Paper Reference(s)

6678/01

Edexcel GCE

Mechanics M2
Bronze Level B1

Time: 1 hour 30 minutes

Materials required for examination	**Items included with question papers**
Mathematical Formulae (Green)	Nil

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 formulas stored in them.

Instructions to Candidates

In the boxes on the answer book, write the name of the examining body (Edexcel), your centre number, candidate number, the unit title (Mechanics M2), the paper reference (6678), your surname, other name and signature.
Whenever a numerical value of g is required, take $g = 9.8 \text{ m s}^{-2}$.
When a calculator is used, the answer should be given to an appropriate degree of accuracy.

Information for Candidates

A booklet 'Mathematical Formulae and Statistical Tables' is provided.
Full marks may be obtained for answers to ALL questions.
There are 8 questions in this question paper. The total mark for this paper is 75.

Advice to Candidates

You must ensure that your answers to parts of questions are clearly labelled.
You must show sufficient working to make your methods clear to the Examiner. Answers without working may gain no credit.

Suggested grade boundaries for this paper:

A*	A	B	C	D	E
75	70	63	56	48	39

1. A parcel of mass 2.5 kg is moving in a straight line on a smooth horizontal floor. Initially the parcel is moving with speed 8 m s^{-1}. The parcel is brought to rest in a distance of 20 m by a constant horizontal force of magnitude R newtons. Modelling the parcel as a particle, find

(*a*) the kinetic energy lost by the parcel in coming to rest,
(2)

(*b*) the value of R.
(3)

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2. A particle P of mass 0.5 kg moves under the action of a single force **F** newtons. At time t seconds, the velocity **v** m s^{-1} of P is given by

$$\mathbf{v} = 3t^2\mathbf{i} + (1 - 4t)\mathbf{j}$$

Find

(*a*) the acceleration of P at time t seconds,
(2)

(*b*) the magnitude of **F** when $t = 2$.
(4)

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3. A particle moves along the x-axis. At time $t = 0$ the particle passes through the origin with speed 8 m s^{-1} in the positive x-direction. The acceleration of the particle at time t seconds, $t \geq 0$, is $(4t^3 - 12t)$ m s^{-2} in the positive x-direction.

Find

(*a*) the velocity of the particle at time t seconds,
(3)

(*b*) the displacement of the particle from the origin at time t seconds,
(2)

(*c*) the values of t at which the particle is instantaneously at rest.
(3)

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4. A car of mass 750 kg is moving up a straight road inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{15}$. The resistance to motion of the car from non-gravitational forces has constant magnitude R newtons. The power developed by the car's engine is 15 kW and the car is moving at a constant speed of 20 m s^{-1}.

(*a*) Show that $R = 260$.

(4)

The power developed by the car's engine is now increased to 18 kW. The magnitude of the resistance to motion from non-gravitational forces remains at 260 N. At the instant when the car is moving up the road at 20 m s^{-1} the car's acceleration is a m s^{-2}.

(*b*) Find the value of a.

(4)

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5. A cyclist and her bicycle have a total mass of 70 kg. She cycles along a straight horizontal road with constant speed 3.5 m s^{-1}. She is working at a constant rate of 490 W.

(*a*) Find the magnitude of the resistance to motion.

(4)

The cyclist now cycles down a straight road which is inclined at an angle θ to the horizontal, where $\sin\theta = \frac{1}{14}$, at a constant speed U m s^{-1}. The magnitude of the non-gravitational resistance to motion is modelled as $40U$ newtons. She is now working at a constant rate of 24 W.

(*b*) Find the value of U.

(7)

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6. A particle P moves on the x-axis. The acceleration of P at time t seconds is $(t - 4)$ m s^{-2} in the positive x-direction. The velocity of P at time t seconds is v m s^{-1}. When $t = 0$, $v = 6$.

Find

(*a*) v in terms of t,

(4)

(*b*) the values of t when P is instantaneously at rest,

(3)

(*c*) the distance between the two points at which P is instantaneously at rest.

(4)

7.

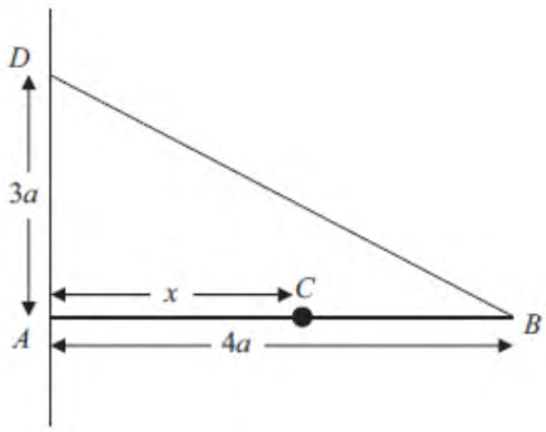


Figure 3

A uniform rod AB, of mass $3m$ and length $4a$, is held in a horizontal position with the end A against a rough vertical wall. One end of a light inextensible string BD is attached to the rod at B and the other end of the string is attached to the wall at the point D vertically above A, where $AD = 3a$. A particle of mass $3m$ is attached to the rod at C, where $AC = x$. The rod is in equilibrium in a vertical plane perpendicular to the wall as shown in Figure 3. The tension in the string is $\frac{25}{4}mg$.

Show that

(*a*) $x = 3a$,

(5)

(*b*) the horizontal component of the force exerted by the wall on the rod has magnitude $5mg$.

(3)

The coefficient of friction between the wall and the rod is μ. Given that the rod is about to slip,

(*c*) find the value of μ.

(5)

8. A particle P of mass m kg is moving with speed 6 m s^{-1} in a straight line on a smooth horizontal floor. The particle strikes a fixed smooth vertical wall at right angles and rebounds. The kinetic energy lost in the impact is 64 J. The coefficient of restitution between P and the wall is $\frac{1}{3}$.

(*a*) Show that $m = 4$.

(6)

After rebounding from the wall, P collides directly with a particle Q which is moving towards P with speed 3 m s^{-1}. The mass of Q is 2 kg and the coefficient of restitution between P and Q is $\frac{1}{3}$.

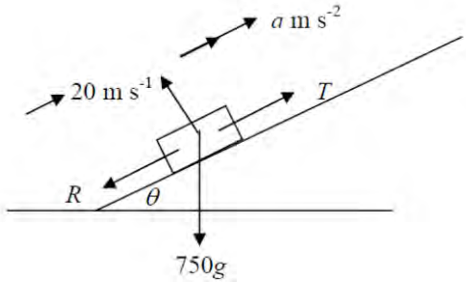
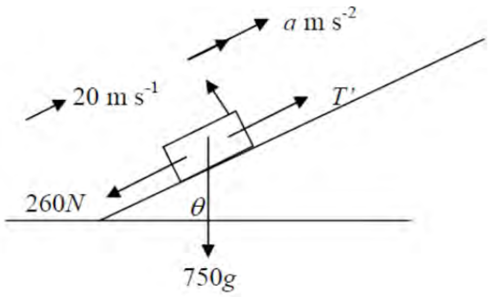
(*b*) Show that there will be a second collision between P and the wall.

(7)

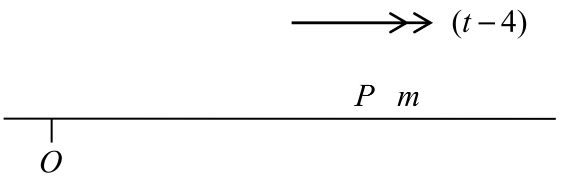
TOTAL FOR PAPER: 75 MARKS

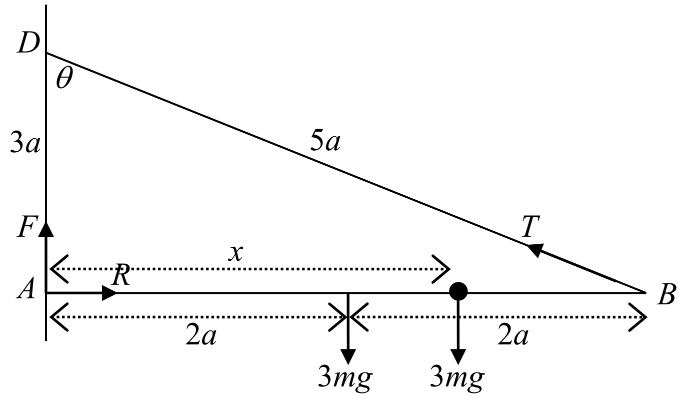
END

Question Number	Scheme	Marks
1. (a)	KE lost is $\frac{1}{2}\times 2.5\times 8^2 = 80\ (\text{J})$	M1 A1 **(2)**
(b)	Work energy $80 = R\times 20$ ft their (a) $R = 4$	M1 A1 ft A1 **(3)** **[5]**
2. (a)	$\mathbf{a} = \text{d}\mathbf{v}/\text{d}t = 6t\mathbf{i} - 4\mathbf{j}$	M1 A1
(b)	Using $\mathbf{F} = ½\mathbf{a}$, sub $t = 2$, finding modulus e.g. at $t = 2$, $\mathbf{a} = 12\mathbf{i} - 4\mathbf{j}$ $\mathbf{F} = 6\mathbf{i} - 2\mathbf{j}$ $\lvert\mathbf{F}\rvert = \sqrt{(6^2 + 2^2)} \approx$ <u>6.32 N</u>	M1, M1, M1 A1(CSO)
3. (a)	$a = 4t^3 - 12t$ Convincing attempt to integrate M1 $v = t^4 - 6t^2 (+ c)$ Use initial condition to get $v = t^4 - 6t^2 + 8\ (\text{ms}^{-1})$	M1 A1 A1 **(3)**
(b)	Convincing attempt to integrate $s = \frac{t^5}{5} - 2t^3 + 8\ (+0)$ Integral of their v	M1 A1ft **(2)**
(c)	Set their $v = 0$ Solve a quadratic in t^2 $(t^2 - 2)(t^2 - 4) = 0 \Rightarrow$ at rest when $t = \sqrt{2}$, $t = 2$	M1 DM1 A1 **(3)** **[8]**

Question Number	Scheme	Marks
4.		
(a)	$T = \frac{15000}{20} = 750$	**M1**
	R(parallel to road) $T = R + 750g \sin\theta$	**M1 A1**
	$R = 750 - 750 \times 9.8 \times \frac{1}{15}$	
	$R = 260$ *	**A1**
		(4)
		
(b)	$T = \frac{18000}{20} = 900$	**M1**
	$T = 260 - 750g \times \sin\theta = 750a$	**M1 A1**
	$a = \frac{900 - 260 - 750 \times 9.8 \times \frac{1}{15}}{750}$	
	$a = 0.2$	**A1**
		(4) **[8]**

Question Number	Scheme	Marks
5. (a)		
	$\frac{490}{3.5} - R = 0$	B1 M1 A1
	$R = 140$ N	A1 (4)
(b)	$\frac{24}{u} + 70g.\frac{1}{14} - 40u = 0$	B1
	$40u^2 - 49u - 24 = 0$	M1 A2,1,0
	$(5u - 8)(8u + 3) = 0$	DM1
	$u = 1.6$	DM1 A1 (7)
		[11]

Question Number	Scheme	Marks
6. (a)		
	$\frac{dv}{dt} = t - 4$	
	$v = \frac{1}{2}t^2 - 4t\left(+c\right)$	M1 A1
	$t = 0 \quad v = 6 \quad \Rightarrow c = 6$	M1
	$\therefore v = \frac{1}{2}t^2 - 4t + 6$	A1
		(4)
(b)	$v = 0 \quad 0 = t^2 - 8t + 12$	M1
	$\left(t-6\right)\left(t-2\right) = 0$	DM1
	$t = 6 \quad t = 2$	A1
		(3)
(c)	$x = \frac{t^3}{6} - 2t^2 + 6t + k$	M1 A1 ft
	$x_6 - x_2 = \frac{6^3}{6} - 2\times 6^2 + 6^2 + k$	DM1
	$-\left(\frac{2^3}{6} - 2\times 2^2 + 6\times 2 + k\right)$	
	$= -5\frac{1}{3}$	
	$\therefore$ Distance is $5\frac{1}{3}$ m	A1
		(4)
		11

Question Number	Scheme	Marks
7. (a)		
	M(A) $3mg\times 2a+3mgx=T\cos\theta\times 4a$	M1 A2,1,0
	$=\frac{12}{5}aT$	
	$\frac{12}{5}aT=6mga+3mgx$	
	$T=\frac{25}{4}mg$ $\quad\frac{12}{5}a\times\frac{25}{4}mg=6mga+3mgx$	M1
	$15a=6a+3x$	
	$x=3a$ **	A1
		(5)
(b)	R$(\rightarrow)$ $R=T\sin\theta$	M1
	$=\frac{25}{4}mg\times\frac{4}{5}$	A1
	$=5mg$ **	A1
		(3)
(c)	R$(\uparrow)$ $F+\frac{25}{4}mg\times\frac{3}{5}=3mg+3mg$	M1 A2,1,0
	$F=6mg-\frac{15}{4}mg=\frac{9}{4}mg$	
	$\mu=\frac{F}{R}=\frac{\frac{9}{4}mg}{5mg}=\frac{9}{20}$	DM1 A1
		(5)
		13

Question Number	Scheme	Marks
8		
(a)	KE lost : $\frac{1}{2} \times m \times 36 - \frac{1}{2} \times m \times v^2 = 64$	M1A1
	Restitution: $v = \frac{1}{3} \times 6 = 2$	M1A1
	Substitute and solve for m: $\frac{1}{2} \times m \times 36 - \frac{1}{2} \times m \times 4 = 64 = 16m$	DM1
	$m = 4$ answer given	A1
		(6)
(b)		
	Conservation of momentum: $6 - 8 = 4w - 2v$ their "2"	M1A1ft
	Restitution: $v + w = ⅓(2 + 3)$ their "2"	M1A1ft
	Solve for w: $-2 = 4w - 2\left(\frac{5}{3} - w\right) = 6w - \frac{10}{3}$	DM1
	$\frac{4}{3} = 6w$	A1
	$\left(w = \frac{4}{18} = \frac{2}{9}\ \text{s}^{-1}\right)$	
	$w > 0 \Rightarrow$ will collide with the wall again	A1
		(7)
		[13]

Examiner reports

Question 1

This proved to be a very straightforward "starter" for most candidates and full marks were generally scored. Where students lost marks this was usually due to a lack of appreciation that the kinetic energy lost and the value of R should both have been positive. The methods used for part (b) were divided equally between the method using work done against R and the method of calculating the acceleration. A small minority of students became confused about the nature of the horizontal force acting in part (b), and duplicated the force by considering the sum of both work-energy and Newton's 2nd law. It was not uncommon to see candidates using their own notation, with F frequently being used for R. Many candidates gave the final answer as 4 N rather than the number 4.

Question 2

There were many correct solutions to this question. Only a small minority of candidates failed to differentiate $\mathbf{v}$ to find $\mathbf{a}$ in part (a), and most candidates obtained the correct value for the magnitude of the force in part (b). Incorrect answers were usually due to arithmetic errors, or originated from the sign error $\mathbf{a} = 6t\mathbf{i} + 4\mathbf{j}$ in part (a). Other common differentiation errors gave $\mathbf{a} = 6t\mathbf{i} - 4t\mathbf{j}$ or $\mathbf{a} = 6t\mathbf{i}+(1 - 4)\mathbf{j}$.

Question 3

The vast majority of candidates knew that integration was required for parts (a) and (b) and they performed this competently with only a small minority omitting the constants of integration. A small number did try to use *suvat* inappropriately, and one or two differentiated instead of integrating. Part (c) most candidates knew that they needed to put $v = 0$ and most of these recognised the equation as a quadratic in t^2 and factorised or sometimes completed the square to obtain values of 2 and 4 for t^2. The final mark was occasionally lost by a failure to reject negative values of t. Candidates who did not recognise the quartic as a quadratic in t^2 sometimes went to considerable lengths to use the factor theorem and/or trial and improvement to find factors of the quartic, but they rarely reached the correct final answer. Another common error was to rearrange the equation as $t^4 - 6t^2 = -8$ and attempt to set factors of the left hand side equal to factors of -8.

Question 4

This question produced a very good response with many candidates scoring full marks. The connection between power, driving force and velocity is clearly understood.

In part (a) the given answer ensured that those who were uncertain how to proceed could review their work and find the correct approach. Candidates should be reminded to use the notation introduced in a question (R) and to be careful not to omit any steps when deriving a given answer.

In part (b) the most common error was the omission of either the weight component or the resistance when applying Newton's second law parallel to the slope.

Question 5

Very few students were unable to find the magnitude of the resistance to motion in (a) although some did produce some lengthy arguments before achieving the required solution. Others omitted to justify that the resistance had the same magnitude as the driving force.

In part (b) most candidates were able to attempt the equation of motion, although some failed to notice or to take correct account of the fact that this cyclist is moving down the road, rather than up, resulting in several sign errors. Most candidates were able to manipulate the equation, successfully incorporating $F = \frac{24}{u}$ (or equivalent) and going on to obtain and solve a quadratic equation.

Question 6

The candidates appear to have been well prepared for the variable acceleration question with many fully correct answers seen. In part (a), most solutions included the constant of integration which was then successfully found. Any integration errors usually involved omission of the $\frac{1}{2}$ from the t^2 term.

Most candidates realised that they had to solve $v = 0$ but this seemed to take much effort for some in part (b).

In part (c), having doubled their expression for v in solving the quadratic equation in (b), some candidates tried to integrate their doubled equation here. There were many calculation errors in the substitution of the t values and a few candidates were stumped as to what to do with the indeterminable constant of integration. Most candidates realised that the final answer had to be positive. Some candidates tried, inappropriately, to use *suvat* equations to find the distance.

Question 7

This question proved to be more accessible than those of a similar type in recent years, possibly because it was a little more obvious which were the best points about which to take moments and, having given answers, candidates had the opportunity to backtrack if they made a mistake. However candidates should be reminded that when the answer is given, the onus is on them to give a more detailed solution than might otherwise be expected.

It was surprising that some candidates failed to note that *DAB* was a 3, 4, 5 triangle with corresponding simple trig ratios and instead used their calculators to find an angle and, with subsequent rounding, often failed to achieve the required final accuracy.

Many candidates were able to gain full marks in part (a) by taking moments about *A*. Those who did not take moments about *A* usually failed to realise that there were forces at *A* that should be taken into account. A missing *g* in the moments equation was surprisingly common. A few candidates missed out at least one distance, and some did not consider the angle at all.

Part (b) was usually done well, but some candidates lost marks because they did not show sufficient working to support the given answer or they lost accuracy through using an approximate value for the size of the angle.

Part (c) was often well answered but sometimes an extra vertical force was introduced for the friction at *A* and sometimes unfortunate labelling of the forces at *A* (*F* horizontally and *R* vertically) led to confusion for some candidates when it came to calculating μ.

Question 8

Candidates found this impact question more straight forward than some in recent years. In part (a) many candidates derived the given answer correctly. A few made sign errors in equating the change in KE to energy lost and a small number were not able to complete this part because they could not find the speed immediately after the impact. In part (b), a lack of clear diagrams sometimes led to sign errors and confusion over the direction of motion of the particles after the collision, but many candidates gained full marks in this question. Most candidates formed a correct equation for the conservation of momentum, and there were fewer errors this time in applying Newton's Experimental Law. There were arithmetic and algebraic errors in solving the simultaneous equations, but the standard of justification of the second collision was good.

Statistics for M2 Practice Paper Bronze 1

				Mean average scored by candidates achieving grade:							
Qu	**Max Score**	**Modal score**	**Mean %**	**ALL**	**A***	**A**	**B**	**C**	**D**	**E**	**U**
1	5		91.6	4.58		4.92	4.50	4.44	4.44	3.43	3.04
2	6		89.8	5.39		5.84	5.57	5.34	4.83	4.37	2.98
3	8		86.9	6.95	7.66	7.33	6.68	6.06	5.08	3.22	3.43
4	8		89.4	7.15	7.86	7.68	7.33	6.92	6.07	5.02	3.23
5	11		83.8	9.22		9.99	8.69	7.16	6.31	4.08	3.60
6	11		90.3	9.93	10.77	10.55	10.17	9.72	8.98	7.71	5.30
7	13		75.9	9.87	12.25	11.62	9.97	8.01	5.44	3.55	2.28
8	13		82.5	10.73	12.05	11.49	10.02	8.00	7.26	3.85	3.94
	75		**85.1**	**63.82**		**69.42**	**62.93**	**55.65**	**48.41**	**35.23**	**27.80**