A2 Mechanics Practice Paper E
60 Marks

60 Minutes

1. The driver of a car accelerating uniformly from rest sees an obstruction. She brakes immediately bringing the car to rest with constant deceleration at a distance of 6 m from its starting point. The car travels in a straight line and is in motion for 3 seconds.

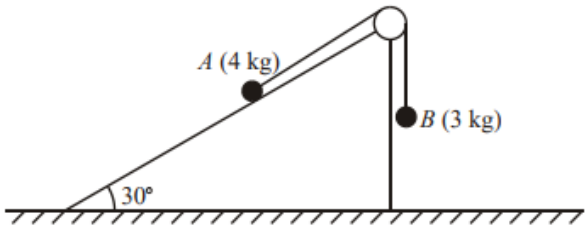
a. Sketch the (t, v) graph for the car's motion. **(2)**

b. Calculate the maximum speed of the car during its motion. **(3)**

c. Hence, given that the acceleration of the car is 2.4 m s^{-2}, calculate its deceleration. **(4)**

(Total: 9 marks)

2.



A particle A of mass 4 kg moves on the inclined faced of a smooth wedge. This face is inclined at 30° to the horizontal. The wedge is fixed on horizontal ground. Particle A is connected to a particle B, of mass 3 kg, by a light inextensible string. The string passes over a small light smooth pulley which is fixed at the top of the plane. The section of the string from A to the pulley lies in a line of greatest slope of the wedge. The particle B hangs freely below the pulley, as shown in the diagram above. The system is released from rest with the string taut. For the motion before A reaches the pulley and before B hits the ground, find

a. The tension in the string, **(6)**

b. The magnitude of the resultant force exerted by the string on the pulley. **(3)**

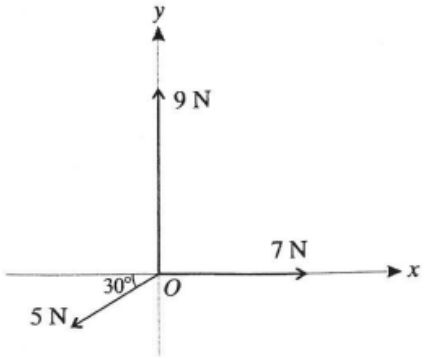
c. The string in this question is described as being 'light'.

i. Write down what you understand by this description.
ii. State how you have used the fact that the string is light in your answer to part (a). **(2)**

(Total: 11 marks)

Please turn over

3.



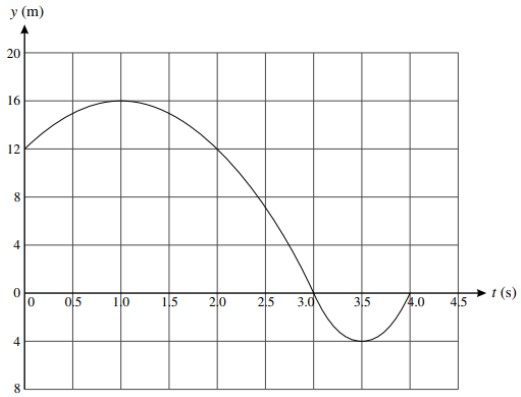
Three horizontal forces act at the point *O*. One force has magnitude 7 N and acts along the positive *x*-axis. The second force has magnitude 9 N and acts along the positive *y*-axis. The third force has magnitude 5 N and acts at an angle of 30° below the negative *x*-axis (see diagram).

a. Find the magnitudes of the components of the 5 N force along the two axes. **(2)**

b. Calculate the magnitude of the resultant of the three forces. Calculate also the angle the resultant makes with the positive *x*-axis. **(6)**

(Total: 8 marks)

4. A point *P* on a piece of machinery is moving in a vertical straight line. The displacement of *P* above ground level at time *t* seconds is *y* metres. The displacement-time graph for the motion during the time interval $0 \leq t \leq 4$ is shown in the figure below.



a. Using the graph, determine for the time interval $0 \leq t \leq 4$

i. The greatest displacement of *P* above its position when $t = 0$,

ii. The greatest distance of *P* from its position when $t = 0$,

iii. The time interval in which *P* is moving downwards,

iv. The times when *P* is instantaneously at rest. **(6)**

b. The displacement of *P* in the time interval $0 \leq t \leq 3$ is given by $y = -4t^2 + 8t + 12$.

i. Use calculus to find expressions in terms of *t* for the velocity and for the acceleration of *P* in the interval $0 \leq t \leq 3$. **(3)**

ii. At what times does *P* have a speed of 4 ms^{-1} in the interval $0 \leq t \leq 3$? **(2)**

c. In the time interval $3 \leq t \leq 4$, P has a constant acceleration of 32 ms^{-2}. There is no sudden change in velocity when $t = 3$.

Find an expression in terms of t for the displacement of P in the interval $3 \leq t \leq 4$. **(5)**

(Total: 16 marks)

5. A beam AB has length 15 m. The beam rests horizontally in equilibrium on two smooth supports at the points P and Q, where $AP = 2$ m and $QB = 3$ m. When a child of mass 50 kg stands on the beam at A, the beam remains in equilibrium and is on the point of tilting about P. When the same child of mass 50 kg stands on the beam at B, the beam remains in equilibrium and is on the point of tilting about Q. The child is modelled as a particle and the beam is modelled as a non-uniform rod.

a. (i) Find the mass of the beam.

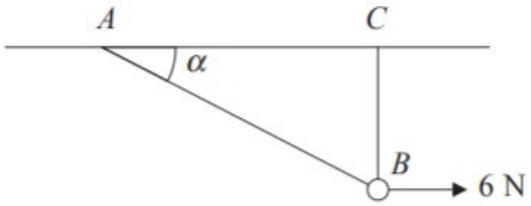
(ii) Find the distance of the centre of mass of the beam from A. **(8)**

When the child stands at the point X on the beam, it remains horizontal and in equilibrium. Given that the reactions at the two supports are equal in magnitude,

b. Find AX. **(6)**

(Total: 14 marks)

6.



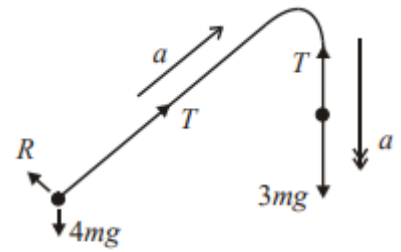
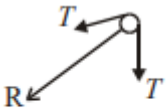
A smooth bead B is threaded on a light inextensible string. The ends of the string are attached to two fixed points A and C on the same horizontal level. The bead is held in equilibrium by a horizontal force of magnitude 6 N acting parallel to AC. The bead B is vertically below C and $\angle BAC = \alpha$, as shown in the figure below. Given that $\tan \alpha = \frac{3}{4}$, find the tension in the string.

(Total: 2 marks)

Total Marks: 60

Mark Scheme

1a	Inverted V shape with straight lines. Starts at origin, ends on t-axis, or horizontal axis if no labelling evident	B1 B1
1b	$6 = 3v/2$ $v = 4$ ms^{-1} Not awarded if special (right angled, isosceles) triangle assumed, or $s = (u+v)t/2$, or max v at specific t.	M1 A1 A1
1c	T accn = 4/2.4 or s accn = 16/(2x2.4) T accn = 1 2/3 s or s accn = 10/3 Deceleration = 4/(3 - 1 2/3) or 16/2(6-10/3) Deceleration = 3 ms^{-2} Uses $t = v/a$ or $s = v^2/2a$. May be implied Accept 4/(3 - 1.67) or 16/2(6-3.33) Accept 3.01; award however $v = 4$ obtained in (ii). $a = -3$ gets A0.	M1* A1 D*M1 A1

2a	 A: $T - 4g \sin 30 = 4a$ B: $3g - T = 3a$ $\Rightarrow T = \frac{18g}{7} = \underline{25.2 \text{ N}}$	 M1 A1 M1 A1 M1 A1
2b	 $R = 2T \cos 30$ $\approx \underline{44 \text{ or } 43.6 \text{ N}}$	 M1 A1 A1
2c	(i) String has no weight/mass (ii) Tension in string constant, i.e. same at A and B	B1 B1

3a	5cos30 or 5 sin 60 or 4.33 5cos 60 or 5sin30 or 2.5 Order immaterial, accept +/-. May be awarded in (ii) if no attempt in (i)	B1 B1
3b	7-4.33 (= 2.67) and 9 - 2.5 (= 6.5) $R^2 = 2.67^2 + 6.5^2$ R = 7.03 tanθ = 6.5/2.67 θ = 67.6, 67.7degrees Subtracts either component from either force 3sf or better Valid trig for correct angle 3sf or better	M1* A1 D*M1 A1 D*M1 A1

4a(i)	4 m	B1
4a(ii)	$12 - (-4) = 16$ m Looking for distance. Need evidence of taking account of +ve and –ve displacements.	M1
4a(iii)	$1 < t < 3.5$ The values 1 and 3.5 Strict inequality	B1 B1
4a(iv)	$t = 1$, $t = 3.5$ Do not award if extra values given.	B1

4b(i)	$v = -8t + 8$ Differentiating		M1
			A1
	$a = -8$		F1
4b(ii)	$-8t + 8 = 4$ so $t = 0.5$ so 0.5 s FT **their** v.		B1
	$-8t + 8 = -4$ so $t = 1.5$ so 1.5 s FT **their** v.		B1
4c(i)	**method 1**		
	Need velocity at $t = 3$		
	$v(3) = -8 \times 3 + 8 = -16$	FT **their** v from (ii)	B1
	either		
	$v = \int 32\ dt = 32t + C$	Accept $32t + C$ or $32t$. SC1 if $\int_3^4 32dt$ attempted.	M1
	$v = -16$ when $t = 3$ gives $v = 32t - 112$	Use of **their** -16 from an attempt at v when t=3	A1
	$y = \int (32t - 112)dt = 16t^2 - 112t + D$	FT **their** v of the form $pt + q$ with $p \neq 0$ and $q \neq 0$. Accept if at least 1 term correct. Accept no D.	M1
	$y = 0$ when $t = 3$ gives $y = 16t^2 - 112t + 192$	cao.	A1
	or		
	$y = -16 \times (t-3) + \frac{1}{2} \times 32 \times (t-3)^2$	Use of $s = ut + \frac{1}{2}at^2$	M1
		Use of **their** -16 (not 0) from an attempt at v when t=3 and 32. Condone use of just t	A1
		Use of $t \pm 3$	M1
		cao	A1
	(so $y = 16t^2 - 112t + 192$)		
	method 2		
	Since accn is constant, the displacement y is a quadratic function. Since we have $y = 0$ at $t = 3$ and $t = 4$		
	$y = k(t-3)(t-4)$	Use of a quadratic function (condone no k)	M1
		Correct use of roots	A1
		k present	B1
	When $t = 3.5$, $y = -4$		
	so $-4 = k \times \frac{1}{2} \times -\frac{1}{2}$	Or consider velocity at $t = 3$	M1
	so $k = 16$ (and $y = 16t^2 - 112t + 192$)	cao. Accept k without y simplified.	A1

5ai	$M(P)$, $50g$ x 2 = Mg x $(x - 2)$	**M1 A1**
	$M(Q)$, $50g$ x 3 = Mg x $(12 - x)$	**M1 A1**
	$M = 25$ kg	**M1 A1**
	$x = 6m$	**M1 A1**
5b	$R + R = 25g + 50g$	**M1 A1**
	$M(A)$, $2R + 12R = 25g$ x 6 + $50g$ x AX	**M1 A1**
	$AX = 7.5$ m	**M1 A1**

6	Resolving Horizontally, $T \cos \alpha = 6$	**M1**
	$T = 7.5N$	**A1**