)$
E $\sqrt{uv}$

J85/I/5; J88/I/4

65 Two magnetised bodies slide directly towards each other on a frictionless surface, and are repelled back along their original paths without touching. Which one of the following statements is correct?

A Neither kinetic energy nor momentum is conserved *throughout* the collision.
B Both kinetic energy and momentum are conserved *throughout* the collision.
C Although momentum is conserved work is done against the magnetic forces and so kinetic energy is not conserved *throughout* the collision.
D As the bodies do not touch, the principle of conservation of momentum can only be applied at the position of closest approach.
E The bodies can be described as undergoing an inelastic collision, but only if work against magnetic forces is neglected.

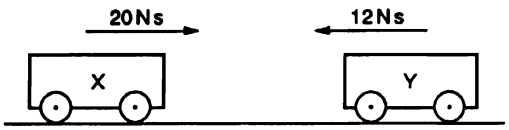
N85/I/3

66 A positron, a positively-charged particle of mass 10^{-30} kg, is moving at a speed v, which is much less than the speed of light. It makes a head-on elastic collision with a stationary proton of mass 10^{-27} kg. Which one of the following correctly describes the outcome of the collision?

A The positron comes to rest and the proton moves on at speed v.
B The positron rebounds at speed v and the proton moves on at speed v.
C The positron rebounds at speed $v/2$ and the proton moves on at speed $v/2$.
D The positron rebounds at a speed nearly equal to v, and the proton moves on at a speed much less than v.
E The positron travels on at a speed about $v/1000$, and the proton moves on at a speed nearly equal to v.

J86/I/3

67 The diagram shows two trolleys, X and Y, about to collide and gives the momentum of each trolley before the collision.



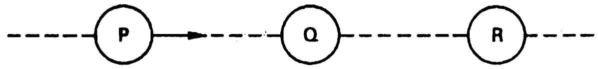
After the collision, the directions of motion of both trolleys are reversed and the magnitude of the momentum of X is then 2 N s.

What is the magnitude of the corresponding momentum of Y?

A 6 Ns
B 8 Ns
C 10 Ns
D 30 Ns

N88/I/4; N98/I/4

68 Three identical stationary discs, **P**, **Q** and **R** are placed in a line on a horizontal, flat, frictionless surface. Disc **P** is projected straight towards disc Q.



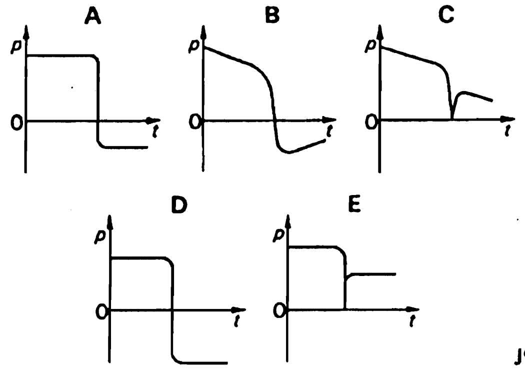
If all consequent collisions are perfectly elastic, what will be the final motion of the three discs?

	P	Q	R
A	moving left	moving left	moving right
B	moving left	stationary	moving right
C	moving left	moving right	moving right
D	stationary	stationary	moving right
E	moving right	moving right	moving right

J91/I/4

69 An ice-hockey puck slides along a horizontal, frictionless ice-rink surface. It collides inelastically with a wall at right angles to its path, and then rebounds along its original path.

Which graph shows the variation of the momentum p of the puck with time t?



J92/I/4

70 Two similar spheres, each of mass m and travelling with speed v, are moving towards each other.

The spheres have a head-on elastic collision.

Which statement is correct?

A The sum of the momenta before impact is $2\,mv$.
B The kinetic energies before impact are zero.
C The sum of the kinetic energies after impact is mv^2.
D The spheres stick together on impact giving a resultant speed of zero.

N94/I/4

71 Two satellites in space collide inelastically.

What happens to the kinetic energy and momentum?

	kinetic energy	momentum
A	conserved	conserved
B	conserved	reduced
C	reduced	conserved
D	reduced	reduced

N96/I/5; J2000/I/4

72 A proton moves with initial speed v directly towards another proton which is initially at rest. No external forces act on the system.

(a) What are the final speeds of the two protons?

(b) What can you say about the motion of the centre of mass (centre of gravity) of the system during the collision? J78/I/2

73 A particle of mass m moving with speed u makes a head-on collision with an identical particle which is initially at rest. The particles coalesce and move off with a common velocity.

(a) Find the common speed of the particles after the collision.

(b) Find the ratio of the kinetic energy of the system after the collision to that before it.

(c) What happens to the kinetic energy that is 'lost'?

N82/I/1

74 A stone is dropped from a point a few metres above the Earth's surface. Considering the system of stone and Earth, discuss briefly how the principle of conservation of momentum applies *before* the impact of the stone with the Earth. J85/II/2

75 *(a)* (i) Define linear momentum.

(ii) State whether linear momentum is a vector or a scalar quantity. [2]

(b) State the principle of conservation of momentum. [1]

(c) The principle can be applied in different types of interaction. These are illustrated by the following examples.

(i) Inelastic collision: a piece of plasticine of mass 0.20 kg falls to the ground and hits the ground with a velocity of 8.0 m s^{-1} vertically downward. It does not bounce but sticks to the ground. Calculate the momentum of the plasticine just before it hits the ground.

State the transfers of momentum and of kinetic energy of the plasticine which occur as a result of the collision. [3]

(ii) Elastic collision: a neutron of mass 1.00 u travelling with velocity 6.50×10^5 ms^{-1} collides head on with a stationary carbon atom of mass 12.00 u. The carbon atom moves off in the same direction with velocity 1.00×10^5 ms^{-1}. Calculate the velocity of the neutron after the collision. State what happens to the total kinetic energy as a result of this collision. [3]

(iii) There is a third type of interaction: this happens when two strong magnets are held stationary with the north pole of one pushed against the north pole of the other. On letting go, the magnets spring apart. It is apparent that the kinetic energy of the magnets has increased. Explain how the law of conservation of momentum applies in this case. [2] J94/II/1

76 *(a)* Collisions between objects are said to be either *elastic* or *inelastic*. Complete Fig. 12 by placing a tick (✓) in the relevant-boxes to indicate which quantities are conserved in these collisions. [3]

collision	momentum	kinetic energy	total energy
elastic			
inelastic			

Fig. 12

(b) (i) A fast-moving neutron of mass m collides head-on with a stationary atom of hydrogen, also of mass m, as illustrated in Fig. 13.

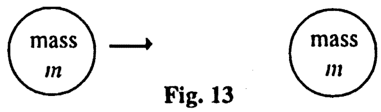


Fig. 13

The neutron is captured by the atom to form a 'heavy' isotope of hydrogen of mass $2m$ which moves off with a speed of 3.0×10^7 m s^{-1}.

1. State whether the collision process whereby the neutron is captured is elastic or inelastic.
2. Calculate the speed of the neutron before capture.

speed = ... m s^{-1}

(ii) A similar neutron to that in (i) now collides head-on with a stationary nitrogen atom of mass 14 m to form a 'heavy' isotope of nitrogen. Calculate the speed of this 'heavy' nitrogen atom.

speed = ... m s^{-1} [5]

N99/II/1

Long Questions

77 Explain the difference between an *elastic* and an *inelastic* collision.

*Two deuterium nuclei may undergo a fusion reaction to give a neutron and an isotope of helium. State, with reasons, whether this interaction between the deuterium nuclei may be regarded as an example of an elastic or an inelastic collision.

Discuss briefly what one means when speaking of collision between particles such as molecules or nuclei.

J76/I/13 (part)

78 State the *principle of conservation of momentum.*

'The molecules of an ideal gas are assumed to make perfectly elastic collisions with their container, and so momentum is conserved; but the molecules of a real gas are not perfectly elastic, and momentum is not conserved.' Criticise this statement.

A stream of sand falls at a constant rate from a height h on to the pan of a direct-reading balance. After a time T, a total mass M has fallen and the delivery of sand ceases.

(a) Draw a sketch graph to show the reading m of the balance as a function of time t, giving the values of m at $t = 0$, $t = T$ and $t = 2T$.

(b) Explain the form of the graph.

(c) How would the graph differ if the sand were allowed to fall from a height $2h$, a mass M again being delivered in time T?

(d) Trace the transformations of energy during such a process. N77/I/14

79 State the *principle of conservation of momentum.*

A particle of mass m moving with speed v makes a head-on collision with an identical particle which is initially at rest. How would you tell from the subsequent motion of the particles whether they had made *(a)* an elastic, *(b)* a completely inelastic, collision? In each case, work out how (if at all) the kinetic energy of the first particle, and the kinetic energy of the system as a whole, is affected by the collision.

The neutrons in a beam from a reactor have an average energy of 6.0×10^{-13} J. This is reduced to 6.0×10^{-21} J by causing the neutrons to make a series of collisions with carbon nuclei in a moderator. On average, the fractional loss of kinetic energy of a neutron at each collision in the moderator is 0.14. About how many collisions must a neutron make in this process? J80/I/13

***80** Name the conservation principles that apply to a system of interacting particles.

Explain in detail how they apply in the following cases.

(a) The inelastic impact of a bullet of mass m travelling with speed v with a stationary bag of sand of mass 1000 m suspended by a cord from the ceiling. The bullet comes to rest in the sand.

(b) The elastic impact of a gas molecule with the walls of its container.

(c) The emission of an alpha-particle from a radioactive nucleus, of mass number A, which is initially at rest.

(d) The absorption of photons by a black surface. N81/I/13

81 A ball of mass 0.025 kg, dropped from a height of 1.5 m on to a solid floor, bounces repeatedly. The ball rises to a maximum height of 1.0 m after its fourth impact.

(a) Draw two sketch graphs showing how (i) the displacement s of the ball relative to the floor, (ii) its velocity v, vary with time t from the instant of release to the fifth impact. Label clearly the instants corresponding to successive impacts. (Neglect air resistance.)

(b) Calculate the momentum of the ball as it reaches the floor just before the first impact. (Neglect air resistance.)

(c) 'For any closed system, the total linear momentum of the system is constant.' Explain how (if at all) this statement of the principle of conservation of momentum applies to the system of ball and floor.

(d) The general relation between the maximum height h_n attained in the nth bounce and the height h_0 from which the ball is first dropped is

$$h_n = R^{2n} h_0 ,$$

where R is a quantity characteristic of the impact between ball and floor. In an experiment, the value h_0, h_1, h_n, ... were measured. Explain how the value of R could be found by drawing a suitable linear graph involving the experimental results.

(e) What fraction of the kinetic energy available just before an impact with the floor disappears as a result of the impact? (Express your answer as a decimal fraction, not in terms of R.) What happens to this energy? J82/I/14

82 *(a)* A particle A of mass m, moving with velocity u in the direction shown (Fig. 14), makes a head on, elastic collision with a particle B of mass M that is originally at rest. After the collision, A and B move off with velocities v and V respectively (Fig. 15)

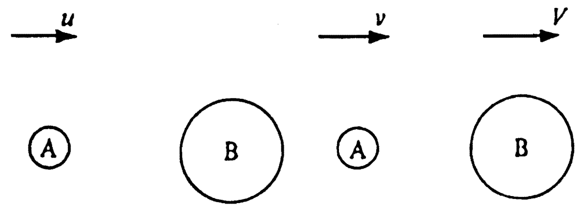


Fig. 14 **Fig. 15**

(i) Write down the equations that summarise the application of the principles of conservation of energy and momentum to this collision.

(ii) It can be shown from these equations that $v = V - u$. Using this result, or otherwise, find an expression for the fractional loss of kinetic energy of A, in terms of m and M only.

(iii) Evaluate this fractional loss for $M = 50\ m$.

**(b)* An alpha-particle is projected directly towards a stationary gold nucleus, which is free to move, and collides with it.

(i) Sketch a graph showing how the electrostatic force between the alpha-particle and the nucleus depends on their separation x.

(ii) Discuss whether the existence of this force would make it incorrect to calculate the fractional loss of kinetic energy of the alpha-particle in its collision with the gold nucleus by the method you have followed above. N84/I/14 (part)

83 Explain what is meant by the *linear momentum* of a body. Obtain a relation between the linear momentum p of a body of mass m and its kinetic energy T.

Linear momentum is a vector quantity. How do you take this into account when solving problems involving the conservation of momentum? N86/II/9 (part)

84 How would you attempt an experimental verification of the principle of conservation of momentum?

A body A of mass m moving with velocity u makes a *perfectly elastic* head-on collision with an identical body B which is initially at rest. Describe in words the motion of the bodies after the collision.

The elastic collision mentioned above is one in which the bodies become temporarily compressed and remain in contact for a short time. On the same axes of velocity against time, sketch labelled graphs of the velocity of A and the velocity of B. The time axis should extend from a time before the bodies come into contact to a time after they separate: mark on this axis the time t_C at which they first touch, the time t_O at which they suffer maximum compression, and the time t_S at which they separate.

Explain why bodies have the same velocity at t_O (the time of maximum compression). What is this velocity? Hence find, in terms of m and u, the total kinetic energy of the bodies at t_O, and again at a time after they have completely separated. Account for the difference between these energies. J87/II/9

85 *(a)* A neutron of mass m and velocity u collides elastically head-on with a stationary carbon atom of mass M. The velocities of the neutron and the carbon atom after the collision are v and V respectively.

(i) Write an equation which represents the conservation momentum in this collision.

(ii) Write the corresponding equation for the conservation of energy.

(iii) Given that eliminating M and m from these equations results in the equation $(V - v) = u$, find an expression for v in terms of m, M and u. [8]

(b) In a nuclear reactor, carbon atoms are used to slow down neutrons.

(i) Assuming that m, the mass of a neutron, is 1.0 m_U, and M, the mass of a carbon atom, is 12 m_U, what fraction of its kinetic energy does a neutron retain after an elastic head-on collision with a carbon atom?

(ii) How many such head-on collisions would be needed to reduce the kinetic energy of the neutron to one millionth of its original value?

Discuss qualitatively the effect on your two answers of not restricting the problem to head-on collisions only. [10]

(c) Explain why very light particles, such as electrons, or massive particles, such as uranium nuclei, are unsuitable for slowing down neutrons. [4] N89/II/12

86 *(a)* Explain what is meant by the *linear momentum* of a body. Obtain a relation between p, the linear momentum of a body of mass m, and E_K, its kinetic energy. [3]

(b) A bullet is fired from a gun into a block which is suspended by thin threads from fixed points. The bullet remains in the block which swings upwards as shown in Fig. 16.

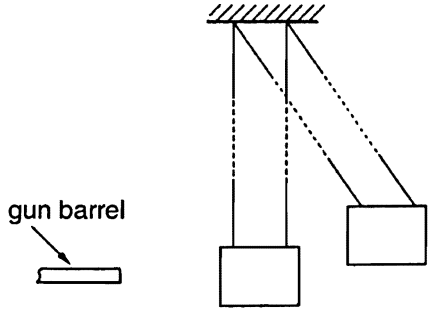


Fig. 16

Explain how you would use this equipment to determine the velocity of the bullet. [7]
J90/III/1 (part)

87 *(a)* Show that E_k, the kinetic energy of a body of mass m moving with speed v is given by the expression

$$E_k = \tfrac{1}{2} mv^2. \quad [3]$$

(b) A particle A of mass M moving with velocity U in the direction shown in Fig. 17 collides head-on with a particle B of mass m which is originally at rest.

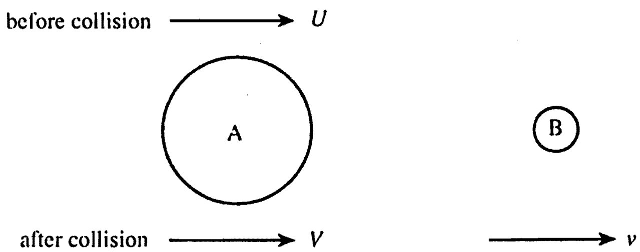


Fig. 17

The collision is perfectly elastic. After the collision, A and B move off with velocities V and v as shown.

(i) Write down equations which summarise the application of the principles of conservation of energy and momentum to this collision.

(ii) What is the ratio m/M such that all the kinetic energy of A is transferred to B during the collision (i.e. $V = 0$)? [5]

(c) An executive toy consists of two identical steel spheres suspended so that they are free to move in a vertical plane as shown in Fig. 18.

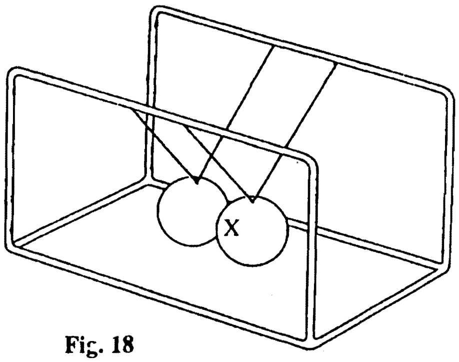


Fig. 18

The separation of the pairs of suspension threads is equal to the diameter of a sphere. Sphere X is displaced to the right and then released. With reference to your answer to *(b)*, discuss the subsequent motion of the spheres. [5]

N91/III/2 (part)

88 *(a)* (i) State the *principle of conservation of linear momentum.*

(ii) Explain what is meant by a *perfectly elastic* collision between two bodies. [3]

(b) A sphere of mass m travelling in a straight line with speed u collides head-on with a stationary sphere, also of mass m. The collision is perfectly elastic. The final speeds are v_1, and v_2 respectively, as shown in Fig. 19.

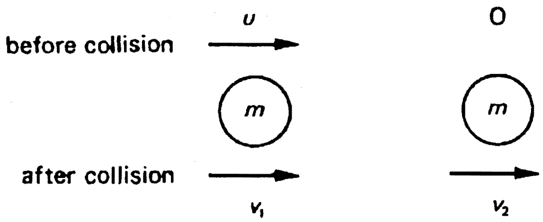


Fig. 19

Write down expressions in terms of the quantities shown in Fig. 19, to illustrate

(i) the principle of conservation of linear momentum,

(ii) the principle of conservation of energy.

Use these expressions to find v_2 in terms of u.

What happens after the collision to the incoming sphere? [7]

(c) The collision experiment in *(b)* is repeated but this time the second sphere is not stationary but has speed u_2. The speed u of the incoming sphere is greater than u_2, (see Fig. 20).

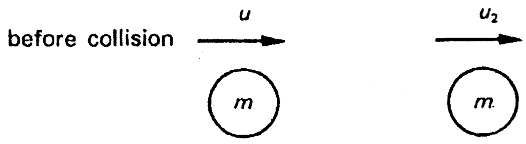


Fig. 20

The incoming sphere of kinetic energy E may lose an amount of kinetic energy W. Fig. 21 shows how W/E, the fractional energy lost by the incoming sphere, depends on the ratio u_2/u.

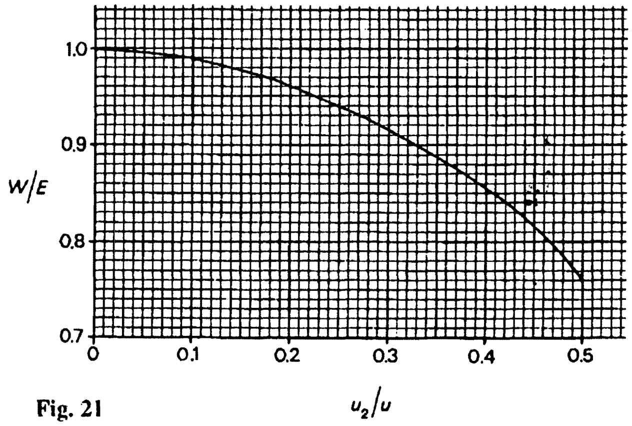


Fig. 21

(i) What happens to the kinetic energy lost by the in-coming sphere? [2]

(ii) Given that the initial energy of the incoming sphere is 1.6×10^{-13} J, calculate the energy lost by this sphere in the perfectly elastic collision when $u_2/u = 0.40$. [4]

(iii) Use the graph of Fig. 21 to suggest why paraffin wax, which has a high number density of protons, is a good absorber of high speed neutrons. [4]

N93/III/1

89 *(a)* (i) Define *linear momentum.*

(ii) State the principle of conservation of linear momentum. [3]

(b) (i) Name the type of interaction between two bodies when linear momentum and energy, but not kinetic energy, of the system are conserved.

(ii) Explain why the interaction of gas molecules with each other and with the walls of the containing vessel must, on average, be elastic. [4]

**(c)* A stationary radium nucleus ($^{224}_{88}Ra$) of mass 224 u spontaneously emits an α-particle ($^{4}_{2}He$) of mass 4 u. The α-particle is emitted with an energy of 9.2×10^{-13} J and the reaction gives rise to a nucleus of radon (Rn).

(i) Write down a nuclear equation to represent the α-decay of a radium nucleus.

(ii) Show that the speed at which the α-particle is ejected from the radium nucleus is 1.7×10^{7} m s^{-1}.

(iii) Calculate the speed of the radon nucleus on emission of the α-particle. Explain how the principle of conservation of linear momentum is applied in your calculation. [8]

J99/III/1 (part)

90 *(a)* (i) Define *linear momentum.*

(ii) Use your definition of momentum to define *force*.

(iii) Show that this definition leads to the equation $F = m \times a$.

(iv) State the principle of conservation of momentum. [7]

(b) In a gas a hydrogen molecule, mass 2.00 *u* and velocity 1.88×10^3 ms^{-1}, collides elastically and head-on with an oxygen molecule, mass 32.0 *u* and velocity 405 m s^{-1}, as illustrated in Fig. 22.

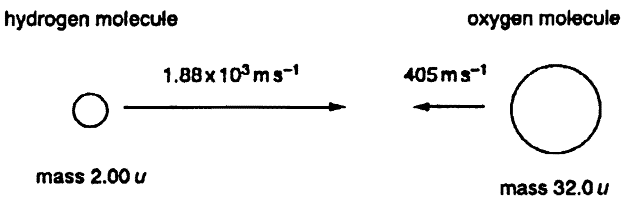


Fig. 22

In qualitative terms, what can be stated about the subsequent motion as a result of knowing that

(i) the collision is elastic,

(ii) the collision is head on? [3]

(c) Using your answers to *(b)*,

(i) determine the velocity of separation of the two molecules after the collision,

(ii) apply the law of conservation of momentum to the collision,

(iii) determine the velocity of both molecules after the collision. [6]

N2000/III/1 (part)