Write your name here

Surname	Other names

Pearson Edexcel
International
Advanced Level

Centre Number | | | | | |

Candidate Number | | | | |

Mechanics M1

Advanced/Advanced Subsidiary

Monday 25 January 2016 – Afternoon
Time: 1 hour 30 minutes

Paper Reference
WME01/01

You must have:
Mathematical Formulae and Statistical Tables (Blue)

Total Marks

Candidates may use any calculator allowed by the regulations of the Joint Council for Qualifications. Calculators must not have the facility for symbolic algebra manipulation, differentiation and integration, or have retrievable mathematical formulae stored in them.

Instructions

- Use **black** ink or ball-point pen.
- If pencil is used for diagrams/sketches/graphs it must be dark (HB or B). Coloured pencils and highlighter pens must not be used.
- **Fill in the boxes** at the top of this page with your name, centre number and candidate number.
- Answer **all** questions and ensure that your answers to parts of questions are clearly labelled.
- Answer the questions in the spaces provided
  – *there may be more space than you need.*
- You should show sufficient working to make your methods clear. Answers without working may not gain full credit.
- Whenever a numerical value of g is required, take $g = 9.8$ m s^{-2}, and give your answer to either two significant figures or three significant figures.
- When a calculator is used, the answer should be given to an appropriate degree of accuracy.

Information

- The total mark for this paper is 75.
- The marks for **each** question are shown in brackets
  – *use this as a guide as to how much time to spend on each question.*

Advice

- Read each question carefully before you start to answer it.
- Try to answer every question.
- Check your answers if you have time at the end.

Turn over ▶

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1. A truck of mass 2400 kg is pulling a trailer of mass M kg along a straight horizontal road. The tow bar, connecting the truck to the trailer, is horizontal and parallel to the direction of motion. The tow bar is modelled as being light and inextensible. The resistance forces acting on the truck and the trailer are constant and of magnitude 400 N and 200 N respectively. The acceleration of the truck is 0.5 m s^{-2} and the tension in the tow bar is 600 N.

(a) Find the magnitude of the driving force of the truck.

(3)

(b) Find the value of M.

(3)

(c) Explain how you have used the fact that the tow bar is inextensible in your calculations.

(1)

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Question Number	Scheme	Marks
1(a)	For truck: $D - 600 - 400 = 2400$ x 0.5 $D = 2200$N	M1 A1 A1 (3)
(b)	For both: $D - 600 = (M + 2400)$ x 0.5 (or trailer: 600 - 200 = M x0.5) $M = 800$ $M = 800$	M1 A1 A1 (3)
(c)	Truck and trailer have same acceleration.	B1 (1) **7**
	Notes **Can mark (a) and (b) 'together' if it helps the candidate, provided no wrong working seen.**	
1(a)	M1 for NL2 for truck only (or for a complete method if they find *M* first), with correct no. of terms, in *D* only. (M0 if 600 or 400 is replaced by 200) First A1 for a correct equation . Second A1 for 2200 (N). .	
1(b)	M1 for NL2 for whole system or trailer only, with correct no. of terms. First A1 for a correct equation. (Allow '*D*' or their *D*) Second A1 for 800. **N.B.** In both parts of this question use the mass which is being used in their equation to guide you as to which part of the system is being considered.	
1(c)	B0 if extras included. E.g if 'tension is same' is included. B1 Must include 'truck and trailer' or 'both particles' or 'accln is same throughout the system' B0 for 'accln is same'	

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2. Two particles P and Q are moving in opposite directions along the same horizontal straight line. Particle P is moving due east and particle Q is moving due west. Particle P has mass $2m$ and particle Q has mass $3m$. The particles collide directly. Immediately before the collision, the speed of P is $4u$ and the speed of Q is u. The magnitude of the impulse in the collision is $\frac{33}{5}mu$.

(a) Find the speed and direction of motion of P immediately after the collision.

(4)

(b) Find the speed and direction of motion of Q immediately after the collision.

(4)

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Question Number	Scheme	Marks
2(a)	$For P: \quad \frac{33}{5}mu = 2m(-v_P - -4u)$ $v_P = 0.7u$ due E	M1 A1 **dM1** A1 (4)
(b)	$For Q: \quad \frac{33}{5}mu = 3m(v_Q - -u)$ $v_Q = 1.2u$ due E	M1 A1 **dM1** A1 (4)
	Notes	
2(a)	**(c)**	
2(b)	First M1 for attempt at impulse = difference in momenta, for Q only, (i.e. must be using $3m$ and u). M0 if g's are included on RHS First A1 for either $^{33}/_5\ mu = 3m(v_Q - -u)$ or $^{33}/_5\ mu = 3m(-v_Q - -u)$ oe Second dM1 for answer $^{c}/_5\ u$, where c is an integer, oe Second A1 for $1.2u$ oe due E (or 'reversed' or 'original direction of P') But A0 if just 'changed' or 'to the right' or 'in positive direction'	
2(b) **ALT**	First M1 for attempt at CLM equation, with correct no. of terms, dimensionally correct, with their v_P substituted. Allow consistent extra g's and cancelled m's and sign errors but masses and velocities must be correctly matched. First A1 for $2m.4u - 3mu = 2m.0.7u + 3m\ v_Q$ oe or $2m.4u - 3mu = 2m.0.7u - 3m\ v_Q$ oe Second dM1 for answer $^{c}/_5\ u$, where c is an integer, oe Second A1 for $1.2u$ oe due E	
2(a) **ALT**	They may find v_Q first, then First M1 for attempt at CLM equation, with correct no. of terms, dimensionally correct, with their v_Q substituted. Allow consistent extra g's and cancelled m's and sign errors but masses and velocities must be correctly matched. First A1 for $2m.4u - 3mu = 2mv_P + 3m \times 1.2u$ oe or $2m.4u - 3mu = -2mv_P + 3m \times 1.2u$ oe Second dM1 for answer $^{k}/_{10}\ u$, where k is an integer, oe Second A1 for $0.7u$ oe due E (or unchanged)	

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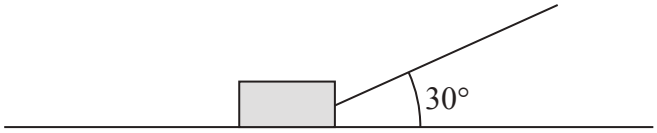

Figure 1

A boy is pulling a sledge of mass 8 kg in a straight line at a constant speed across rough horizontal ground by means of a rope. The rope is inclined at 30° to the ground, as shown in Figure 1. The coefficient of friction between the sledge and the ground is $\frac{1}{5}$. By modelling the sledge as a particle and the rope as a light inextensible string, find the tension in the rope.

(8)

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Question Number	Scheme	Marks
3	$F = 0.2R$ $R + T\sin 30^o = 8g$ $F = T\cos 30^o$ $0.2(8g - T\sin 30^o) = T\cos 30^o$ $T = 16$ N or 16.2 N	B1 M1 A1 M1 A1 **ddM1** **dM1** A1 **8**
	Notes	
	B1 for $F = 0.2R$ or $F = \mu R$ <u>*and*</u> $\mu = 0.2$, seen (could just be on a diagram). First M1 for resolving vertically with correct no. of terms and T resolved (allow missing g). First A1 for a correct equation. Second M1 for resolving horizontally with correct no. of terms and T resolved. (M0 if there is an 'ma' term which does not subsequently disappear.) Second A1 for a correct equation. Third ddM1 (dependent on both previous M's) for producing an equation in T only. Fourth dM1 (dependent on previous M) for solving for T Third A1 for $T = 16$ (N) or 16.2 (N) No other answers.	

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4. A small stone is projected vertically upwards from the point O and moves freely under gravity. The point A is 3.6 m vertically above O. When the stone first reaches A, the stone is moving upwards with speed 11.2 m s^{-1}. The stone is modelled as a particle.

(a) Find the maximum height above O reached by the stone.

(4)

(b) Find the total time between the instant when the stone was projected from O and the instant when it returns to O.

(5)

(c) Sketch a velocity-time graph to represent the motion of the stone from the instant when it passes through A moving upwards to the instant when it returns to O. Show, on the axes, the coordinates of the points where your graph meets the axes.

(4)

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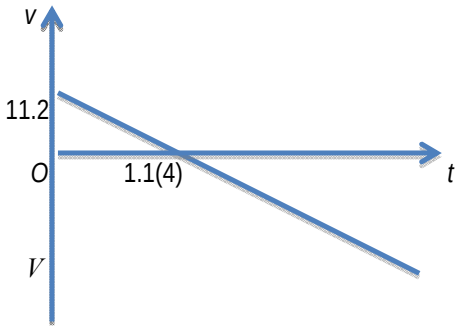
Question Number	Scheme	Marks
4(a)	$0^2 = 11.2^2 - 2gd$ $d = 6.4$ max ht. $= 3.6 + 6.4 = 10$ m	M1 A1 A1 A1 (4)
ALT	$11.2^2 = u^2 - 2g$ x 3.6 $u = 14$ $0^2 = 14^2 - 2gh$ $h = 10$ m	M1 A1 A1 A1 (4)
(b)	$10 = \frac{1}{2}gt^2$ $t = \frac{10}{7}$ Total $= 2\text{x}\frac{10}{7} = 2.9$ or 2.86	M1 A1 A1 **dM1** A1 (5)
(c)		B1 single line **dB1** $V <$ -11.2 B1 11.2 B1 1.1(4) (4) **13**
	Notes	
4(a)	M1 for a complete method to find d (d = distance from A to top) First A1 for a correct equation in d only. Second A1 for $d = 6.4$ Third A1 for 6.4 + 3.6 = 10 (m)	
ALT	M1 for a complete method (must have 2nd equation) to find h First A1 for $u = 14$ Second A1 for correct 2nd equation Third A1 for $h = 10$ (m)	
4(b)	First M1 for a complete method to find an intermediate time (A to top or A to O) First A1 for a correct equation or equations. Second A1 for any intermediate time (e.g. $_At_{TOP} = {}^8/_7$, $_At_O = {}^2/_7$, $_At_O = {}^{18}/_7$, $_At_A =$	

	16/7) Second **dM1** for a complete method to find the total time. Third A1 for 2.9 or 2.86 (s) No other final answers. For a *complete* method which does not involve an intermediate time e.g find u (=14) at O, then use u to find the whole time: First **dM1** dependent <u>on 2nd M1</u>, for finding u First A1 for $u = 14$ Second M1 for: $0 = 14t - 1/2gt^2$ or $-14 = 14 - gt$ Second A1 Third A1 for $t = 2.86$ or 2.9	
4(c)	First B1 for a SINGLE straight line (N.B. If they have a <u>continuous</u> vertical line as well, give B0), with –ve gradient, starting on +ve v-axis (at A say) and *crossing* the t-axis. (at B say). **SC**: A single str. line, with –ve gradient, which starts at (2/7, 11.2) (clearly marked) can score a max B1B1B0B0.	
	Second **dB1,** dependent on first B1, for the line finishing at C say, with $AB < BC$ if no scale, or at $v = V$,where $V < -11.2$, if marked.	
	Third B1 (independent) for their (possibly first) line starting at (0,11.2)	
	Fourth B1 (independent) for 1.1(4) (allow 8/7 if over accuracy already penalised elsewhere) marked correctly (line may not cross the axis and there may be more than one line)	
	N.B. Line may be reflected in t-axis, with appropriate adjustments to marks.	

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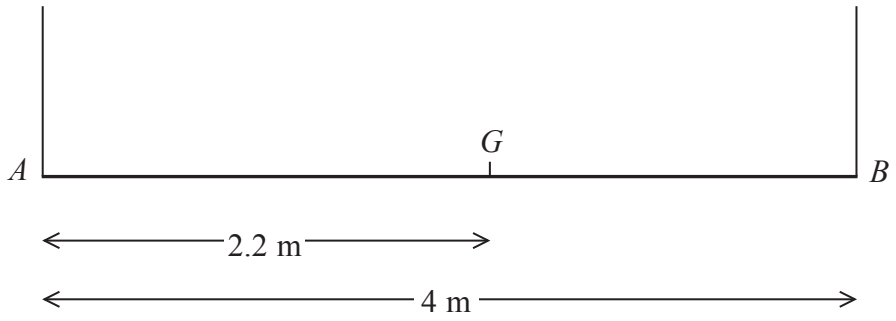

Figure 2

A non-uniform rod AB has length 4 m and weight 120 N. The centre of mass of the rod is at the point G where $AG = 2.2$ m. The rod is suspended in a horizontal position by two vertical light inextensible strings, one at each end, as shown in Figure 2. A particle of weight 40 N is placed on the rod at the point P, where $AP = x$ metres. The rod remains horizontal and in equilibrium.

(a) Find, in terms of x,

(i) the tension in the string at A,

(ii) the tension in the string at B.

(6)

Either string will break if the tension in it exceeds 84 N.

(b) Find the range of possible values of x.

(4)

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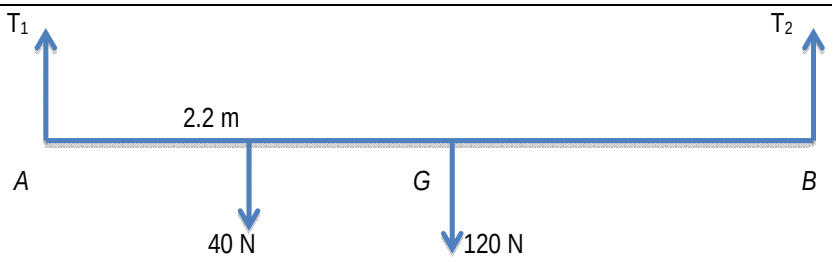
Question Number	Scheme	Marks
5(a)		
(i)	$M(B),\ \ 4T_1 = 120 \text{ x } 1.8 + 40(4-x)$ $T_1 = 94 - 10x$	M1 A1 A1
(ii)	$M(A),\ \ 4T_2 = 120 \text{ x } 2.2 + 40x$ $T_2 = 66 + 10x$	M1 A1 A1 (6)
(b)	$94 - 10x \le 84$ $x \ge 1$ $66 + 10x \le 84$ $x \le 1.8$ $1 \le x \le 1.8$	M1 M1 A1 both CV A1 (4) **10**
	Notes	
5(a)(i) **(ii)**	First M1 for a complete method to find an equation in T_A and x only. First A1 for a correct equation in T_A and x only. Second A1 for $94 - 10x$ Second M1 for a complete method to find an equation in T_B and x only. First A1 for a correct equation in T_B and x only. Second A1 for $66 + 10x$	
5(b)	First M1 for their $T_A \le 84$ or $= 84$ or < 84 to give equation or inequality in x only. (> 84 is M0) Second M1 for their $T_B \le 84$ or $= 84$ or < 84 to give equation or inequality in x only. (> 84 is M0) First A1 for both critical values of x, 1 and 1.8 SEEN. Second A1 $1 \le x \le 1.8$ or $1 \le x$ AND $x \le 1.8$ or [1, 1.8]	

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6. [*In this question* **i** and **j** *are horizontal unit vectors due east and due north respectively and position vectors are given relative to a fixed origin.*]

At 2 pm, the position vector of ship P is $(5\mathbf{i} - 3\mathbf{j})$ km and the position vector of ship Q is $(7\mathbf{i} + 5\mathbf{j})$ km.

(a) Find the distance between P and Q at 2 pm.

(3)

Ship P is moving with constant velocity $(2\mathbf{i} + 5\mathbf{j})$ km h^{-1} and ship Q is moving with constant velocity $(-3\mathbf{i} - 15\mathbf{j})$ km h^{-1}.

(b) Find the position vector of P at time t hours after 2 pm.

(2)

(c) Find the position vector of Q at time t hours after 2 pm.

(1)

(d) Show that Q will meet P and find the time at which they meet.

(5)

(e) Find the position vector of the point at which they meet.

(2)

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Question Number	Scheme	Marks
6(a)	$\overrightarrow{PQ} = (7\mathbf{i}+5\mathbf{j})-(5\mathbf{i}-3\mathbf{j}) = (2\mathbf{i}+8\mathbf{j})$ $PQ = \sqrt{2^2+8^2} = \sqrt{68} = 8.2$ or better	M1 M1 A1 (3)
(b)	$\mathbf{r}_P = (5\mathbf{i}-3\mathbf{j})+t(2\mathbf{i}+5\mathbf{j}) = (2t+5)\mathbf{i}+(5t-3)\mathbf{j}$	M1 A1 (2)
(c)	$\mathbf{r}_Q = (7\mathbf{i}+5\mathbf{j})+t(-3\mathbf{i}-15\mathbf{j}) = (7-3t)\mathbf{i}+(5-15t)\mathbf{j}$	A1 (1)
(d)	$(2t+5) = (7-3t) \Rightarrow t = \frac{2}{5}$ $(5t-3) = (5-15t) \Rightarrow t = \frac{2}{5}$ time is 2.24 pm Allow just $t = 0.4$	M1 A1 M1 A1 A1 (5)
(e)	$\mathbf{r}_P = (5.8\mathbf{i}-\mathbf{j})$	M1 A1 (2) **13**
	Notes **Allow column vectors throughout.**	
6(a)	First M1 for clear attempt to subtract in either order. Condone missing brackets. Second M1 for attempt to find magnitude of their **PQ** or **QP** A1 √68, 2√17 or 8.2 or better	
(b)	M1 for (either $\mathbf{r}_P$ or $\mathbf{r}_Q$) a clear attempt at: (M0 if they use $(t+2)$) $\mathbf{r}_P = (5\mathbf{i}-3\mathbf{j})+t(2\mathbf{i}+5\mathbf{j}) = (2t+5)\mathbf{i}+(5t-3)\mathbf{j}$ A1 if correct (**i**'s and **j**'s do not need to be collected.)	
(c)	A1 for $\mathbf{r}_Q = (7\mathbf{i}+5\mathbf{j})+t(-3\mathbf{i}-15\mathbf{j}) = (7-3t)\mathbf{i}+(5-15t)\mathbf{j}$	
(d)	First M1 for equating coefficients of **i** (coeffs. of form $a + bt$) First A1 for $t = 2/5$ Second M1 for equating coefficients of **j** (coeffs. of form $a + bt$) Second A1 for $t = 2/5$ Third A1 for 2.24 (pm) , dependent on *both* previous M marks	
(e)	This answer must appear in part (e). M1 for substituting their t value (allow even if they have only equated coefficients once to obtain it) into their $\mathbf{r}_P$ or $\mathbf{r}_Q$ expression A1 for $\mathbf{r}_P = (5.8\mathbf{i}-\mathbf{j})$	

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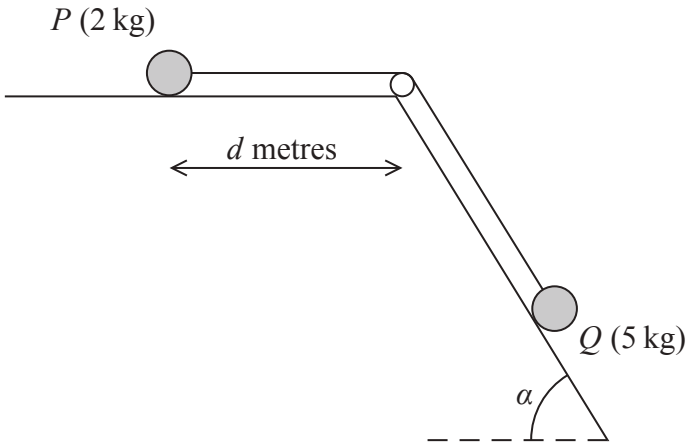

Figure 3

A particle P of mass 2 kg is attached to one end of a light inextensible string. A particle Q of mass 5 kg is attached to the other end of the string. The string passes over a small smooth light pulley. The pulley is fixed at a point on the intersection of a rough horizontal table and a fixed smooth inclined plane. The string lies along the table and also lies in a vertical plane which contains a line of greatest slope of the inclined plane. This plane is inclined to the horizontal at an angle α, where $\tan\alpha = \frac{3}{4}$. Particle P is at rest on the table, a distance d metres from the pulley. Particle Q is on the inclined plane with the string taut, as shown in Figure 3. The coefficient of friction between P and the table is $\frac{1}{4}$.

The system is released from rest and P slides along the table towards the pulley.

Assuming that P has not reached the pulley and that Q remains on the inclined plane,

(a) write down an equation of motion for P,

(2)

(b) write down an equation of motion for Q,

(2)

(c) (i) find the acceleration of P,

(ii) find the tension in the string.

(5)

When P has moved a distance 0.5 m from its initial position, the string breaks. Given that P comes to rest just as it reaches the pulley,

(d) find the value of d.

(7)

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Question Number	Scheme	Marks
7(a)	$T - F = 2a$	M1 A1 (2)
(b)	$5g\sin\alpha - T = 5a$	M1 A1 (2)
(c)	$R = 2g$ $F = \frac{1}{4}R$ $a = \frac{5g}{14} = 3.5 \text{ ms}^{-2}$ $T = 11.9 \text{ N}$ or 12 N	B1 B1 M1 A1 A1 (5)
(d)	$v^2 = 2 \text{ x } 3.5 \text{ x } 0.5 = 3.5$ $(\rightarrow) \ -0.5g = 2a \Rightarrow a = -0.25g \ (-2.45)$ $0 = 3.5 + 2(-2.45)s$ $s = \frac{5}{7}$ (0.7142..) $d = \frac{1}{2} + \frac{5}{7} = \frac{17}{14} = 1.2$ or 1.21	M1 A1 **ft** M1 A1 M1 A1 A1 **ft** (7) **16**
	Notes	
7(a)	M1 for N2L for P with correct no. of terms etc. A1 for a correct equation	
(b)	M1 for N2L for Q with correct no. of terms etc. A1 for a correct equation	
(c) **(i)** **(ii)**	First B1 for $R = 2g$ Second B1 for $F = ¼ R$ seen, possibly on a diagram First M1 for eliminating T or a and solving for T or a but must have had two equations, each in T *and* a. First A1 for 5g/14 or 3.5 or 7/2 (ms^{-2}) Second A1 for 17g/14 , 11.9 or 12 (N)	
(d)	First M1 for a complete method for finding v or v^2 when the string breaks. First A1 **ft** for a correct expression (may not be evaluated), ft on their accln Second M1 for N2L for P Second A1 for a correct value of a (may not be negative) Third M1 (Must have found a deceleration using N2L and a value for v or v^2) for a complete method to find distance moved by P Third A1 for a correct distance (s) cao. Fourth A1 **ft** for (their s + 0.5) **N.B.** For both third and fourth A marks, allow a fraction or any number of decimal places, since g cancels.	