

Question	Answer	Marks	Guidance
1	Impulse = 0·2 × (250 – 40) = 42	**M1 A1**	Find impulse from change in momtm. (may be implied) (if sign of 40 wrong here or below, can allow M1)
	T = 42 / 1200 = 7/200 *or* 0·035 [s]	**M1 A1**	Find time T from impulse = Ft
	Alternative method for question 1		
	a = 1200 / 0·2 = 6000	**M1 A1**	Find acceleration a from $F = ma$ (may be implied)
	T = (250 – 40) / 6000 = 7/200 *or* 0·035 [s]	**M1 A1**	Find time T from $v = u + at$
	Alternative method for question 1		
	K.E. = ½ × 0·2 × ($250^2 - 40^2$) = 6090	**M1**	Find loss of K.E. (may be implied; ignore sign of K.E.)
	Work = 1200 × ½ (250 + 40) T = 174 000 T	**M1 A1**	Find work done from F × ½ ($u + v$) t (A1 for both)
	T = 6090 / 174 000 = 7/200 *or* 0·035 [s]	**A1**	Equate to find T
		4	

Question	Answer	Marks	Guidance
2(i)	$T_A = m\,v_A^2 / a - mg\cos\alpha$ $[= m\,(9ag/4) / a - mg\cos\alpha]$	B1	Find tension T_A at A from $F = ma$ radially
	$T_B = m\,v_B^2 / a + mg\cos\alpha$	B1	Find tension T_B at B from $F = ma$ radially
	$\frac{1}{2}mv_B^2 = \frac{1}{2}m\,v_A^2 + 2mga\cos\alpha$ $[v_B^2 = ag\,(9/4 + 4\cos\alpha)]$	M1 A1	Apply conservation of energy at B (A0 if no m)
	$v_B^2 = 4v_A^2 - 5ag\cos\alpha = v_A^2 + 4ga\cos\alpha$	M1	Combine using $T_B = 4\,T_A$ and $v_A^2 = 9ag/4$ to verify $\cos\alpha$
	$9ag\cos\alpha = 3v_A^2 = 27ag/4$, $\cos\alpha = 3/4$ **AG**	A1	
		6	
2(ii)	$T_B = 4\,T_A = (9 - 4\cos\alpha)\,mg = 6mg$ *or* $v_B^2 = 21ag/4$, $T_B = (21/4 + \cos\alpha)\,mg = 6mg$	M1 A1	Find T_B
		2	

Question	Answer	Marks	Guidance
3(i)	$3mv_A + mv_B = 3mu$ [*or* $3v_A + v_B = 3u$] (AEF)	**M1**	Use conservation of momentum for A and B (correct masses)
	$v_B - v_A = eu$	**M1**	Use Newton's restitution law with consistent LHS signs
	$v_A = ¼\,(3 - e)\,u$ [$v_B = ¾\,(1 + e)\,u$]	**A1**	Combine to find speed of A
	$w_B + v_C = v_B$ *and* $v_C - w_B = ev_B$ (AEF)	**M1**	Use conservation of momentum for B and C *and* Newton's restitution law with consistent LHS signs
	$w_B = ½\,(1 - e)\,v_B$ *and* $v_C = ½\,(1 + e)\,v_B$ $w_B = (3/8)\,(1 - e^2)\,u$ *and* $v_C = (3/8)\,(1 + e)^2\,u$ aef	**A1 A1**	Combine to find w_B *and* v_C in terms of v_B (may be implied) and with v_B replaced (note: $v_C = \frac{3}{8}e^2u + \frac{3}{4}eu + \frac{3}{8}u$)
		6	
3(ii)	$¼\,(3 - e) = (3/8)\,(1 + e)^2$	**M1**	Find equation in e by equating their v_A and their v_C
	$3e^2 + 8e - 3 = 0 = (3e - 1)\,(e + 3)$	**M1**	Simplify and solve resulting quadratic eqn for e,
	$e = 1/3$	**A1**	(implicitly) rejecting $e = -3$
		3	

Question	Answer	Marks	Guidance
4(i)	I_{AB} = ⅓ $5M(7a/2)^2 + 5M(7a/2)^2$ *or* $(4/3)\,5M(7a/2)^2$ [= $(245/3)\,Ma^2$]	**B1**	Find or state MI of rod *AB* about axis at *A*
	I_M = ⅔ $M(2a)^2 + M(7a)^2$ [= $(155/3)\,Ma^2$]	**M1 A1**	M1 for one term correct, A1 for both terms correct
	I_{kM} = ⅔ $kMa^2 + kM(4a)^2$ [= $(50/3)\,kMa^2$]	**M1 A1**	M1 for one term correct, A1 for both terms correct
	I = [$(245/3 + 155/3 + 50k/3)\,Ma^2$ =] $(50/3)(8 + k)\,Ma^2$	**A1**	Find MI of object about axis at *A,* simplified to 2 terms aef
		6	
4(ii)	½ $I\omega^2$ = $5Mg(7a/2)(1 - \cos 60°) + Mg(7a)(1 - \cos 60°)$	***M1 A1**	Find eqn. for ω^2 when *AB* vertical by energy (3 terms on RHS, same trig expression in each for M1) A1 for 2 terms correct on RHS
	$+ kMg(4a)(1 - \cos 60°)$	**A1**	A1 for RHS and LHS all correct
	¼ $(49 + 8k)$ / ½ $(50/3)(8 + k) = 81/400$	**DM1**	Equate ω^2 to $81g / 400a$ to find k
	$4(49 + 8k) = 27(8 + k)$, $k = 4$	**A1**	
	Alternative method for question 4(ii)		
	$6 + k)\,Mg \times \{(49 + 8k)/2(6 + k)\}(1 - \cos 60°)$ = ½ $(49 + 8k)\,Mga(1 - \cos 60°)$ = ¼ $(49 + 8k)\,Mga$	***M1 A1** **A1**	M1 for mass × com × trig expression, A1 for 2 parts correct A1 all correct
	¼ $(49 + 8k)$ / ½ $(50/3)(8 + k) = 81/400$	**DM1**	Equate ω^2 to $81g / 400a$ to find k
	$4(49 + 8k) = 27(8 + k)$, $k = 4$	**A1**	
		5	

Question	Answer	Marks	Guidance
5(i)	$R_B \cos\theta + F_B \sin\theta = W \sin\theta + ¼\, W \sin\theta$	*M1 A1	Resolve forces along rod AB ($\sin\theta = 3/5$, $\cos\theta = 4/5$)
	$F_B = ⅓\, R_B$	B1	Relate F_B and R_B (may be implied)
	$(4/5 + ⅓ \times 3/5)\, R_B = (1 + ¼)\,(3/5)\, W$, $R_B = ¾\, W$ **AG**	DM1 A1	Combine using $\tan\theta = ¾$ to verify R_A
		5	
5(ii)	$R_C = F_B \cos\theta - R_B \sin\theta + W \cos\theta + ¼\, W \cos\theta$	*M1 A1	Resolve forces perpendicular to rod AB, where C denotes rim Substitute to find R_C
	$= (⅓ \times ¾ \times 4/5)\, W - (¾ \times 3/5)\, W + (5/4 \times 4/5)\, W$	DM1	
	$= (1/5 - 9/20 + 1)\, W = ¾\, W$	A1	
		4	
5(iii)	A: $R_C \times AC + (R_B \sin\theta - F_B \cos\theta) \times 2x - W \cos\theta \times x$ [$= W\,(¾ \times 2x - ¾ \times 8a/5 + 9/20 \times 2x - 1/5 \times 2x - 4x/5)$] C: $(R_B \sin\theta - F_B \cos\theta) \times 2a \cos\theta - W \cos\theta \times CG + ¼W \cos\theta \times AC$ [$= W\,(9/20 \times 2a - 1/5 \times 2a - 8a/5 + x + ¼ \times 2x - ¼ \times 8a/5) \cos\theta$] G: $R_C \times CG - (R_B \sin\theta - F_B \cos\theta) \times x - ¼\, W \cos\theta \times x$ [$= W\,(¾ \times 8a/5 - ¾ \times x - 9/20 \times x + 1/5 \times x - 1/5 \times x)$] B: $R_C \times 2a \cos\theta - W \cos\theta \times x - ¼W \cos\theta \times 2x$ [$= W\,(¾ \times 2a - x - ¼ \times 2x) \cos\theta$]	M1 A1	Find total moments about any point, denoting rod's centre by G (taken on either side of C) where $AC = 2x - 2a \cos\theta = 2x - 8a/5$ $CG = x - AC = 2a \cos\theta - x = 8a/5 - x$
	$x = a$	A1	Substitute and equate to zero to find x
		3	

Question	Answer	Marks	Guidance
6(i)	f(t) = (1/400) exp (– t/400) *or* 0·0025 exp (– 0·0025 t) [= 0 (t < 0)]	B1	State probability density function f(t) for $t \geqslant 0$
		1	
6(ii)	P(T < 500) $= \int_0^{500} f(t)\,dt = [\exp(-t/400)]_0^{500}$ $= 1 - e^{-5/4} = 0{\cdot}7135$ *or* 0·713 (allow 0·714)	M1 A1	Find P(T < 500): (M0 for 1 – F(500) = 0.287)
		2	
6(iii)	$1 - e^{-m/400}$ *or* $e^{-m/400} = ½$, $e^{m/400} = 2$	M1	Find median value m from F(m) = ½
	m = 400 ln 2 *or* 277	M1 A1	
		3	

Question	Answer	Marks	Guidance
7(i)	$E(X) = 1 / (½ \times ½) = 4$	**B1**	Find or state E(X)
		1	
7(ii)	$P(X = 3) = q^2 p$ (with $p = ¼$, $q = ¾$) = 9/64 *or* 0·141	**M1 A1**	Find prob. of exactly 3 throws needed
		2	
7(iii)	$P(X < 4) = 1 - q^3 = 37/64$ *or* 0·578	**M1 A1**	Find prob. of fewer than 4 throws needed
		2	
7(iv)	$1 - q^{N-1} > 0{\cdot}95$ (AEF)	**M1**	Formulate condition for N ($1 - q^N$ is M0)
	$0{\cdot}05 > (3/4)^{N-1}$, $N - 1 > \log 0{\cdot}05 / \log 0{\cdot}75$	**M1**	Set q = 3/4, rearrange and take logs (any base) to give bound
	$N - 1 > 10{\cdot}4$, $N_{min} = 12$	**A1**	Find N_{max} (< or = can earn M1 M1 A0, max 2/3)
		3	

Question	Answer	Marks	Guidance
8	H_0: Holidays are independent of salesman *or* no association between holidays and salesman (AEF)	**B1**	State (at least) null hypothesis Find expected values (lose A1 if rounded to integers) Find value of X^2 from $\Sigma (E_i - O_i)^2 / E_i$ [or $\Sigma O_i^2/E_i - n$] State or use correct tabular χ^2 value
	E_i: 29·68 33·04 21·28 23·32 25·96 16·72 (to 1 d.p.)	**M1 A1**	
	X^2 = 0·7380 + 0·7446 + 0·0037 + 0·9392 + 0·9477 + 0·0047	**M1**	
	= 3·38 (to 3 s.f.)	**A1**	
	$\chi_{2,\,0.9}{}^2$ = 4·605 (to 3 s.f.)	**B1**	
	Accept H_0 if X^2 < tabular value	**M1**	Compare their calculated value with their X^2 value and appropriate conclusion
	Type of holidays is independent of salesman (AEF)	**A1**	Correct conclusion, from correct values $(3.37 - 3.39)$
		8	

Question	Answer	Marks	Guidance
9(i)	$\bar{x} = 0{\cdot}785$	B1	Find sample mean
	$s^2 = (6{\cdot}19 - 7{\cdot}85^2/10) / 9$ [= 37/12 000 *or* 0·003083 *or* $0{\cdot}05553^2$]	M1	Estimate population variance (allow biased here: 0·002775 *or* $0{\cdot}05268^2$)
	H_0: $\mu = 0{\cdot}75$, H_1: $\mu > 0{\cdot}75$ (AEF)	B1	State hypotheses (B0 for $\bar{x}$ ...)
	$t_{9,\,0.95} = 1{\cdot}83[3]$	B1	State or use correct tabular *t*-value
	$t = (\bar{x} - 0{\cdot}75)/(s/\sqrt{10}) = 1{\cdot}99$ [Reject H_0 and accept H_1]	M1 A1	Find value of *t* (or compare $\bar{x}$ with $0{\cdot}75 + 0{\cdot}032 = 0{\cdot}782$) Consistent conclusion
	Claim (of yield per plant increased) is justified (AEF)	B1	**FT** on both *t*-values (must be *t* value)
		7	
9(ii)	$\bar{x} \pm t\sqrt{(s^2/10)}$	M1	Find confidence interval (must be a *t* value)
	$t_{9,\,0.975} = 2{\cdot}26[2]$	B1	State or use correct tabular value of *t*
	$0{\cdot}785 \pm 0{\cdot}04$ *or* [0·745, 0·825]	A1	Evaluate confidence interval (either form)
		3	

Question	Answer	Marks	Guidance
10(i)	$b = S_{xy} / S_{xx}$ and $r = S_{xy} / \sqrt{(S_{xx} S_{yy})}$ so	**M1**	Relate gradient b in $y = bx + c$ to r, S_{xx}, S_{yy}
	$b = r \sqrt{(S_{yy} / S_{xx})}$	**A1**	
	$= 0{\cdot}5815 \sqrt{(7{\cdot}9473 / 3{\cdot}3086)} = 0{\cdot}901[2]$	**M1 A1**	Find S_{xx} and S_{yy} and hence find b to 3 s.f.
	$(y – 6{\cdot}7375) = b (x – 3{\cdot}3125)$, $y = 0{\cdot}901x + 3{\cdot}75$	**M1 A1**	Find equation of regression line of y on x
	Alternative method for question 10(i)		
	$S_{xy} = r \sqrt{(S_{xx} S_{yy})} = r \sqrt{\{(8s_x^2) (8s_y^2)\}}$ $= 8 \times 0{\cdot}5815 \sqrt{(7{\cdot}9473 \times 3{\cdot}3086)}$	**M1**	Find S_{xy} (allow values consistently scaled by factor 8)
	$= 23{\cdot}855$ (allow $2{\cdot}9818$) (to 4 s.f.)	**A1**	
	$b = S_{xy} / S_{xx} = 23{\cdot}85 / (8 \times 3{\cdot}3086) = 0{\cdot}901[2]$	**M1 A1**	Hence find b to 3 s.f.
	$(y – 6{\cdot}7375) = b (x – 3{\cdot}3125)$, $y = 0{\cdot}901x + 3{\cdot}75$	**M1 A1**	Find equation of regression line of y on x
		6	

Question	Answer	Marks	Guidance
10(ii)	H_0: $\rho = 0$, H_1: $\rho > 0$	**B1**	State both hypotheses (B0 for r …)
	$r_{8,\,5\%} = 0{\cdot}621$	**B1**	State or use correct tabular one-tail r-value
	Accept H_0 if $0{\cdot}5815 <$ tab. r-value (AEF)	**M1**	State or imply valid method for conclusion
	No evidence of positive correlation (AEF)	**A1**	Correct conclusion
	Alternative method for question 10(ii)		
	H_0: $\rho = 0$, H_1: $\rho > 0$	**B1**	State both hypotheses (B0 for r …)
	$t_r = r\sqrt{((n\text{-}2) / (1 - r^2))} = 1{\cdot}75$, $t_{6,0{\cdot}95} = 1{\cdot}943$	**B1**	
	Accept H_0 if $\mid t_r \mid <$ tab. t-value (AEF)	**M1**	State or imply valid method for conclusion
	No evidence of positive correlation (AEF)	**A1**	Correct conclusion
		4	
10(iii)	$y = 9{\cdot}16$	**B1**	Find y when $x = 6{\cdot}0$
	Unreliable since r is small *or* r is not close to 1 *or* no correlation *or* 6·0 is not close to mean of x (AEF)	**B1**	Reasonable comment on reliability
		2	

Question	Answer	Marks	Guidance
11E(i)	$\frac{1}{2} mu^2 = \frac{1}{2} kmg (\frac{1}{4} a)^2/a$, $k = 16u^2/ag$ **AG**	**M1 A1**	Verify k by using conservation of energy (M0 if ω is found and SHM formula $v = a\omega$ then used)
		2	
11E(ii)	$\pm m\, d^2x/dt^2 = kmg\, x/a$	***M1**	Apply Newton's law at general point (e.g. $OP = a + x$), requires m
	$d^2x/dt^2 = -(kg/a)\, x$ *or* $-(16u^2 / a^2)\, x$ [$\omega = \sqrt{(kg/a)}$ *or* $4u/a$]	**A1**	Derive standard SHM form (requires minus sign)
	Period is $2\pi\sqrt{(a / kg)} = 2\pi\sqrt{(a^2 / 16u^2)} = \pi a / 2u$	**DM1 A1**	Find period from $2\pi/\omega$
		4	
11E(iii)	[$\frac{1}{2} mv^2 = \frac{3}{4} \times \frac{1}{2} mu^2$] $v^2 = \frac{3}{4} u^2$ *or* $v = (\sqrt{3}/2)\, u$	**M1**	Relate v and u using given loss in energy
	$x = (\frac{1}{4} a) \sin \omega t$, $v = (\frac{1}{4} a)\, \omega \cos \omega t$ *or* $u \cos \omega t$	**M1**	Relate v and t
	$\cos \omega t = (\sqrt{3}/2)\, u / (\frac{1}{4} a)\, \omega = (\sqrt{3}/2)$	**M1 A1**	Combine to find $\cos \omega t$
	$t = (\pi/6) / (4u/a) = \pi a / 24u$ *or* $0{\cdot}0417\, \pi a / u$ *or* $0{\cdot}131\, a/u$	**M1 A1**	and hence t
		6	

Question	Answer	Marks	Guidance
11O	$\bar{x} - \bar{y} = 0{\cdot}448 - 0{\cdot}48 = [-]\ 0{\cdot}032$	**B1**	Find difference in sample means (either sign; may be implied)
	$s_X^2 = (10{\cdot}1 - 22{\cdot}4^2/50) / 49 = 0{\cdot}0648 / 49$ [= 0·001322]	**M1 A1**	Estimate both population variances (may be implied)
	$s_Y^2 = (16{\cdot}3 - 28{\cdot}8^2/60) / 59 = 2{\cdot}476 / 59$ [= 0·04197]	**A1**	(allow biased here: 0·001296 *and* 0·04127)
	$s_C^2 = s_X^2/50 + s_Y^2/60$	**M1**	Estimate combined variance
	$= 0{\cdot}0007259$ *or* $0{\cdot}02694^2$ (to 3 s.f. throughout)	**A1**	
	$z = 0{\cdot}032 / s_C$ [or $0{\cdot}032 / s_P\sqrt{(1/50 + 1/60)}$] $= 1{\cdot}188$ [or 1·0895]	**M1 A1**	Find value of z (either sign)
	$\Phi(z) = 0{\cdot}8826$ [or 0·8620]	**A1**	Find $\Phi(z)$
	$100 \times (1 - \Phi(z)) = 11{\cdot}7$ [or 13·8]	**M1 A1**	Find limiting value for α, based on one-tail test (M0 for basing on two-tail test)
	$\alpha >$ (*or* $\geqslant$) 11·7 [or 13·8]	**A1**	Find set of possible values of α Allow 11.8 if 11.74 seen (Misreading α% as α loses only last A1)

Question	Answer	Marks	Guidance
11O	**Alternative method for question 11O**		
	$\bar{x} - \bar{y} = 0{\cdot}448 - 0{\cdot}48 = [-]\ 0{\cdot}032$	**B1**	Find difference in sample means (either sign; may be implied)
	$s_X^2 = (10{\cdot}1 - 22{\cdot}4^2/50) / 49 = 0{\cdot}0648 / 49$ [= 0·001322]	**M1 A1**	Estimate both population variances (may be implied)
	$s_Y^2 = (16{\cdot}3 - 28{\cdot}8^2/60) / 59 = 2{\cdot}476 / 59$ [= 0·04197]	**A1**	(allow biased here: 0·001296 *and* 0·04127)
	Assume equal [population] variances	**B1**	State assumption
	$s_P^2 = (49\, s_X^2 + 59\, s_Y^2) / 108$ *or* (0·0648 + 2·476) / 108 = 0·02353 *or* $0{\cdot}1534^2$	**B1**	(Find pooled estimate of common variance s_X^2 and s_Y^2 not needed explicitly so may be implied by result)
	$z = 0{\cdot}032 / s_C$ [or $0{\cdot}032 / s_P\sqrt{(1/50 + 1/60)}$] = 1·188 [or 1·0895]	**M1 A1**	Find value of z (either sign)
	$\Phi(z) = 0{\cdot}8826$ [or 0·8620]	**A1**	Find $\Phi(z)$
	$100 \times (1 - \Phi(z)) = 11{\cdot}7$ [or 13·8]	**M1 A1**	Find limiting value for α, based on one-tail test (M0 for basing on two-tail test)
	$\alpha >$ (*or* $\geqslant$) 11·7 [or 13·8]	**A1**	Find set of possible values of α Allow 11.8 if 11.74 seen (Misreading α% as α loses only last A1)
		12	

