A2 Mechanics Practice Paper C
60 Marks

60 Minutes

1. A firework rocket starts from rest at ground level and moves vertically. In the first 3 s of its motion, the rocket rises 27 m. The rocket is modelled as a particle moving with constant acceleration a ms^{-2}. Find

a. The value of a, **(2)**

b. The speed of the rocket 3 s after it has left the ground. **(2)**

c. After 3 s, the rocket burns out. The motion of the rocket is now modelled as that of a particle moving freely under gravity. Find the height of the rocket above the ground 5 s after it has left the ground. **(4)**

(Total: 8 marks)

2. A competitor makes a dive from a high springboard into a diving pool. She leaves the springboard vertically with a speed of 4 ms^{-1} upwards. When she leaves the springboard, she is 5 m above the surface of the pool. The diver is modelled as a particle moving vertically under gravity alone and it is assumed that she does not the springboard as she descends. Find

a. Her speed when she reaches the surface of the pool, **(3)**

b. The time taken to reach the surface of the pool. **(3)**

c. State two physical factors which have been ignored in the model. **(2)**

(Total: 8 marks)

3. A car of mass 800 kg pulls a trailer of mass 200 kg along a straight horizontal road using a light towbar which is parallel to the road. The horizontal resistances to motion of the car and the trailer have magnitudes 400 N and 200 N respectively. The engine of the car produces a constant horizontal driving forced on the car of magnitude 1200 N. Find

a. The acceleration of the car and trailer, **(3)**

b. The magnitude of the tension in the towbar **(3)**

c. The car is moving along the road when the driver sees a hazard ahead. He reduces the force produced by the engine to zero and applies the brakes. The brakes produce a force on the car of magnitude F newtons and the car and trailer decelerate. Given that the resistances to motion are unchanged and the magnitude of the thrust in the towbar is 100 N, find the value of F. **(7)**

(Total: 13 marks)

4. The acceleration of a particle of mass 4 kg is given by $\mathbf{a} = (9\mathbf{i} - 4t\mathbf{j})$ m s^{-2}, where $\mathbf{i}$ and $\mathbf{j}$ are unit vectors and t is the time in seconds.

a. Find the acceleration of the particle when $t = 0$ and also when $t = 3$ **(1)**

b. Calculate the force acting on the particle when $t = 3$. **(1)**

c. The particle has velocity $(4\mathbf{i} + 2\mathbf{j})$ m s^{-1} when $t = 1$. Find an expression for the velocity of the particle at time t. **(4)**

(Total: 6 marks)

5. A ball is projected vertically upwards with speed 21 m s^{-1} from a point A, which is 1.5 m above the ground. After projection, the ball moves freely under gravity until it reaches the ground. Modelling the ball as a particle, find

a. The greatest height above A reached by the ball **(3)**

b. The speed of the ball as it reaches the ground **(3)**

c. The time between the instant when the ball is projected from A and the instant when the ball reaches the ground. **(4)**

(Total: 10 marks)

6. A plank AE, of length 6 m and mass 10 kg, rests in a horizontal position on supports at B and D, where $AB = 1$ m and $DE = 2$ m. A child of mass 20 kg stands at C, the mid-point of BD, as shown in the diagram above. The child is modelled as a particle and the plank as a uniform rod. The child and the plank are in equilibrium. Calculate,

a. The magnitude of the force exerted by the support on the plank at B **(4)**

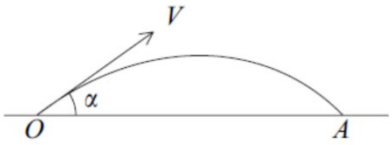
b. The magnitude of the force exerted by the support on the plank at D. **(3)**

The child now stands at a point F on the plank. The plank is in equilibrium and on the point of tilting about D.

c. Calculate the distance DF **(4)**

(Total: 11 marks)

7. A golf ball is projected from a point O with initial velocity V at an angle α to the horizontal. The ball first hits the ground at a point A which is at the same horizontal level as O, as shown in the diagram.



It is given that $V\cos\alpha = 6u$ and $V\sin\alpha = 2.5u$

a. Show that the time taken for the ball to travel from O to A is $\frac{5u}{g}$ **(4)**

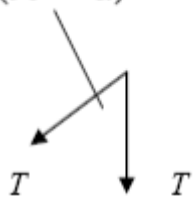
(Total: 4 marks)

Total Marks: 60

Mark Scheme

1a	$27 = 0 + ½.a.3^2 \Rightarrow a = \underline{6}$	M1A1
1b	$v = 6 \times 3 = \underline{18 \text{ m s}^{-1}}$	M1A1ft
1c	From $t = 3$ to $t = 5$, $s = 18 \times 2 - ½ \times 9.8 \times 2^2$ Total ht. $= s + 27 = \underline{43.4 \text{ m}, 43 \text{ m}}$	M1A1

2a	"$v^2 = u^2 + 2as$" : $v^2 = 4^2 + 2 \times g \times 5$ $v \approx 10.7 \text{ m s}^{-1}$ (accept 11 m s^{-1})	M1 A1 A1
2b	"$v = u + at$" : $-10.7 = 4 - gt$ $t = \dfrac{14.7}{g} = 1.5 \text{ s}$	M1 A1 ft A1
2c	Air resistance; 'spin'; height of diver; hit board again <u>or</u> horizontal component of velocity (any two)	B1 B1

3a	$T - 5g\sin\alpha = 5a$ $15g - T = 15a$ solving for a $a = 0.6g$ solving for T $T = 6g$	M1 A1 M1 A1 M1 A1 M1 A1
3b	For Q: $5g - N = 5a$ $N = 2g$	M1 A1 A1 f.t.
3c	$(90^\circ - \alpha)$  $F = 2T\cos\left(\dfrac{90^\circ - \alpha}{2}\right)$ $= 12g\cos 26.56..^\circ$ $= 105$ N	M1 A2 A1 f.t. A1

4a	$9\mathbf{i} \text{ m s}^{-2}$; $(9\mathbf{i} - 12\mathbf{j}) \text{ m s}^{-2}$	Award for either. Accept no units. (isw e.g. finding magnitudes) B1
4b	2L $\mathbf{F} = 4(9\mathbf{i} - 12\mathbf{j}) = (36\mathbf{i} - 48\mathbf{j})$ N	Accept factored form. isw. FT **a**(3). Accept 60 N or **their** $4\lvert\mathbf{a}\rvert$ B1

4c	$\mathbf{v} = \int \begin{pmatrix} 9 \\ -4t \end{pmatrix} dt = \begin{pmatrix} 9t + C \\ -2t^2 + D \end{pmatrix}$	Integration. At least one term correct.	M1
		Neglect arbitrary constant(s)	A1
	Using $\mathbf{v} = 4\mathbf{i} + 2\mathbf{j}$ when $t = 1$	Sub at $t = 1$ to find arb const(s)	M1
	$\begin{pmatrix} 4 \\ 2 \end{pmatrix} = \begin{pmatrix} 9 + C \\ -2 + D \end{pmatrix}$		
	$\Rightarrow C = -5, D = 4$ so $\mathbf{v} = (9t - 5)\mathbf{i} + (4 - 2t^2)\mathbf{j}$	y form	A1

5a	$v^2 = u^2 + 2as$	**M1**
	$0^2 = 21^2 - 2 \times 9.8 \times h$	**A1**
	$h = 22.5$m	**A1**
5b	$v^2 = u^2 + 2as$	**M1**
	$v^2 = 0^2 + 2 \times 9.8 \times 24$	**A1**
	$v = 22$ ms^{-1}	**A1**
5c	$v = u + at$	**M1**
	$-\sqrt{470.4} = 21 - 9.8t$	**A1** **A1**
	$t = 4.4\ s$	**A1**

6a	$M(D) = 20g \times 1.5 + 10g \times 1 = R_B \times 3$	**M1** **A1**
	$R_B = \frac{40g}{3} = 131$ N	**M1** **A1**
6b	R(Vertically): $R_D + \frac{40g}{3} = 20g + 10g$	**M1** **A1**
	$R_D = \frac{50g}{3}$ N	**A1**
6c	$R_B = 0$	**M1**
	M(D): $20g \times x = 10g \times 1$	**M1** **A1**
	x = DF = 0.5m	**A1**

7	$s = ut + \frac{1}{2}at^2$	**M1**
	$0 = 2.5ut - \frac{1}{2}gt^2$	**A1**
	$0 = t(2.5u - 0.5gt)$	**M1**
	$t = \frac{5u}{g}$	**A1**