OCR Physics Unit 4

Topic Questions from Papers

Momentum

Answer **all** the questions.

1 **(a)** State Newton's second and third laws of motion.

In your answer, you should use appropriate technical terms spelled correctly.

(i) second law

....

....

.... **[1]**

(ii) third law

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....

.... **[1]**

(b) A golfer uses a golf club to hit a stationary golf ball off the ground. Fig. 1.1 shows how the force F on the golf ball varies with time t when the club is in contact with the ball.

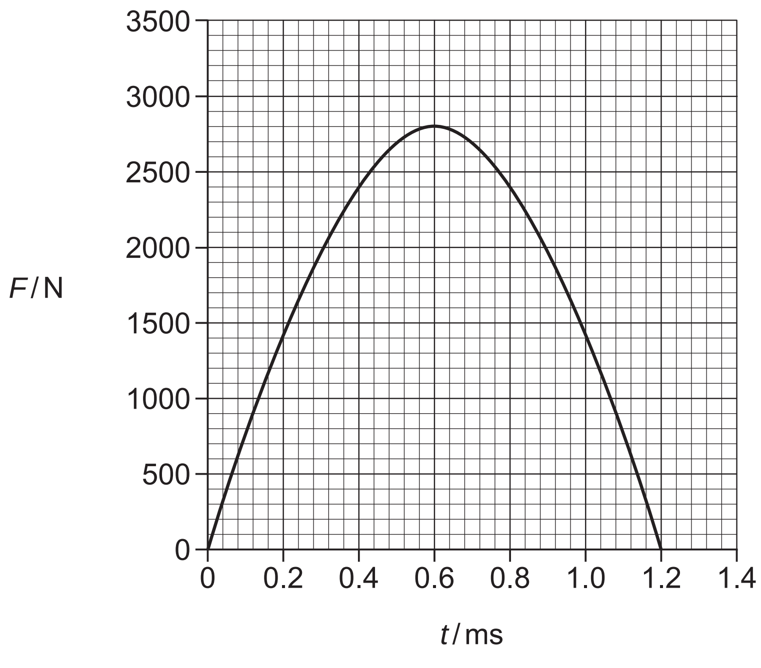

Fig. 1.1

(i) Estimate the area under the graph.

area = ... Ns **[2]**

(ii) Name the physical quantity represented by the area under the graph in **(i)**.

In your answer, you should use appropriate technical terms spelled correctly.

.... **[1]**

(iii) Show that the speed of a golf ball, of mass 0.046 kg, as it leaves the golf club is about 50 $m\,s^{-1}$.

speed = ... $m\,s^{-1}$ **[2]**

(iv) The ground is level. The ball leaves the ground at a velocity of 50 $m\,s^{-1}$ at an angle of 42° to the horizontal. Determine the horizontal distance travelled by the ball before it hits the ground.

State **one** assumption that you make in your calculations.

distance = ... m

assumption ....

.... **[5]**

[Total: 12]

Answer **all** the questions.

1 **(a)** A particular collision between two objects is *inelastic*. Place a tick (✓) at the end of each statement that applies to such a collision. **[2]**

Statement	
The magnitude of the impulse on each object is the same.	
Kinetic energy and momentum for the objects are conserved.	
Total energy is conserved.	
After the collision, the objects have the same momentum.	

(b) Fig. 1.1 shows a tennis ball before and after striking a wall at right angles.

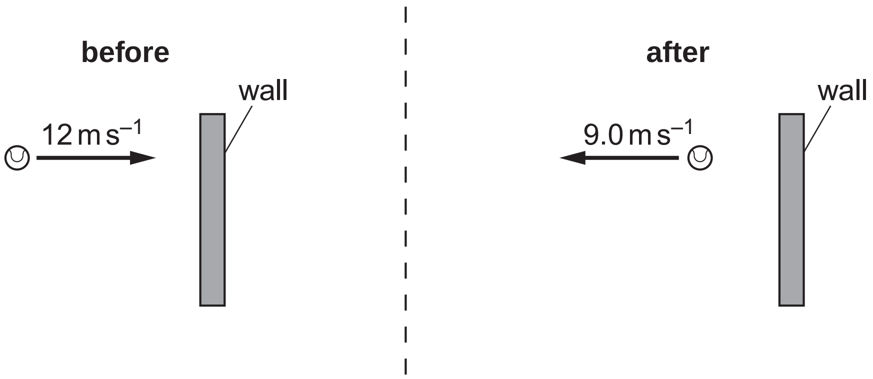

Fig. 1.1

The ball of mass 0.060 kg hits the wall at a speed of $12\,\text{m s}^{-1}$. The ball is in contact with the wall for 0.15 s. It rebounds with a speed of $9.0\,\text{m s}^{-1}$. Calculate

(i) the loss of kinetic energy during the collision

loss of kinetic energy = ... J **[2]**

(ii) the magnitude of the average force exerted on the ball by the wall

average force on ball = ... N **[2]**

(iii) the magnitude of the average force exerted on the wall by the ball during this collision.

average force on wall = ... N **[1]**

(c) (i) State **three** assumptions of the kinetic model of ideal gases.

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.... **[3]**

(ii) Use the kinetic theory of gases to explain how a gas exerts a pressure.

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.... **[3]**

[Total: 13]

5 A car of mass 970 kg is travelling at 27 m s^{-1} when the brakes are applied. The car is brought to rest in a distance of 40 m.

(a) **(i)** Calculate the kinetic energy of the car when it is travelling at 27 m s^{-1}.

kinetic energy = ... J **[1]**

(ii) Hence calculate the average braking force on the car stating any assumption that you make.

average braking force = ... N

assumption ....

.... **[3]**

(b) The car has four brake discs each of mass 1.2 kg. The material from which the discs are made has a specific heat capacity of 520 J kg^{-1} K^{-1}.

(i) Calculate the temperature rise of each disc after braking from a speed of 27 m s^{-1}. Assume all the kinetic energy of the car is converted into internal energy of the brake discs equally during braking.

temperature rise = ... °C **[2]**

Answer **all** the questions.

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

....

....

.... **[2]**

(ii) Explain what is meant by an *inelastic collision*.

....

.... **[1]**

(iii) Fig. 1.1 shows the head-on-collision of two blocks on a frictionless surface.

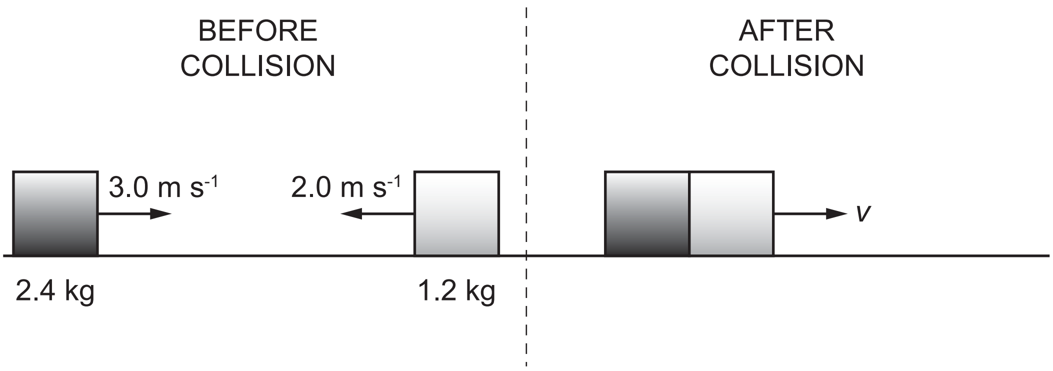


Fig. 1.1

Before the collision, the 2.4 kg block is moving to the right with a speed of $3.0\,m\,s^{-1}$ and the 1.2 kg block is moving to the left at a speed of $2.0\,m\,s^{-1}$. During the collision the blocks stick together. Immediately after the collision the blocks have a common speed *v*.

1 Calculate the speed *v*.

v = ... $m\,s^{-1}$ **[2]**

2 Show that this collision is inelastic.

[2]

(b) Fig. 1.2 shows a helicopter viewed from above.

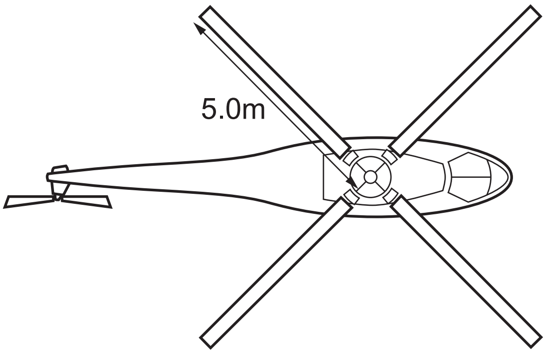


Fig. 1.2

The blades of the helicopter rotate in a circle of radius 5.0 m. When the helicopter is hovering, the blades propel air vertically downwards with a constant speed of 12 m s^{-1}. Assume that the descending air occupies a uniform cylinder of radius 5.0 m.

The density of air is 1.3 kg m^{-3}.

(i) Show that the mass of air propelled downwards in a time of 5.0 seconds is about 6000 kg.

[2]

(ii) Calculate

1 the momentum of this mass of descending air

momentum = ... $kg\,m\,s^{-1}$ **[1]**

2 the force provided by the rotating helicopter blades to propel this air downwards

force = ... N **[2]**

3 the mass of the hovering helicopter.

mass = ... kg **[1]**

[Total: 13]

Answer **all** the questions.

1 **(a)** **(i)** State Newton's first law of motion.

....

....

.... **[1]**

(ii) Define the *newton*.

....

.... **[1]**

(b) A jet plane on the deck of an aircraft carrier is accelerated before take-off using a catapult. The mass of the plane is 3.2×10^4 kg and it is accelerated from rest to a velocity of $55\,\mathrm{m\,s^{-1}}$ in a time of 2.2 s. Calculate

(i) the mean acceleration of the plane

mean acceleration = ... $\mathrm{m\,s^{-2}}$ **[2]**

(ii) the distance over which the acceleration takes place

distance = ... m **[2]**

(iii) the mean force producing the acceleration.

mean force = ...N **[1]**

Answer **all** the questions.

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

....

.... **[1]**

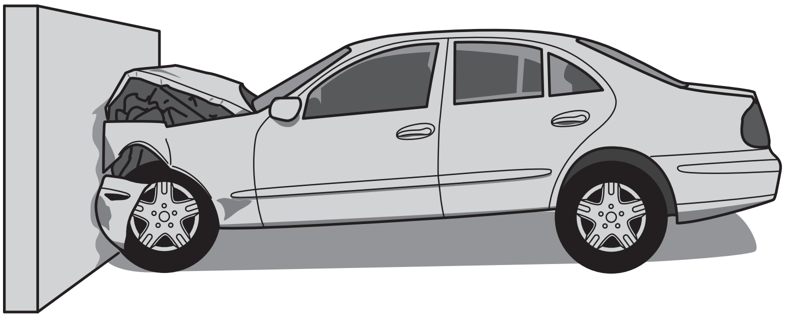
(ii) Linear momentum is a vector quantity. Explain why.

....

....

.... **[2]**

(b) The crumple zone of a car is a hollow structure at the front of the car designed to collapse during a collision. In a laboratory road-test, a car of mass 850 kg was driven into a concrete wall. A video recording of the impact showed that the car, initially travelling at 7.5 m s^{-1}, was brought to rest in 0.28 s when it hit the wall.



(i) Calculate

1 the deceleration of the car, assuming it to be uniform

deceleration = ... m s^{-2} **[1]**

2 the average force exerted by the wall on the car.

force = ... N **[2]**

(ii) The crumple zone of the car is designed to absorb 0.45 MJ of energy before any distortion of the passenger cabin occurs. For this design of crumple zone, calculate the maximum speed of the car at impact.

speed = ... $m\,s^{-1}$ **[2]**

(c) In a different test, another car of mass 850 kg is travelling at a speed of $7.5\,m\,s^{-1}$. It makes a head-on collision with a stationary car of mass 1200 kg. Immediately after the impact, both cars move off together with a common speed v. Calculate this speed.

v = ... $m\,s^{-1}$ **[2]**

[Total: 10]

Answer **all** the questions.

1 (a) State the effect a net force has on the motion of an object.

....

....

.... **[1]**

(b) (i) Define the *impulse of a force*.

....

.... **[1]**

(ii) A force F is applied to an object. The graph in Fig. 1.1 shows the variation of this force with time t.

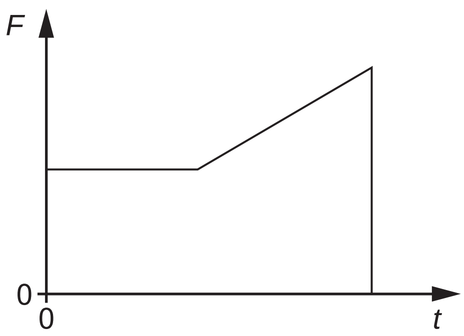


Fig. 1.1

The initial velocity of the object is zero and its mass is known. Explain how this graph can be used to determine the final velocity of the object.

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.... **[2]**

(c) A tennis ball is hit by a racket as shown in Fig. 1.2.

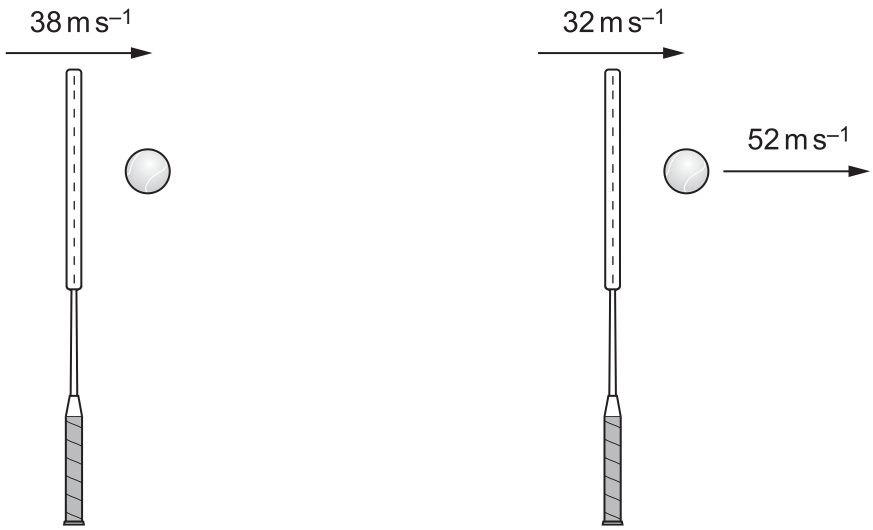

Fig. 1.2a **Fig. 1.2b**

Fig. 1.2

The mass of a tennis ball is 0.058 kg. During a serve the racket head and the ball are in contact for 4.2 ms. Just before contact, the racket head is travelling towards the ball at 38 $m\,s^{-1}$ and the ball is stationary. Fig.1.2a shows the situation just before contact. Immediately after contact, the racket head is travelling in the same direction at 32 $m\,s^{-1}$ and the ball is travelling away from the racket at 52 $m\,s^{-1}$. This is shown in Fig. 1.2b.

(i) Calculate the mean force provided by the racket on the ball.

mean force = ……………….N **[2]**

(ii) Estimate the mass of the racket.

mass = ……………….. kg **[2]**

(iii) Suggest why the value of the mass calculated in **(ii)** will be different from the actual mass of the racket.

....

.... **[1]**

[Total: 9]

Answer **all** the questions.

1 **(a)** State, in words, Newton's second law of motion.

In your answer you should use appropriate technical terms spelled correctly.

....

....

.... **[2]**

(b) Fig. 1.1 shows the masses and velocities of two objects **A** and **B** moving directly towards each other. **A** and **B** stick together on impact and move with a common velocity *v*.

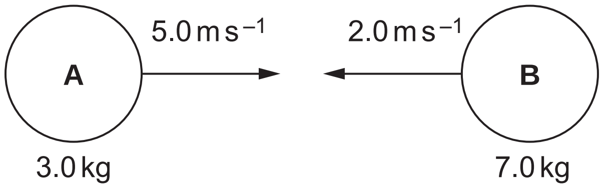

Fig. 1.1

(i) Determine the velocity *v*.

magnitude of velocity = ... $m\,s^{-1}$

direction = ...

[3]

(ii) Determine the impulse of the force experienced by the object **A** and state its direction.

impulse = ... N s

direction = ...

[2]

(iii) Explain, using Newton's third law of motion, the relationship between the impulse experienced by **A** and the impulse experienced by **B** during the impact.

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....

.... **[2]**

[Total: 9]

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^{2} N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^{2} kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

Conversion factors

unified atomic mass unit	1 u = 1.661×10^{-27} kg
electron-volt	1 eV = 1.60×10^{-19} J
	1 day = 8.64×10^{4} s
	1 year ≈ 3.16×10^{7} s
	1 light year ≈ 9.5×10^{15} m

Mathematical equations

arc length = $r\theta$

circumference of circle = $2\pi r$

area of circle = πr^2

curved surface area of cylinder = $2\pi rh$

volume of cylinder = $\pi r^2 h$

surface area of sphere = $4\pi r^2$

volume of sphere = $\frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg(\frac{A}{B}) = \lg(A) - \lg(B)$

$\ln(x^n) = n \ln(x)$

$\ln(e^{kx}) = kx$

Formulae and relationships

Unit 1 – Mechanics

$F_x = F\cos\theta$
$F_y = F\sin\theta$

$a = \dfrac{\Delta v}{\Delta t}$

$v = u + at$

$s = \dfrac{1}{2}(u + v)t$

$s = ut + \dfrac{1}{2}at^2$

$v^2 = u^2 + 2as$

$F = ma$

$W = mg$

moment = Fx

torque = Fd

$\rho = \dfrac{m}{V}$

$p = \dfrac{F}{A}$

$W = Fx\cos\theta$

$E_k = \dfrac{1}{2}mv^2$

$E_p = mgh$

efficiency = $\dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

$F = kx$

$E = \dfrac{1}{2}Fx$ $\quad E = \dfrac{1}{2}kx^2$

stress = $\dfrac{F}{A}$

strain = $\dfrac{x}{L}$

Young modulus = $\dfrac{\text{stress}}{\text{strain}}$

Unit 2 – Electrons, Waves and Photons

$\Delta Q = I\Delta t$

$I = Anev$

$W = VQ$

$V = IR$

$R = \dfrac{\rho L}{A}$

$P = VI$ $\quad P = I^2R$ $\quad P = \dfrac{V^2}{R}$

$W = VIt$

e.m.f. = $V + Ir$

$V_{\text{out}} = \dfrac{R_2}{R_1 + R_2} \times V_{\text{in}}$

$v = f\lambda$

$\lambda = \dfrac{ax}{D}$

$d\sin\theta = n\lambda$

$E = hf$ $\quad E = \dfrac{hc}{\lambda}$

$hf = \phi + \text{KE}_{\text{max}}$

$\lambda = \dfrac{h}{mv}$

$R = R_1 + R_2 + \ldots$

$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \ldots$

Unit 4 – Newtonian World

$F = \frac{\Delta p}{\Delta t}$

$v = \frac{2\pi r}{T}$

$a = \frac{v^2}{r}$

$F = \frac{mv^2}{r}$

$F = -\frac{GMm}{r^2}$

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

$f = \frac{1}{T}$

$\omega = \frac{2\pi}{T} = 2\pi f$

$a = -(2\pi f)^2 x$

$x = A\cos(2\pi ft)$

$v_{max} = (2\pi f)A$

$E = mc\Delta\theta$

$pV = NkT$

$pV = nRT$

$E = \frac{3}{2}kT$

Unit 5 – Fields, Particles and Frontiers of Physics

$E = \frac{F}{Q}$

$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$

$E = \frac{V}{d}$

$F = BIL\sin\theta$

$F = BQv$

$\phi = BA\cos\theta$

induced e.m.f. = – rate of change of magnetic flux linkage

$\frac{V_s}{V_p} = \frac{n_s}{n_p}$

$Q = VC$

$W = \frac{1}{2}QV \qquad W = \frac{1}{2}CV^2$

time constant = CR

$x = x_0 e^{-\frac{t}{CR}}$

$C = C_1 + C_2 + \ldots$

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

$A = \lambda N$

$A = A_0 e^{-\lambda t}$

$N = N_0 e^{-\lambda t}$

$\lambda t_{1/2} = 0.693$

$\Delta E = \Delta mc^2$

$I = I_0 e^{-\mu x}$