Impulse and momentum – exam questions

Question 1: June 2006 – Q3

A ball of mass 0.45 kg is travelling horizontally with speed $15\,\text{m s}^{-1}$ when it strikes a fixed vertical bat directly and rebounds from it. The ball stays in contact with the bat for 0.1 seconds.

At time t seconds after first coming into contact with the bat, the force exerted on the ball by the bat is $1.4 \times 10^5(t^2 - 10t^3)$ newtons, where $0 \leqslant t \leqslant 0.1$.

In this simple model, ignore the weight of the ball and model the ball as a particle.

(a) Show that the magnitude of the impulse exerted by the bat on the ball is 11.7 N s, correct to three significant figures. *(4 marks)*

(b) Find, to two significant figures, the speed of the ball immediately after the impact. *(4 marks)*

(c) Give a reason why the speed of the ball immediately after the impact is different from the speed of the ball immediately before the impact. *(1 mark)*

Question 2: June 2007 – Q3

A particle P, of mass 2 kg, is initially at rest at a point O on a smooth horizontal surface. The particle moves along a straight line, OA, under the action of a horizontal force. When the force has been acting for t seconds, it has magnitude $(4t + 5)$ N.

(a) Find the magnitude of the impulse exerted by the force on P between the times $t = 0$ and $t = 3$. *(3 marks)*

(b) Find the speed of P when $t = 3$. *(2 marks)*

(c) The speed of P at A is $37.5\,\text{m s}^{-1}$. Find the time taken for the particle to reach A. *(4 marks)*

Question 3: June 2008 – Q3

A particle of mass 0.2 kg lies at rest on a smooth horizontal table. A horizontal force of magnitude F newtons acts on the particle in a constant direction for 0.1 seconds. At time t seconds,

$$F = 5 \times 10^3 t^2, \quad 0 \leqslant t \leqslant 0.1$$

Find the value of t when the speed of the particle is $2\,\text{m s}^{-1}$. *(4 marks)*

Question 4: June 2009 – Q4

A particle of mass 0.5 kg is initially at rest. The particle then moves in a straight line under the action of a single force. This force acts in a constant direction and has magnitude $(t^3 + t)$ N, where t is the time, in seconds, for which the force has been acting.

(a) Find the magnitude of the impulse exerted by the force on the particle between the times $t = 0$ and $t = 4$. *(3 marks)*

(b) Hence find the speed of the particle when $t = 4$. *(2 marks)*

(c) Find the time taken for the particle to reach a speed of $12\,\text{m s}^{-1}$. *(5 marks)*

Question 5: June 2011 – Q1

A ball of mass 0.2 kg is hit directly by a bat. Just before the impact, the ball is travelling horizontally with speed $18\,\text{m s}^{-1}$. Just after the impact, the ball is travelling horizontally with speed $32\,\text{m s}^{-1}$ in the opposite direction.

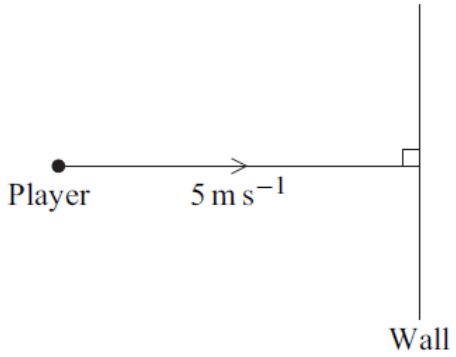
(a) Find the magnitude of the impulse exerted on the ball. *(2 marks)*

(b) At time t seconds after the ball first comes into contact with the bat, the force exerted by the bat on the ball is $k(0.9t - 10t^2)$ newtons, where k is a constant and $0 \leqslant t \leqslant 0.09$. The bat stays in contact with the ball for 0.09 seconds.

Find the value of k. *(4 marks)*

Question 6: June 2012 – Q1

An ice-hockey player has mass 60 kg. He slides in a straight line at a constant speed of $5\,\text{m s}^{-1}$ on the horizontal smooth surface of an ice rink towards the vertical perimeter wall of the rink, as shown in the diagram.



The player collides directly with the wall, and remains in contact with the wall for 0.5 seconds.

At time t seconds after coming into contact with the wall, the force exerted by the wall on the player is $4 \times 10^4 t^2 (1 - 2t)$ newtons, where $0 \leqslant t \leqslant 0.5$.

(a) Find the magnitude of the impulse exerted by the wall on the player. *(4 marks)*

(b) The player rebounds from the wall. Find the player's speed immediately after the collision. *(3 marks)*

Impulse and momentum – exam questions MS

Question 1: June 2006 – Q3

(a)	$I = 1.4\times10^5\int_0^{0.1}(t^2-10t^3)\,dt$	M1A1	
	$=1.4\times10^5\left[\frac{1}{3}t^3-\frac{10}{4}t^4\right]_0^{0.1}$	m1	
	$=11.7$ Ns	A1	4
(b)	initial momentum $=0.45(-15)$	M1	
	$=-6.75$ Ns		
	final momentum $=11.7-6.75$	M1	
	$=4.95$ Ns		
	velocity after impact $=\frac{4.95}{0.45}$	m1	
	$=11\ \text{ms}^{-1}$	A1	4
(c)	The ball is not perfectly elastic		
	or $e\neq1$ or energy loss	E1	1
	Total		**9**

Question 2: June 2007 – Q3

(a)	$I=\int_0^3(4t+5)dt$	M1	
	$=\left[2t^2+5t\right]_0^3$	m1	
	$=33$ Ns	A1	3
	Alternative:		
	I = Area under the Force–Time graph	(M1)	
	$=\frac{17+5}{2}\times3$	(m1)	
	$=33$ Ns	(A1)	(3)
b)	$I=mv-mu$		
	$33=2v-2(0)$	M1	
	$v=16.5\ \text{ms}^{-1}$	A1F	2
(c)	$I=\int_0^t(4t+5)dt=2(37.5)-2(0)$	M1	
	$2t^2+5t-75=0$	A1	
	$t=\frac{-5\pm\sqrt{25+8\times75}}{4}$	m1	
	$t=5$	A1F	4
	Total		**9**

Question 3: June 2008 – Q3

$\int_0^t 5\times10^3t^2dt=0.2(2)-0.2(0)$	M1A1	
$\frac{5\times10^3}{3}t^3=0.4$	A1F	
$t=0.0621$	A1F	4
Total		**4**

Question 4: June 2009 – Q4

(a)	$I=\int_0^4(t^3+t)\,dt$	M1	
	$=\left[\frac{1}{4}t^4+\frac{1}{2}t^2\right]_0^4$	m1	
	$=72$ Ns	A1	3
(b)	$72=0.5v-0.5(0)$	M1	
	$v=144$	A1F	2
(c)	$\int_0^T(t^3+t)\,dt=0.5(12)-0.5(0)$	M1	
	$\left[\frac{1}{4}t^4+\frac{1}{2}t^2\right]_0^T=6$		
	$T^4+2T^2-24=0$	A1	
	$T^2=\frac{-2\pm\sqrt{2^2-4(1)(-24)}}{2(1)}$	m1	
	or $(T^2-4)(T^2+6)=0$	A1F	
	$T^2=4$		
	$T=2$	A1F	5
	Total		**10**

Question 5: June 2011 – Q1

(a)	$I=0.2(32)+0.2(18)$	M1	
	$I=10$ Ns	A1	2
(b)	$\int_0^{0.09}k(0.9t-10t^2)dt=10$	M1	
	$k\left[0.45t^2-\frac{10}{3}t^3\right]_0^{0.09}=10$	A1F	
	$1.215\times10^{-3}k=10$	m1	
	$k=8230$	A1F	4
			6

Question 6: June 2012 – Q1

(a)	$I=\int_0^{0.5}4\times10^4t^2(1-2t)\,dt$	M1	
		A1	
	$=4\times10^4\left[\frac{1}{3}t^3-\frac{1}{2}t^4\right]_0^{0.5}$	A1F	
	$=417\ \left(\text{or }\frac{1250}{3}\right)$ Ns	A1F	4
(b)	$416.\dot{6}=60v+60\times5$	M1A1F	
	$v=1.94$	A1F	3
	Total		**7**