A level Applied Paper 3B Mechanics Practice Paper M17 MARK SCHEME

Question 1

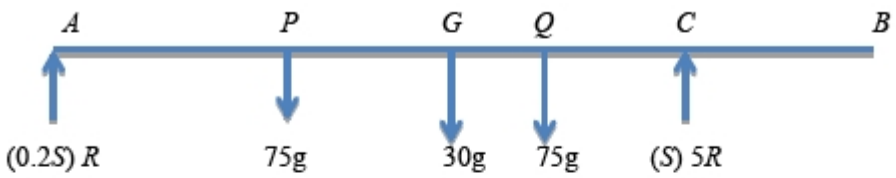
Question Number	Scheme	Marks
(a)	$s = vt - \frac{1}{2}at^2$ $40 = 10 \times 5 - \frac{1}{2}a5^2$ $a = 0.8$	M1 A2 A1 (4)
(b)	Finding u $(=6)$ $s = ut + \frac{1}{2}at^2$ $(A \text{ to } M)$ $20 = 6t + \frac{1}{2}0.8t^2$ $t = \frac{-15 \pm \sqrt{225+200}}{2}$ $= 2.8$ or 2.81 or better	M1 M1 A1 **DM1** A1 (5)
	Alternative : Finding v $(=\sqrt{68})$ $s = vt - \frac{1}{2}at^2$ $(A \text{ to } M)$ $20 = \sqrt{68}t - \frac{1}{2}0.8t^2$ $t = \frac{\sqrt{68} \pm \sqrt{68-32}}{0.8}$ $= 2.8$ or 2.81 or better	M1 M1 A1 **DM1** A1 (5)
	Alternative : $s = vt_1 - \frac{1}{2}at_1^2$ $(M \text{ to } B)$ $20 = 10t_1 - \frac{1}{2}0.8t_1^2$ $t_1 = \frac{10 \pm \sqrt{100-32}}{0.8}$ $= 2.192$ $t = 5 - t_1 = 2.8$ or 2.81 or better	M2 A1 **DM1** A1 (5) **9**

	Notes	
(a)	First M1 for a complete method to produce a value for a. They may use two (or more equations) and solve for a.(see possible equations) A2 if all correct, A1A0 for one error Third A1 for 0.8 (m s^{-2}) Possible equations: $40 = 5u + \frac{1}{2}a.5^2$ $10^2 = u^2 + 2a.40$ $10 = u + 5a$ $40 = \frac{(u+10)}{2}.5$	
(b)	First M1 for attempt to find a value for u (This may have been done in part (a) but MUST be used in (b)) Second M1 for a complete method (may involve 2 or more *suvat* equations) for finding an equation in t *only* First A1 for a correct equation Third M1, **dependent** on previous M, for solving their equation for t Second A1 for 2.8 (s) or better or $\frac{5(2\sqrt{17}-6)}{4}$; $\frac{40}{6+2\sqrt{17}}$	

Question 2

Question Number	Scheme	Marks
	$T - 0.5g = 0.5a$ $15 - T - 0.75g = 0.75a$ (OR: $15 - 0.5g - 0.75g = 1.25a$) $(a = 2.2 \text{ m s}^{-2})$ $T = 6 \text{ N}$	M1 A1 M1 A1 M1 A1 **6**
	Notes	
	First M1 for an equation of motion for either P or Q with usual rules i.e. correct no. of terms, dimensionally correct but condone sign errors First A1 for a correct equation (allow T replaced by $-T$ and/or a replaced by $-a$) Second M1 for another equation of motion (for either P or Q or whole system) with usual rules as above Second A1 for a correct equation (allow T consistently replaced by $-T$ and/or a consistently replaced by $-a$) Third M1 for solving two THREE term equations of **motion** for T Third A1 for 6 (N). Must be positive but allow a change from – 6 to 6, if they have consistently used $-T$ instead of T.	

Question 3

Question Number	Scheme	Marks
(a)	 $(\uparrow)\ R+5R=75g+30g+75g$ $M(A)\quad 75gx+75g2x+30g\times 3=5R\times 4$ $x=\frac{34}{15}=2.3$ or better (N.B. Or another Moments Equation)	M1 A2 M1 A2 A1 (M1 A2) (7)
(b)	uniform – mass is or acts at midpoint of plank; centre of mass is at middle of plank; weight acts at the middle of the plank, centre of gravity is at midpoint rod - plank does not bend, remains straight, is inflexible, is rigid	B1 B1 (2) **9**
	Notes	
(a)	First M1 for either a vertical resolution (with correct of terms) or a moments equation (all terms dim correct and correct no. of terms) First A1 and Second A1 for a correct equation in R (or S where $S = 5R$) only or R and x only or S and x only. (–1 each error , A1A0 or A0A0) Second M1 for a moments equation (all terms dim correct and correct no. of terms) Third A1 and Fourth A1 for a correct equation in R (or S where $S = 5R$) only or R and x only or S and x only. (–1 each error, A1A0 or A0A0) Fifth A1 for $x = {}^{34}/_{15}$ oe or 2.3 (or better) **(i)** In a moments equation, if R and $5R$ (or S and $0.2S$) are interchanged, treat as 1 error. **(ii)** Ignore diagram if it helps the candidate. **(iii)** If an equation is correct but contains both R and S, *or $S = 5R$ is never used*, treat as 1 error. **(iv)** Full marks possible if all g's omitted. **(v)** For inconsistent omission of g, penalise each omission. $M(B),\ R\times 6+5R\times 2=75g(6-x)+75g(6-2x)+30g\times 3$ $M(C),\ 75g(4-x)+75g(4-2x)+30g\times 1=R\times 4$ $M(G),\ 75g(3-x)+5R\times 1=R\times 3+75g(2x-3)$ $M(P),\ Rx+30g(3-x)+75gx=5R(4-x)$ $M(Q),\ 75gx+30g(2x-3)+5R(4-2x)=R\times 2x$	
(b)	First B1 for first correct answer seen. Second B1 for the other answer, but only award this second mark if no extras given.	

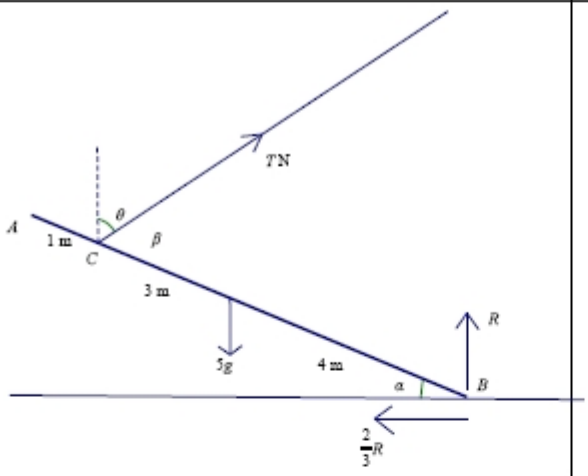
Question 4

Question Number	Scheme	Marks
	$(15\mathbf{i}+\mathbf{j})+(5q\mathbf{i}-p\mathbf{j})+(-3p\mathbf{i}-q\mathbf{j})=\mathbf{0}$ $3p-5q=15$ $p+q=1$ $p=2.5 \quad q=-1.5$	M1 M1 A1 M1 A1 A1 **6**
	Notes	
	First M1 for equating the sum of the three forces to zero (can be implied by subsequent working) Second M1 for equating the sum of the **i** components to zero AND the sum of the **j** components to zero oe to produce TWO equations, each one being in p and q ONLY. First A1 for TWO correct equations (in any form) **N.B.** It is possible to obtain TWO equations by using $\lambda(3p-5q-15)=\mu(p+q-1)$ with TWO different pairs of values for λ and μ, with one pair not a multiple of the other e.g λ=1, μ=1 AND λ=1, μ=2. Third M1(independent) for attempt (either by substitution or elimination) to produce an equation in either p ONLY or q ONLY. Second A1 for p = 2.5 (any equivalent form, fractions do not need to be in lowest terms) Third A1 for q = - 1.5 (any equivalent form, fractions do not need to be in lowest terms)	

Question 5

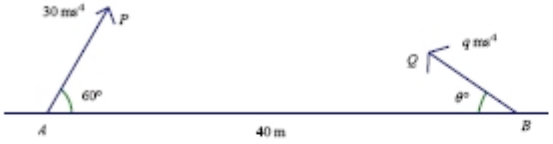
Question Number	Scheme	Marks
	$F=\mu R$ $(\nwarrow\searrow), \quad R=10\sin\alpha+5g\cos\alpha \quad (45.2)$ $(\nearrow), \quad F=5g\sin\alpha-10\cos\alpha \quad (21.4)$ $\mu=\dfrac{g\sin\alpha-2\cos\alpha}{2\sin\alpha+g\cos\alpha}=0.47 \text{ or } 0.473$	B1 M1 A2 M1 A2 M1 A1 **9**
	Notes	
	B1 for $F=\mu R$ seen or implied First M1 for resolving perpendicular to the plane with usual rules First and second A1's for a correct equation. A1A0 if one error. Second M1 for resolving parallel to the plane with usual rules Third and fourth A1's for a correct equation. A1A0 if one error. If m is used instead of 5, penalise once in each equation. Third M1 independent for eliminating R to produce an equation in μ only. Does not need to be μ = ... Fifth A1 for 0.47 or 0.473.	

Question 6

Q.	Scheme	Marks	Notes
a			
	$F=\frac{2}{3}R$ seen or implied	B1	Use of $F=\mu R$. Could be on diagram. Allow in (b) if not seen before
	$\text{M}(C): 5g\times 3\cos\alpha + F\times 7\sin\alpha = 7\cos\alpha\times R$	M1	Moments about C or alternative complete method to find equation in F and R or R only. Dimensionally correct and all terms needed. Condone sin/cos confusion and sign error(s).
		A1	At most one error
		A1	Correct unsimplified equation
	$15g\cos\alpha = R\left(7\cos\alpha - \frac{14}{3}\sin\alpha\right)$		
	$15g\times\frac{4}{5} = R\left(7\times\frac{4}{5} - \frac{14}{3}\times\frac{3}{5}\right) = \frac{14}{5}R$	dM1	Substitute for F and trig and solve for R Dependent on previous M1
	$R=\frac{30}{7}g = 42\,(\text{N})$	A1	
		(6)	
	e.g. of alternative for M1A1A1:		
	$\text{M}(A): T\sin\beta + 8R\cos\alpha = 8F\sin\alpha + 20g\cos\alpha$ **and** $\text{M}(B): 7T\sin\beta = 20g\cos\alpha$	(M1)	
		(A1)	At most 1 error
	$\frac{20g}{7}\cos\alpha + 8R\cos\alpha = 8F\sin\alpha + 20g\cos\alpha$	(A1)	Correct unsimplified equation in F and R or R only

Q.	Scheme	Marks	Notes
b	Resolve ↕: $T\cos\theta + R = 5g$ $R + T\sin(\beta-\alpha) = 5g$	M1	Need all terms. Condone sin/cos confusion and sign error(s).
		A1	Correct in R or *their* R
	Resolve ↔: $T\sin\theta = F\,(=28)$ $F\left(=\frac{2}{3}R\right) = T\cos(\beta-\alpha)$	M1	Need both terms. Condone sin/cos confusion
		A1	Correct in R or *their* R
	Solve simultaneous equations for $\beta-\alpha$		
	$\tan(\beta-\alpha)=4$, $\beta = 50.9°$ $(51°)$	A1	cso . Max 3 s.f.
		(5)	
Alt b	M(*B*): $7\times T\sin\beta = 5g\cos\alpha\times 4$	M1	Moments equation. Dimensionally correct. Condone sin/cos confusion and sign error(s).
	$\left(T\sin\beta = \frac{16}{7}g\right)$	A1	
	OR: resolve perpendicular to the rod: $T\sin\beta + R\cos\alpha = 5g\cos\alpha + \frac{2}{3}R\sin\alpha$	(M1) (A1)	
	Resolve parallel to rod: $T\cos\beta + 5g\sin\alpha = F\cos\alpha + R\sin\alpha$ $\left(=\frac{2}{3}R\cos\alpha + R\sin\alpha\right)$	M1	All terms needed. Condone sin/cos confusion and sign error(s).
	$\left(T\cos\beta = \frac{13}{7}g\right)$	A1	
	Solve simultaneous equations for β		
	$\tan\beta = \frac{16}{13}$, $\beta = 50.9°$ $(51°)$	A1	cso. Max 3 s.f.
		(5)	
		[11]	

Question 7

Q.	Scheme	Marks	Notes
a			
	$30\cos 60\times 2+q\cos\theta\times 2=40$	M1	Equation for horizontal distance Need to be using the 40 m
		A1	Correct unsimplified
	$30\sin 60\times 2-4.9\times 4=q\sin\theta\times 2-4.9\times 4$ $30\sin 60=q\sin\theta$	M1	Equal vertical distance or initial vertical components of velocity
		A1	Correct unsimplified (no error seen)
	$q\cos\theta=\pm 5$ $q\sin\theta=15\sqrt{3}$		
	$\tan\theta=3\sqrt{3}$ $(\tan\theta=6\sin 60)$	DM1	Solve for q or θ Dependent on both preceding M marks
	$\theta=79.1\ \ (79)$		(1.38 radians) or better
	$q=26.45...=26.5$	A1	(26 or better) $(10\sqrt{7})$ Both correct and no error seen
		(6)	
b	Vertical component of speed =	M1	Must be working towards speed of P (or v^2) (condone if working on Q - they equal vertical components of velocity)
	$30\sin 60-2g\ (=6.38...)$	A1	Correct unsimplified. Accept ±
	speed $=\sqrt{(30\cos 60)^2+6.38^2}$	DM1	Use Pythagoras. Dependent on previous M Follow their vertical component.
		A1ft	Correct unsimplified equation in v or v^2.
	$=\sqrt{15^2+6.38^2}=16.3\,(\text{m s}^{-1})$	A1	or 16 2 or 3 sf only
		(5)	
b alt	Vertical distance =	M1	Must be working towards speed of P
	$30\sin 60\times 2-4.9\times 4=32.36$	A1	Correct unsimplified
	Conservation of energy:	DM1	Dependent on previous M. Follow their vertical distance.
	$\frac{1}{2}mv^2+mg\times 32.36=\frac{1}{2}m\times 900$	A1ft	Correct unsimplified equation in v or v^2.
	$v=16.3\ (\text{m s}^{-1})\ \ (16)$	A1	
		(5)	
		[11]	

Question 8

Question Number	Scheme	Marks
(a)	$\tan\theta = \frac{2}{9}$ $\theta = 12.5^\circ$ bearing 103°	M1 A1 A1 (3)
(b) **(i)** **(ii)**	$\mathbf{p} = (9\mathbf{i}+10\mathbf{j})+t(9\mathbf{i}-2\mathbf{j})$ $\mathbf{q} = (\mathbf{i}+4\mathbf{j})+t(4\mathbf{i}+8\mathbf{j})$	M1 A1 A1 (3)
(c)	$\overrightarrow{QP} = (8+5t)\mathbf{i}+(6-10t)\mathbf{j}$	M1 A1 (2)
(d)	$D^2 = (8+5t)^2+(6-10t)^2$ $= 125t^2-40t+100$ $100 = 125t^2-40t+100$ $0 = 5t(25t-8)$ $t = 0$ or 0.32	M1 A1 M1 M1 A1 A1 (6) **14**
	Notes	
(a)	M1 for $\tan\theta = \pm\frac{2}{9}$ or $\pm\frac{9}{2}$ or use $\sin\theta$ or $\cos\theta$	
	First A1 for $\theta = \pm 13^\circ$ or $\pm 77^\circ$ or $\pm 12.5^\circ$ or $\pm 77.5^\circ$ or better	
	Second A1 for 103°	
(b)	M1 for clear attempt at $\mathbf{p} = (9\mathbf{i}+10\mathbf{j})+t(9\mathbf{i}-2\mathbf{j})$ or $\mathbf{q} = (\mathbf{i}+4\mathbf{j})+t(4\mathbf{i}+8\mathbf{j})$ (Allow slips but must be a '+' sign and $\mathbf{r}+t\mathbf{v}$)	
(i)	First A1 for $\mathbf{p} = (9\mathbf{i}+10\mathbf{j})+t(9\mathbf{i}-2\mathbf{j})$oe	
(ii)	Second A1 for $\mathbf{q} = (\mathbf{i}+4\mathbf{j})+t(4\mathbf{i}+8\mathbf{j})$oe	
(c)	M1 for $\mathbf{p}-\mathbf{q}$ or $\mathbf{q}-\mathbf{p}$ with their $\mathbf{p}$ and $\mathbf{q}$ substituted A1 for correct answer $\overrightarrow{QP} = (8+5t)\mathbf{i}+(6-10t)\mathbf{j}$ (don't need $\overrightarrow{QP}$ but on R.H.S must be **identical** coefficients of **i** and **j** but allow column vectors)	
(d)	First M1 for attempt to find QP or QP^2 in terms of t *only*, using correct formula First A1 for a correct expression (with or without √) $125t^2-40t+100$ Second M1 for √ (3 term quadratic) = 10 or (3 term quadratic) =100. Third M1 for quadratic expression = 0 and attempt to solve (e.g. factorising or using formula) Second A1 for $t = 0$ (if they divide by t and lose this value but get 0.32, M1A0A1) Third A1 for $t = 0.32$ oe	

Question 9

Question Number	Scheme	Marks
(a) **(i)** **(ii)**	For A : $T - F = 2ma$ For B : $mg - T = ma$	M1 A1 M1 A1 (4)
(b)	$R = 2mg$ $mg(1-2\mu) = 3ma$ $\frac{g}{3}(1-2\mu) = a$	B1 M1 A1 (3)
(c)	$v^2 = \frac{2gh}{3}(1-2\mu)$ $v = \sqrt{\frac{2gh}{3}(1-2\mu)}$	M1 A1 (2)
(d)	$-\mu R = 2ma'$ $0^2 = \text{their } u^2 - 2a's$ $0 = \frac{2gh}{3}(1-\frac{2}{3}) - 2(\frac{1}{3}g)s$ (or $s = (d-h)$) $s = \frac{1}{3}h$ $d = \frac{1}{3}h + h = \frac{4}{3}h$	M1 M1 A1 (A1) A1 A1 (5)
(e)	A (or B) would not move; **OR** A (or B) would remain in (limiting) equilibrium; **OR** the system would remain in (limiting) equilibrium	B1 (1) **15**

	Notes	
(a)(i)	First M1 for equation of motion for A with usual rules First A1 for a correct equation (allow $-T$ instead of T)	
(ii)	Second M1 for equation of motion for B with usual rules Second A1 for a correct equation (allow consistent $-T$ instead of T)	
(b)	B1 for $R = 2mg$ M1 for using $F = \mu R$ and eliminating to give equation in a and μ only. A1 for PRINTED ANSWER (Must be identical to printed answer)	
(c)	M1 for using $v^2 = u^2 + 2as$ or any other complete method to find the speed of A A1 for correct answer in any form	
(d)	First M1 for equation of motion for A with $T = 0$ and $F = \mu R$ e.g. $\mu R = 2ma'$ (must be $2m$) Second M1 for using $v^2 = u^2 + 2as$ with their u^2 from (c), $v = 0$ and a **new** a (does **not** need to be substituted) First A1 for a correct equation in s, g and h with $\mu = {}^1/_3$ Second A1 for $s = {}^1/_3\, h$ Third A1 for $d = {}^4/_3\, h$ **ALTERNATIVE** using work-energy principle: M2 for $\mu Rs = \frac{1}{2}2mu^2$ (their u^2 from (c)) (M1 if they use m) First A1 for $\frac{1}{3}2mgs = \frac{1}{2}2m\frac{2gh}{3}(1-\frac{2}{3})$ Second A1 for $s = {}^1/_3\, h$ Third A1 for $d = {}^4/_3\, h$	
(e)	B1 for any one of the alternatives listed above.	

Question 10

Q.	Scheme	Marks	Notes
a	$v=0 \Rightarrow 3t^2-16t+21=0$	M1	Set $v=0$ and attempt to solve
	$((3t-7)(t-3)=0) \quad t_1=\frac{7}{3}, \quad t_2=3$	A1	
		(2)	
b	$a=\frac{\mathrm{d}}{\mathrm{d}t}\left(3t^2-16t+21\right)$	M1	Differentiate v to obtain a
	$=6t-16$	A1	
	$t=t_1, \quad a=6\times\frac{7}{3}-16=-2\ (\mathrm{m\,s^{-2}})$ Magnitude 2 $(\mathrm{m\,s^{-2}})$	A1	No errors seen. Must be positive - the Q asks for magnitude.
		(3)	
c	$s=\int\left(3t^2-16t+21\right)\mathrm{d}t$	M1	Integrate v to find s
	$=t^3-8t^2+21t(+C)$	A1	
	$\pm\left(\left(3^3-8\times9+21\times3\right)-\left(\left(\frac{7}{3}\right)^3-8\times\frac{49}{9}+21\times\frac{7}{3}\right)\right)$	M1	Correct use of their limits
	$s=0.148\ (\mathrm{m}) \quad \left(\frac{4}{27}\right)$	A1	Final answer must be positive. 0.15 or better
		(4)	
d	Return to $O \Rightarrow s=0=t\left(t^2-8t+21\right)$	B1	seen or implied
	Discriminant of quadratic $=64-4\times21(=-20)<0$	M1	Or equivalent. ***given answer so must show some evidence of method***
	No real roots $\Rightarrow$ does not return to O	A1	Sufficient correct working to justify ***given answer***
		(3)	
dalt	Travels away until $t_1=\frac{7}{3}$, turns back at $t_2=3$ then turns away again	M1	Complete story
	$s_3=18$	B1	Seen or implied
	Complete argument	A1	
		(3)	
dalt	Distance time graph	B1	
	Locate min turning point	M1	
	Complete argument	A1	
		(3)	
		[12]	