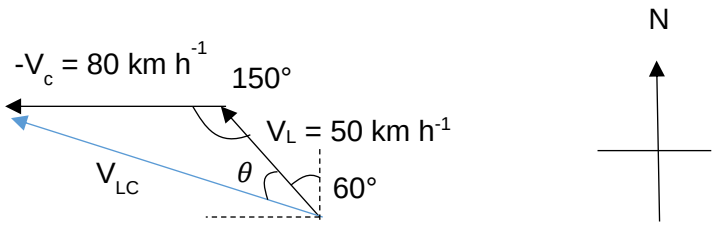
Paper 1 – Multiple Choice Questions

1	**Answer: D**
	(Left hand side): v has units of m s^{-1}. (Right hand side): $\text{units of } p = \frac{\text{units of } F}{\text{units of } A} = \frac{\text{N}}{\text{m}^2} = \frac{\text{kg m s}^{-2}}{\text{m}^2} = \text{kg m}^{-1}\text{ s}^{-2}$ $\text{units of } d = \text{kg m}^{-3}$ $\frac{\text{units of } p}{\text{units of } d} = \frac{\text{kg m}^{-1}\text{ s}^{-2}}{\text{kg m}^{-3}} = \text{m}^2\text{ s}^{-2}$ $\sqrt{\frac{\text{units of } p}{\text{units of } d}} = \text{m s}^{-1}$ Units on LHS = Units on RHS Therefore, γ has no units.

2	**Answer: A**
	 $v_{LC} = v_L - v_c$ $= v_L + (-v_c)$ $v_{LC}^2 = v_L^2 + v_C^2 - 2(v_L)(v_C)\cos 150°$ $v_{LC}^2 = 50^2 + 80^2 - 2(50)(80)\cos 150°$ $v_{LC} = 126 \text{ km h}^{-1}$ $\frac{80}{\sin\theta} = \frac{126}{\sin 150°}$ $\theta = 18.5°$ Bearing = 360°-18.5°-60° = 281.5°

3 **Answer: A**

	Student A	Student B	Student C	Student D
Accuracy	0.85	0.85	0.8625	0.85
Precision (range)	0.17	0.06	0.17	0.04

4 **Answer: C**

Minimum distance occurs when both cars have the same speed.

$$\text{Car X}: \left[\frac{1}{2}\times(3.0+5.0)\times 20\right]+(55\times 5)=355\text{ m}$$

$$\text{Car Y}: (35\times 2.0)+\left[\frac{1}{2}\times(35+55)\times 3.0\right]=205\text{ m}$$

$$\text{Minimum distance} = (450+205)-355 = 300\text{ m}$$

5 **Answer: B**

Can be obtained by looking at the gradient of the s-t graph.

6 **Answer: C**

$$s = ut + \frac{1}{2}at^2$$

$$s = \frac{1}{2}at^2$$

$$s \propto at^2$$

$$\frac{s_m}{s_E} = \frac{a_m t_m{}^2}{a_E t_E{}^2}$$

$$\frac{3}{6} = \left(\frac{1}{6}\right)\frac{t_m{}^2}{t_E{}^2}$$

$$t_m = \sqrt{3}t$$

7 **Answer: A**

Action and reaction forces should act on opposite bodies. For Option A, the correct statement should look like “the gravitational forces of attraction between satellite and Earth”

8 **Answer: B**

By Newton’s Second Law, rate of change of momentum is the resultant force acting on the body. In this case, that would be 4N.

9	**Answer: C**
	$F_{net} = m/t\ \Delta v_{perpendicular}$ $= m/t\ (2v \sin 30°)$ $= 2.5 \times (2 \times 5.0 \sin 30°)$ $= 13$ N Option A: Forgot factor of 2 Option B: Forgot factor of 2 and considered cosine instead of sine Option C: Correct Option D: Considered consine instead of sine

10	**Answer: B**
	For Option A, on both arms at level where the two liquids intersect, pressures are the same. Since pressure decrease (by $\Delta h\rho g$) as we progress upwards, pressure at Pt Q would be diff from pressure at Pt P since decrease in pressure is $\Delta h\rho g$ (same h but diff ρ). For Option B, Pt R and Pt S are at the same pressure. Consider the pressure at bottom-most of tube, the same decrease in liquid pressure by $\Delta h\rho g$ (same h,ρ) For Option C, since the surface level of both arms experience the same pressure (atmospheric) and both liquids are of different densities, the surface levels cannot be changed. For Option D, since the surface level of both arms experience the same pressure (atmospheric) and both liquids are of different densities, the surface levels cannot be aligned.

11	**Answer: C**
	Given that there are 3 forces acting on the beam to bring about equilibrium, the lines of action of these forces must be at the same point (concurrent forces). Hence, either option B or C. Option B is the force action by wall on beam. Option C is the force acted by beam on wall.

12	**Answer: D**
	By principle of conservation of energy, Loss in GPE = gain in EPE of spring 1.0(9.81)(20.0) = average force of spring (5.0) Average force of spring = 39.2 N

13	**Answer: A**
	On level road, $P = F_{engine}\ v$ $108\ 000 = F(15)$ $F_{engine} = 7200$ N $F_{drag} = 7200$ N when $v = 15$ m s^{-1} On slope, Since $v = 10$ m s^{-1} and F_{drag} is proportional to v, New $F_{drag} = (10/15) \times 7200 = 4800$ N At constant power, $F_{engine} = 108000/10 = 10\ 800$ N Resultant force downslope = $4800 + 1500\ (9.81) \sin 30 - 10\ 800$ $= 1357.5$ N Deceleration of car = $1357.5/1500 = 0.905$ m s^{-2}
14	**Answer: C**
	Using $v^2 = u^2 + 2as$ Final velocity of load, $v = 15.65$ m s^{-1} Effective work done = gain in KE + gain in GPE $= ½\ mv^2 + mgh$ $= 23\ 291$ J Efficiency = $23291/(8500 \times 4.47) \times 100 = 61\%$

15	**Answer: D**
	Centripetal force is a resultant force and should not be drawn in free-body-diagrams. The direction of friction along the slope would depend on the speed of the linear velocity.

16	**Answer: C**
	Given $a=\omega^2 r$, and since ω increases steadily with t, and $r_Q > r_P$ (but constant over time for each) $a \propto t^2$ and $a_P/a_Q = r_P/r_Q$ = constant at a given time.

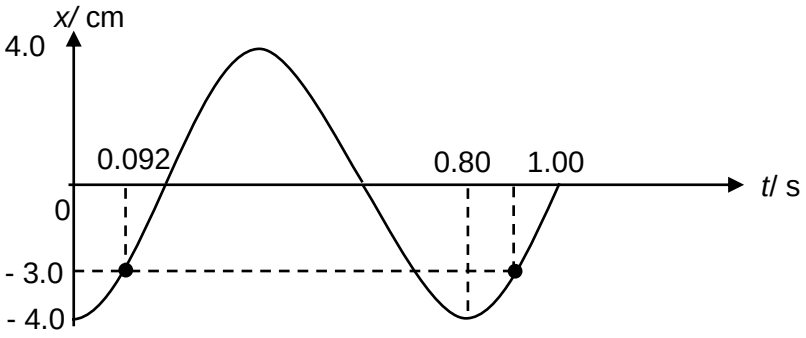
17	**Answer: A**
	For Q: $F_{net} = ma_Q = m\omega^2/2r$ $T_{PQ} = m\omega^2/2r$ For P: $F_{net} = ma_P = m\omega^2/r$ $T_{XP} - T_{PQ} = m\omega^2/r$ $T_{XP} - m\omega^2/2r = m\omega^2/r$ $T_{XP} = 3m\omega^2/2r$ Option B: P and Q experience the same angular velocity Option C: Mass Q experiences a larger velocity since $v=\omega r$ (same ω, $r_Q>r_P$) Option D: Mass Q experiences a larger acc since $a=\omega^2 r$ (same ω, $r_Q>r_P$)

18	**Answer: A**
	Net gravitational field strength at X = gravitational field strength due to moon + gravitational field strength due to earth $=(6.67 \times 10^{-11})[5.97 \times 10^{24}/(387.5\times10^{6})^2 + 7.35 \times 10^{22}/(2.5 \times 10^{6})^2]$ $= 0.787$ N kg^{-1}

19	**Answer: C**
	Gravitational force is the rate of change of potential energy with distance. $F_g = -\frac{dE_p}{dr} = -\frac{d(m\phi)}{dr} = -m\frac{d(\phi)}{dr} = -mP$
20	**Answer: C**
	Velocity is maximum at the equilibrium (region 3). Hence it is hardest to hit.

21	**Answer: B**
	$F = ma$ $W - T = ma$ $T = mg - ma$ $T = m(g - \omega^2 x_o)$ $T = 0 \rightarrow \omega^2 x_o = g$ $(2\pi f)^2(0.030) = 9.81$ $f = 2.9$ Hz

22	**Answer: C**

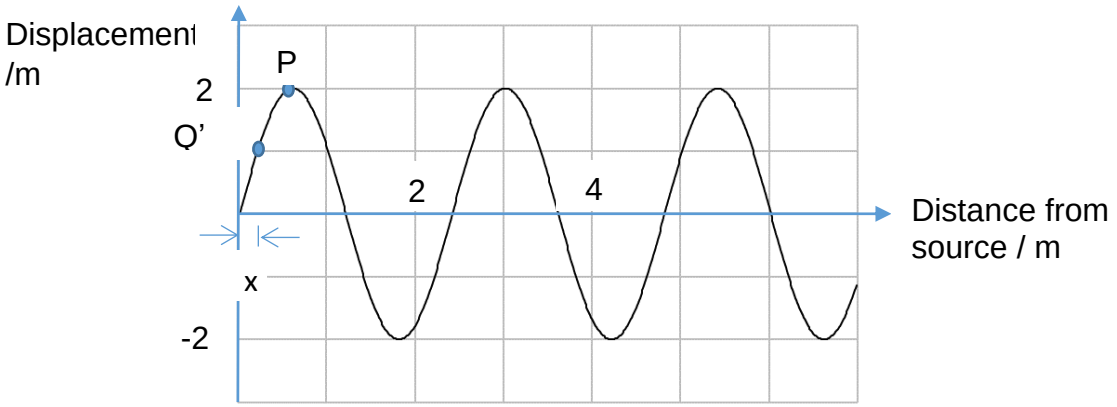


$$-3.0 = -4.0\cos\left(\frac{2\pi}{0.80}t\right)$$

$t = 0.092$ s

Time = 0.80 + 0.0920 = 0.89 s

23	**Answer: D**



Phase difference between P and Q = phase difference between P and Q'.
For Q' , 1 =2 sin θ
Phase corresponding to x = Θ = π/6,
Phase of P = π/2 (corresponding to a quarter of a wavelength)
Phase difference PQ = π/2 - π/6 = π/3

24	**Answer: D**
	Shift the graph to the left. P is instantaneously at rest. Q is moving downwards. R is instantaneously at rest. S is moving upwards and slowing down as its acceleration is towards the equilibrium position.

25	**Answer: C**
	Distance from R to S = 0.27 m = 2.5 λ Speed of sound in air ~ 330 m s^{-1} Frequency = 330/ (0.27/2.5) = 3.1 kHz

26	**Answer: C**
	Loudness is a measure of intensity; power of source is reduced to one third. However, intensity at new location is to be equal to intensity at 8.0 m away. $\frac{P}{4\pi(8)^2} = \frac{\frac{1}{3}P}{4\pi(r_{new})^2}$ $(r_{new}) = \frac{8}{\sqrt{3}}$ $= 4.6m$

27	**Answer: D**
	Tube P: $\lambda = 2L$ $v = (f)(2L) = 2fL$ $\text{freq values} = f, 2f, 3f$ **Tube Q:** $\lambda = 4L$ $f = \frac{v}{\lambda} = \frac{(2fL)}{4L} = \frac{1}{2}f$ $\text{freq values} = \frac{1}{2}f, \frac{3}{2}f, \frac{5}{2}f$

28	**Answer: B**
	The wavelength of the waves before and after passing through the gap does not change.

29	**Answer: C**
	Sources are in antiphase with each other. High intensity occurs when path difference = 0.5, 1.5λ, 2.5λ, …

30	**Answer: D**
	$d \sin\theta = n\lambda$ $d \sin 20^o = (1)\lambda$ $\frac{d}{\lambda} = 2.9$ ----------(1) Max order occurs at sin 90° $d \sin\theta = n\lambda$ $d \sin 90^o = n\lambda$ $n = \frac{d}{\lambda}$ ----------(2) From (1), n = 2.9. Max n = 2 Hence max number of images = 5

Paper 2 – Structured Questions

Qns	Answer	Marks
1(a)	Method 1 $v = \frac{2}{9} g r^2 \left(\frac{\rho_{ball} - \rho_{liquid}}{\mu} \right)$ Solve using max-min method: r_{max} = 0.07 m, r_{min} = 0.05 m $\rho_{ball,max}$ = 7050 kg m^{-3}, $\rho_{ball,min}$ = 6950 kg m^{-3} $\rho_{liquid,max}$ = 1270 kg m^{-3}, $\rho_{liquid,min}$ = 1230 kg m^{-3} μ_{max} = 3.9 Pa S, μ_{min} = 3.7 Pa S $v_{max} = \frac{2}{9} g r_{max}^2 \left(\frac{\rho_{ball,max} - \rho_{liquid,min}}{\mu_{min}} \right)$ $= \frac{2}{9}(9.81)(0.07)^2 \left(\frac{7050 - 1230}{3.7} \right)$ $= 16.8 \text{ m s}^{-1}$ $v_{min} = \frac{2}{9} g r_{min}^2 \left(\frac{\rho_{ball,min} - \rho_{liquid,max}}{\mu_{max}} \right)$ $= \frac{2}{9}(9.81)(0.05)^2 \left(\frac{6950 - 1270}{3.9} \right)$ $= 7.94 \text{ m s}^{-1}$ $\Delta v = \frac{1}{2}(v_{max} - v_{min})$ $= \frac{1}{2}(16.8 - 7.94)$ $= 4.43$ $= 4 \text{ m s}^{-1}$ (1 s.f.)	**M1 (for both correct v_{max} and v_{min}) or correct substitution** **A1**

	Method 2 $v = \frac{2}{9} g r^2 \left(\frac{\rho_{ball} - \rho_{liquid}}{\mu} \right)$ $x = \rho_{ball} - \rho_{liquid}$ $\Delta x = \Delta\rho_{ball} + \Delta\rho_{liquid} = 50 + 20 = 70 \text{ kg m}^{-3}$ $x = 7000 - 1250 = 5750 \text{ kg m}^{-3}$ $v = \frac{2}{9} g r^2 \left(\frac{x}{\mu} \right)$ $\frac{\Delta v}{v} = 2\frac{\Delta r}{r} + \frac{\Delta x}{x} + \frac{\Delta \mu}{\mu}$ $\Delta v = v\left(2\frac{\Delta r}{r} + \frac{\Delta x}{x} + \frac{\Delta \mu}{\mu} \right)$ $v = \frac{2}{9} g r^2 \left(\frac{\rho_{ball} - \rho_{liquid}}{\mu} \right)$ $= \frac{2}{9}(9.81)(0.06)^2 \left(\frac{7000 - 1250}{3.8} \right)$ $= 11.875$ $\Delta v = v\left(2\left(\frac{0.01}{0.06} \right) + \frac{70}{5750} + \frac{0.1}{3.8} \right)$ $= 11.875\left(2\left(\frac{0.01}{0.06} \right) + \frac{70}{5750} + \frac{0.1}{3.8} \right)$ $= 4.42$ $= 4 \text{ m s}^{-1}$ (1s.f.)	**M1 (for correct substitution into Δv) – First line of Δv** **A1**
1(b)	$v = \frac{2}{9} g r^2 \left(\frac{\rho_{ball} - \rho_{liquid}}{\mu} \right)$ $= \frac{2}{9}(9.81)(0.06)^2 \left(\frac{7000 - 1250}{3.8} \right)$ $= 11.875$ $v \pm \Delta v = 12 \pm 4 \text{ m s}^{-1}$	**C1 (for correct value of *v*)** **Also award one mark if student already finds *v* using Method 2 above.** **A1**

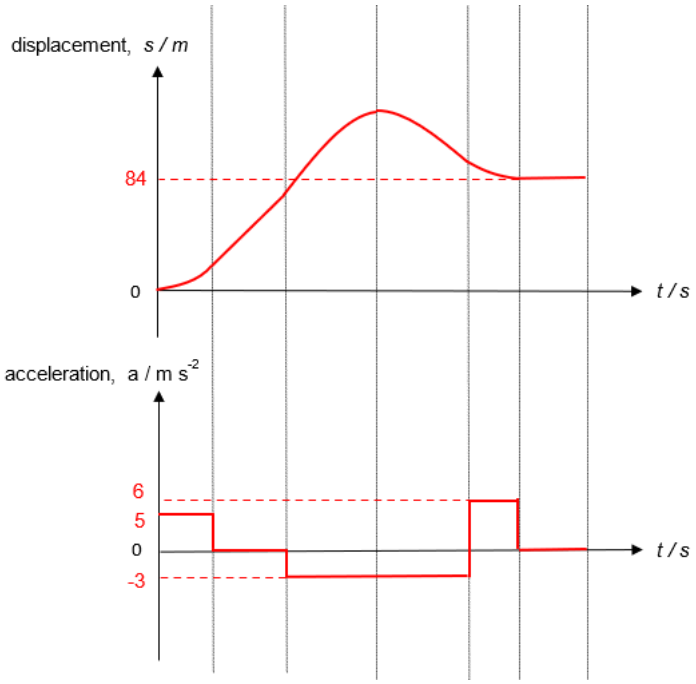
Examiner's Comments:

1 (a) This question is not very well done by candidates. For some students who choose method 1, the v_{max} and v_{min} found are incorrect. Kindly pay attention to the terms in the numerator and denominator to avoid making the same mistakes again. As this question involves M1 and A1, thus, if a student does not get M1, he/she will not obtain A1. There are some students who get the correct final answer but eventually are still awarded zero mark due to not getting the M1 mark.

For some students who choose method 2, the major issue is the substitution of values into the respective terms. Kindly pay attention to how $\frac{\Delta x}{x}$ is being obtained above to find out the mistakes made. Most candidates either make mistakes in the Δx or x.

Another common mistake made by candidates is that the final value of Δv is not put in 1 s.f. This results in the loss of A1 mark.

1 (b) This question is not very well done by candidates. A few students calculate the value of v incorrectly. A common mistake made by candidates is that Δv is not put in 1 s.f and the placement value of v is incorrect.

Qns	Answer	Marks
2 (a)	$u_x = v_x = 8\,\text{m s}^{-1}$ $t = \frac{s_x}{v_x} = \frac{10}{8} = 1.25\,\text{m s}^{-1}$ $\tan 20° = \frac{u_y}{u_x}$ $u_y = 8\tan 20° = 2.91\,\text{m s}^{-1}$ $s_y = u_y t + \frac{1}{2} a_y t^2$ $0 = 2.91(1.25) + \frac{1}{2} a_y (1.25)^2$ $a_y = -4.66\,\text{m s}^{-2}$ OR $a_y = 4.66\,\text{m s}^{-2}$ downwards	**C1** **C1** **A1**
2 (b)	From t=0 to t=t_1, the car is travelling with a constant velocity/speed. From t=t_1 to t=t_2, the car is decelerating. OR From t=t_1 to t=t_2, the car's speed is decreasing. From t=t_2 to t=t_3, the car is moving in the opposite direction with increasing speed/velocity. OR From t=t_2 to t=t_3, the car is accelerating in the opposite direction.	**B1** **B1** **B1**
2 (c)		**For s-t graph: 2 marks for correct curves/lines and 1 mark for final value of *s*. Minus 1 mark for each wrong curve/line up to 2 marks. Also, minus 1 mark if graph is not smooth.** **For a-t graph: 3 marks for correct lines and all values of *a*. Minus 1 mark for each wrong line and corresponding value of *a*.**

Examiner's Comments:

Q2(a) This question is well done by most candidates. There are some students who confuse between the horizontal velocity and vertical velocity used in the kinematics equation. There is also another group of students who look at the highest point reached (half the journey in this case) but they use the whole duration for the journey.

Q2(b) This question is well done by most candidates. There are some students who mention phrases like for example "the car's speed is decreasing at a decreasing rate" or "the car's speed is decreasing at an increasing rate" or "the car's speed is decreasing at a constant rate" which is not quite right. From the graph, we cannot really tell whether speed is decreasing at a decreasing/increasing/constant rate as there are no values provided in the graph.

Q2(c) This question is well done by most candidates. For s-t graph, some students' graph is not smooth (have kinks) and this is not acceptable. Some students also make mistakes in finding the final displacement. For a-t graph, no major issues faced by students.

Qns	Answer	Marks
3(a)(i)	Taking moments about the left edge of the door,	
	clockwise moments = $(mg)(0.80)$	**M1**
	anticlockwise moments = $T_B(1.6) + (T_A \sin 30^o)(0.70\cos 10^o) + (T_A \cos 30^o)(0.70\sin 10^o)$	**M1**
	$T_B(1.6) + (T_A \sin 30^o)(0.70\cos 10^o) + (T_A \cos 30^o)(0.70\sin 10^o) = 0.80mg$	
	$(200)(1.6) + (T_A \sin 30^o)(0.70\cos 10^o) + (T_A \cos 30^o)(0.70\sin 10^o) = 0.80(50)(9.81)$	
	$T_A = 160$ N (or 161 N)	**A1**
3(a)(ii)	$N = T_A \sin 30^o$	
	$N = 160\sin 30^o$	**M1**
	$N = 80$ N (or 80.5 N)	**A1**
3(a)(iii)	$T_A \cos 30^o + T_B + f = mg$	
	$160\cos 30^o + 200 + f = (50)(9.81)$	**M1**
	$f = 150$ N (or 151 N)	**A1**
3(b)(i)	fraction of volume in water = $\dfrac{\frac{1}{2}(0.15+0.60)(0.70)}{(1.5)(0.70)} = 0.25$	
	volume = (0.25)(0.16) = 0.040 m^3	**M1**
	upthrust = $\rho Vg = (1000)(0.040)(9.81)$	
	upthrust = 390 N (or 392 N)	**A1**
3(b)(ii)	Tension + Upthrust = Weight	
	Tension + 390 = (50)(9.81)	**C1**
	Tension = 100 N (or 98.5 N)	**A1**

Examiner's Comments:

3(a)(i) Poorly done. Most candidates are able to choose the correct point for the pivot and managed to find the clockwise moment (moments due to weight of door) correctly. A significant number of candidates did not resolve the Tension A correctly.

Some candidates managed to solve the question by finding the perpendicular distance of Tension from the pivot instead of resolving the Tension A. This is a quicker method for this question.

3(a)(ii) Well done. Most candidates know that the normal contact force is the only other horizontal force besides Tension of rope A. Some candidates included the vertical force (the friction in part (a)(iii)) in the answer.

3(a)(iii) Well done. Most candidates understand that sum of vertical forces equals zero. Some candidates assumed that friction is acting downwards and hence would get a negative value for friction.

3(b)(i) Significant number of candidates did not get two full marks as they found the area of door submerged instead of volume of door submerged.

3(b)(ii) Well done. Most students are able to get full marks for this question.

Qns	Answer	Marks
4(a)(i)	Consider FBD of system: $F_{net} = m_{total}\, a$ $150 - 19.0g\sin30° = 19.0a$ $a = 2.99$ m s^{-2} (3.0 m s^{-2}) Method 1 Consider FBD of (8kg) $150 - 8.0g\sin30° - F_{spring} = 8.0a$ $= 8.0 \times 2.99$ OR Method 2 Consider FBD of (7kg and 4kg) $F_{spring} - 11.0g\sin30° = 11.0a$ $= 11.0 \times 2.99$ $F_{spring} = 86.8$ N	**C1** **C1** **C1** **A1**
4(a)(ii)	Smaller. Method 1 For the same acceleration, the lower spring needed to provide the upward force to accelerate the 4 and 7kg masses while the upper spring only needed to provide the upper force to accelerate the 4kg mass. Method 2 Considering 7kg mass, lower spring force is needed to balance upper spring force, component weight of its mass and provide acceleration.	**A0** **B1** **B1** **B1** **B1**
4(b)(i)	Method 1 By Conservation of Linear momentum, Total Initial Momentum = Total Final Momentum $5.37 + (-3.72) = p_{Afinal} + (-3.30)$ $p_{Afinal} = 4.95$ $v_{Afinal} = 4.95/0.90$ $= 5.5$ m s^{-1} Method 2 OR By Conservation of Linear momentum, $\Delta p_A = -\Delta p_B$ $p_{Af} - (-3.72) = -(-3.30 - 5.37)$ $v_{Afinal} = 4.95/0.90$ $= 5.5$ m s^{-1}	**M1** **M1** **A0** **M1** **M1** **A0**

4(b)(ii)	Given that A and B move in opposite direction before collision $u_A = -4.1$ m s^{-1}; $u_B = 9.0$ m s^{-1}; $v_A = 5.5$ m s^{-1} (from bi) And $v_B = -3.3/0.600 = -5.5$ m s^{-1} Relative speed of approach = $-4.1 - 9.0 = -13.1$ m s^{-1} Relative speed of separation = $-5.5 - 5.5 = -11$ m s^{-1} Since Relative speed of approach is not equal to the relative speed of separation, the collision is NOT elastic. OR Total Initial KE = ½ (0.900)(4.1)^2 +½ (0.600)(9.0)^2 = 32 J Total Final KE = ½ (0.900)(5.5)^2 +½ (0.600)(5.5)^2 = 23 J Since the total initial KE is not equal to the total final KE, the collision is NOT elastic.	**M1** **M1** **A1** **M1** **M1** **A1**

Examiner's Comments:

4(a)(i) Not well done. Common mistakes include:
- Not considering for Fnet at all
- Missing out Wsinθ for all FBDs
- Missing out *g* in *mg*sinθ

4(a)(ii) Poorly done. Common mistakes include:
- Neglecting fact that spring in force does not just balance component of weight but also provides net force for acceleration
- For Method 1 mentioned above, unclear explanations of 4kg vs (4kg+7kg) being compared, as well as the fact that the accelerations for each is the same
- For Method 2 mentioned above, missing out the fact that spring in force also balances for component of weight

4(b)(i) Generally well done. Students should note that good presentation is critical for SHOW questions.

Common mistakes include:
- Not mentioning "By Conservation of Linear Momentum or Total Initial Momentum = Total Final Momentum or Change in Momentum of A = – Change in Momentum of B"
- For Method 2, many considered $p_A = p_B$ instead. They then tried to manipulate the signs to fit the intended final answer.
- Neglecting to show substitution of m_A as 0.900 (kg)

4(b)(ii) Generally well done. Common mistakes include:
- Neglecting to show present $KE_{initial}$ and KE_{final} separately, or Relative Speed of Approach and Separation separately. It does not make sense to start off by "equating" the quantities in the first line, only to subsequently conclude them as being different.
- Sf for $KE_{initial}$ and KE_{final} were often presented as 5sf or even more

Qns	Answer	Marks
5(a)(i)	At equilibrium, extension of springs A and B are equal. $F_A + F_B = 5.1\ (9.81)$ From graphs, Tension in spring A (=35 N) Tension in spring B (=15 N) when extension of springs, e = 10 cm.	**C1** **B1** **A1**
5(a)(ii)	Total elastic potential energy = area under graph for A + area under graph for B = ½ (10×10^{-2}) (35) + ½ (10×10^{-2}) (15) = 2.5 J	 **C1** **A1**
5(b)	By Principle of Conservation of Energy, Loss in gravitational energy per unit time = gain in heat per unit time m g v sin θ = P v = P/(mg sin θ)	 **B1** **B1** **A1**

Examiner's Comments:

5(a)(i) Quite a number of students failed to identify that when two springs are in parallel, they have a common extension and that here the sum of their total tension is equal to the weight of the load that they are supporting together. Finding k_A and k_B alone without understanding that this extension is the same for both is not a marking point. Neither is finding the weight of the load without relating this to the tensions in the two springs.

(a)(ii) ECF is allowed here from the earlier part of the question if students acknowledge that both springs have a common extension. Some careless mistakes include failing to convert 'cm' to 'm' or taking the extension to be the end point of the graph given i.e. at the 12 cm mark.

5(b) Some students applied the principle of conservation of energy wrongly here by including the term "gain in kinetic energy" even though the question clearly stated that the speed of the space shuttle is kept constant.

Students who solved this question by applying P = Fv need to show properly the working and clearly indicate what F stands for when applied to this equation,

Qns	Answer	Marks
6(a)	Rate of angular displacement swept out by the radius.	**B1**
6(b)(i)	Because tension and weight acts in opposite direction to provide centripetal force.	**B1**
6(b)(ii)	At bottom, since $mv_{bot}^2/r = 16$ $(0.30)v_{bot}^2/1.1 = 16$ $v_{bot} = 7.66$ $= 7.7$ m s^{-1}	**M1** **A0**
6(b)(iii)	By PCOE, Loss in KE = Gain in GPE $\frac{1}{2} mv_{bot}^2 - \frac{1}{2} mv_{top}^2 = mg(2l)$ $\frac{1}{2}(0.30)(7.7) - \frac{1}{2}(0.30)v_{top}^2 = (0.30)(9.81)(2.2)$ $V_{top}^2 = 16$ m s^{-1} At top, since tension and weight acts (in the same direction) to provide centripetal force, $F_{net} = mv_{top}^2/r$ $T_{top} + mg = mv_{top}^2/r$ $T_{top} + (0.30)(9.81) = (0.300)(15.5)/1.1$ $T_{top} = 1.28 = 1.3$ N	**C1** **C1** **A1**

Examiner's Comments:

6(a) Poorly done. Common mistakes included omission of "…swept out by radius", not using "angular displacement", and using both "Rate of" and "per unit time" at the same time.

6(b)(i) Average. Common mistakes include:
- Wrongly thinking that tension equals weight (when there is centripetal force)
- Saying that "weight is the greatest at the bottom of circle" (weight is constant)
- Only mentioning "Component of vertical weight is the greatest hence tension is greatest" (which is also true at top of circle)

6(b)(ii) Generally well done.

6(b)(iii) Not well done. Common mistakes include:
- Wrongly assuming that the speeds, as well as centripetal force, at the top and bottom of the circle are the same
- Wrongly writing $\frac{1}{2} m\Delta v^2 = mgh$, and proceeded to calculate Δv from here. This is mathematically wrong.
- Many neglected to write "tension and weight provide for centripetal force"

Qns	Answer	Marks
7(a)(i)	Gravitational force provides the centripetal force $\frac{GMm}{r^2} = \frac{mv^2}{r}$ $Kinetic\ Energy = \frac{1}{2}mv^2 = \frac{GMm}{2r}$ B1 (Statement and equation for gravitational force acting as centripetal force present) B1 (correct equation indicating ½ mv² must be present)	**B1** **B1**
7(a)(ii)	$Total\ energy\ of\ satellite$ $= Kinetic\ Energy + Gravitational\ Potential\ Energy$ $= \frac{GMm}{2r} + (-\frac{GMm}{r})$ $= -\frac{GMm}{2r}$	**B1** **B1** **A0**
7b(i)	Period of rotation of satellite, T = 24.6 x 3 = 73.8 hours Gravitational force of Mars on satellite provides the centripetal force $\frac{GMm}{r^2} = mr\left(\frac{2\pi}{T}\right)^2$ $r^3 = \frac{GM(73.8 * 60 * 60)^2}{4\pi^2}$ $r = 4.24 \times 10^7\ m$	**C1** **M1 (correct formula, substitution and manipulation)** **A1**
7b(ii)	$work\ done = -\frac{GMm}{2(2r)} - (-\frac{GMm}{2r})$ $= \frac{1}{2}\left(\frac{GMm}{2r}\right)$ $= \frac{(6.67 \times 10^{-11})(6.39 \times 10^{23})(470)}{4(4.24 \times 10^7)}$ $= 118\ MJ$	**M1** **A1**

Examiner's Comments:

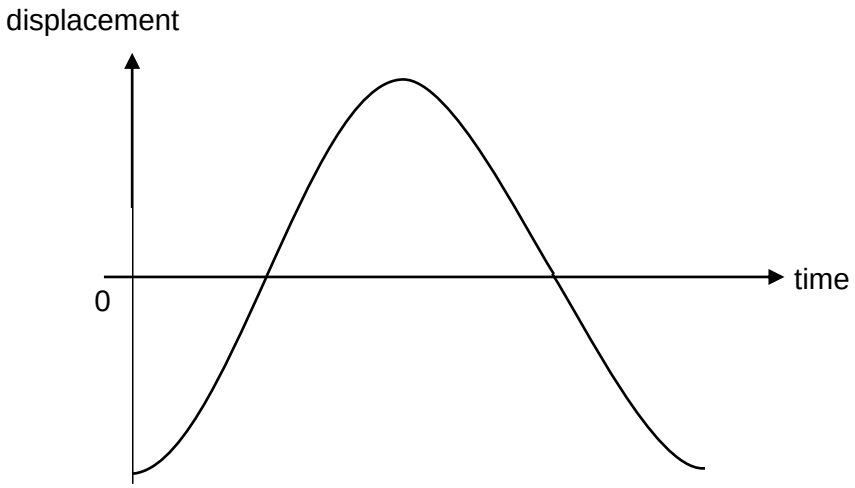
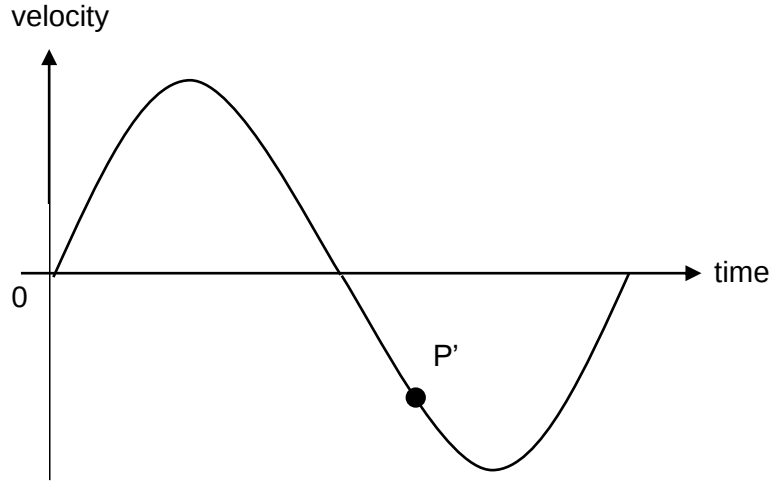
7(a)(i) Question was generally well done. However there are quite a number who did not obtain the full marks for this question for failure to explicit state that the "gravitational force provides the centripetal force". Some other scripts tried to "backtrack" to obtain the proof without understanding what provides the centripetal force.

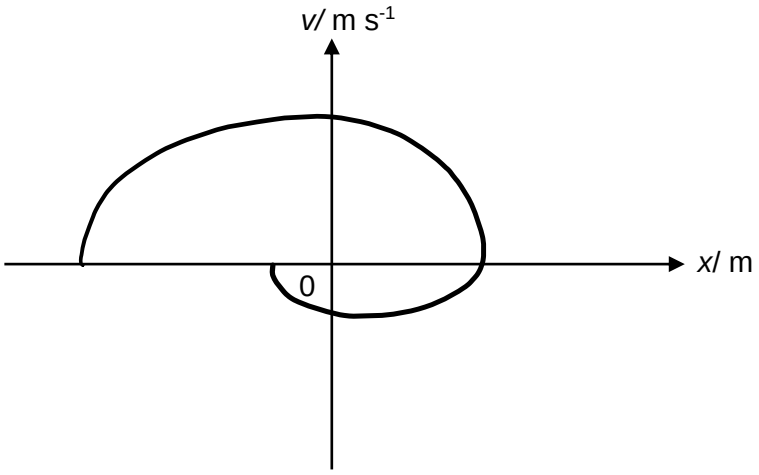
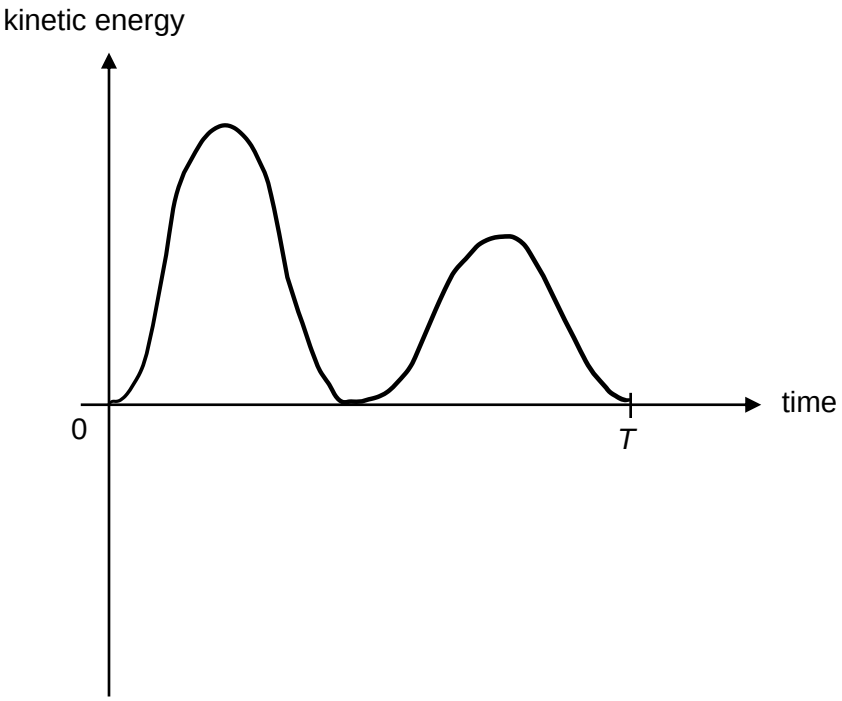
7(a)(ii) This question was generally well done.

7(b)(i) The crucial information that student needs to show is the ability to identify that the period of rotation of the satellite is three times the period of rotation of Mars. Only then would the proper application of the relation between centripetal force and gravitational force be acknowledged. Proper substitution of values (especially the period of rotation of the satellite as mentioned earlier) and manipulation should be done.

Quite a number of students failed to mathematically manipulate the equation well.

7(b)(ii) This question was poorly done. Majority of students equated the work done to the gain in gravitational potential energy of the satellite, neglecting the fact that the satellite also changes its kinetic energy when taking on a different orbit.

Qns	Answer	Marks
8(a)(i)		B1
8(a)(ii)		B1
8(a)(iii)	Total energy = maximum KE (or $=\frac{1}{2}mv_{max}^{2}$) $=\frac{1}{2}m(\omega x_{max})^2$ $=\frac{1}{2}m(\frac{2\pi}{T}x_{max})^2$ $=\frac{1}{2}(0.50)(\frac{2\pi}{0.80}0.030)^2$ = 0.014 J	B1 C1 A1

8(b)(i)	 **OR stopping before the end point shown above**	**B1**
8(b)(ii)	 **OR stretched out over a long time period (assuming damping is to be much heavier)**	**B1**

Examiner's Comments:

Most candidates did badly for this question.

8(a)(i) Some mistakes include drawing a positive cosine graph, which is a differentiation of a sine graph of the velocity-time, rather than an integration. Some did not recognize that a SHM has sinusoidal motion-time graphs. Marks are awarded to those who drew the correct shape but translated vertically, since the question did not state displacement from equilibrium.

8(a)(ii) A good number marked out P' on Fig. 8.3 instead of Fig.8.2 or did not label P'.

8(a)(iii) Most did not state "Total energy = maximum KE", but instead memorised an expression for total energy of SHM. Some used "Total energy = KE + GPE", failing to recognise that PE should be stated instead. Usage of GPE is wrong as EPE could also be present. Some did not square the ω or x_o.

8(b)(i) Some started from the wrong velocity or drew more than once cycle even question required the duration from $t = 0$ to $t = T$.

8(b)(ii) Some started from a non-zero KE. Others drew a wrong profile of a sinusoidal-squared graph, including a negative portion.

Qns	Answer	Marks
9	$\theta_1 = 0^o$, $\theta_2 = 90^o$ The 2 polarisers are perpendicular to each other, hence amplitude and intensity = 0 --- $\theta_1 = 30^o$, $\theta_2 = 30^o$ $A' = A\left(\cos 30^o\right)$ $A' = 0.87A$ $I' = I\left(\cos 30^o\right)^2$ $I' = 0.75I$ --- $\theta_1 = 30^o$, $\theta_2 = 45^o$ $A' = A\left(\cos 30^o\right)\left(\cos 15^o\right)$ $A' = 0.84A$ $I' = I\left(\cos 30^o\right)^2\left(\cos 15^o\right)^2$ $I' = 0.70I$ --- $\theta_1 = 90^o$, $\theta_2 = 90^o$ The incident light and polariser filter 1 are perpendicular to each other, hence amplitude and intensity = 0	**1 mark for each row**

Examiner's Comments:

9 Common issues with answers include leaving answer to only 1 s.f., leaving answer in surd form and cosine and sine form.

Qns	Answer	Marks
10(a)(i)	$\sin\theta = \frac{\lambda}{b}$ $\sin\theta \approx \theta = \frac{s}{r}$ $\frac{s}{3.0} = \frac{400\times10^{-9}}{0.10\times10^{-3}}$ $s = 0.012$ m *(= p/2)* $p = 0.012\times2 = 0.024$ m	**M1** **M1** **A1**
10(a)(ii)	$q = \frac{p}{2} = 0.012$ m	**A1**
10(a)(iii)1.	$p' = \frac{p}{3} = 0.0080$ m	**A1**
10(a)(iii)2.	3 times the energy passes through the slit Area (angular spread) is one-third Hence intensity $= 9.0I_o$	**A1**
10(b)(i)	$x = \frac{\lambda D}{a}$ $x = \frac{(400\times10^{-9})(3.0)}{\left[(2\times0.050)+0.25\right]\times10^{-3}}$ $x = 0.0034$ m	**C1** **A1**
10(b)(ii)	Due to diffraction pattern of each single slit	**A1**

Examiner's Comments:

10(a)(i) A large number of candidates used the formula for Young's Double Slit. Other common mistakes include finding only half the length, converting the units wrongly and using degree mode for small angle approximation.

10(a)(ii) This is generally well done.

10(a)(iii)1. This is generally well done.

10(a)(ii)2. Majority did not analyse this correctly.

10(b)(i) This is generally well done. Those who have gotten this wrong used the wrong value for the slit separation.

10(b)(ii) Most candidates relate the reduced intensity to an increase in distance. The distance has negligible effect on the intensity of bright fringes. Others mentioned central maximum intensity diminishing but did not specify whether this refers to the single-slit diffraction pattern or double slit interference pattern.

Paper 4 – Practical

Qns	Answer	Marks
1(a)(iii)	Values of x, y and z recorded • to the nearest mm (inclusive of average) • with unit (inclusive of average) • with repeated readings Value of z > value of x.	**1** **1**
1(a)(iv)	Absolute uncertainty in y of 1 mm to 20 mm and correct method of calculation to obtain percentage uncertainty. % uncertainty to 2 s.f. If repeated readings have been taken, then the uncertainty can be half the range (but not zero) if working (at least substitution) is clearly shown.	**1**
1(b)	• Correct calculation of C with consistent unit (e.g. g cm^2). • Accept 2 to 4 s.f.	**1**
1(c)(ii)	Evidence of repeat readings for *t.* Raw timings • correct precision (2 d.p.) • correct unit for *t* • no. of oscillations stated • ***t* ≥ 10 s** Average timing • correct precision (2 d.p.) • correct unit for *t* Correct s.f. and unit for *T.*	**1** **1** **1**
1c(iii)	• Correct s.f. (follow s.f. of *T*) • Correct unit	**1**
1c(iv)	• T^2 follows the significant figure of *T* • *T* follows the **s.f. of the time taken** for several oscillations (or equivalent e.g. raw times). OR • T^2 and *T* follows the **s.f. of the time taken** for several oscillations (or equivalent e.g. raw times).	**1**

Qns	Answer	Marks
1(d)	• Second values of x, y and z. Value of y within 10 mm of value in (a)(iii). • **Evidence of repeated readings** • **Correct precision and unit** • Evidence of repeat readings for *t.* • Correct precision and unit for *t.* • **No. of oscillations stated** • ***t* ≥ 10 s** • Correct s.f. and unit for *T* **and T^2.** Second value of *T* < first value of *T*.	**1** **1** **1**
1(e)(i)	Two values of *k* calculated correctly **(Correct transfer of values from previous parts)** • Correct s.f. (follow least s.f.) • Correct unit (e.g. $s^2\ g^{-1}cm^{-2}$)	**B1** **B1**
1(e)(ii)	• Correct calculation of percentage difference (accept 2 to 4 s.f.). • **Smaller number as denominator.** Valid comment consistent with the calculated values of k, testing against percentage uncertainty in (a)(iv). **Evidence of use of value in (a)(iv), namely:** **1. % stated** **2. "value in (a)(iv) or y"** • **"% uncertainty found in (a)(iv)"**	**B1** **B1**

Total Marks: 16

Qns	Answer	Marks
2(b)(i)	Value of θ • to the nearest degree • repeated • accept only from **140° to 170° (OR LARGEST value in table)** • **accept both ° is written out or not**	**1**
2(b)(ii)	Value of L • given to the nearest mm • repeated • with unit	**1**
2(c)	Six sets of readings of θ and L (including correct trend) **Repeated readings of *L*** Column headings: Each column heading must contain a quantity and a unit. The presentation of quantity and unit must conform to accepted scientific convention e.g. θ / °. $\frac{1}{\sin(\theta - 90^o)}$ must have no unit. **Accept** $\frac{1}{\sin(\theta/^o - 90^o)}$, $\frac{1}{\sin[(\theta - 90)/^o]}$, **NOT** $\frac{1}{\sin(\theta - 90)/^o}$ Raw Data: • All values of L must be given to the nearest mm. **(including average)** • All values of θ must be given to the nearest degree. **(including average)** Processed Data: • Every value of $\frac{1}{\sin(\theta - 90^o)}$ must be given to the correct significant figures. **[follow s.f. of θ OR follow s.f. of (θ – 90))** Calculation: • Values of $\frac{1}{\sin(\theta - 90^o)}$ calculated correctly	**2** **1** **1** **1** **1** **1**

2(d)(i)	Axes/Scales: • Sensible scales must be used. Use a scale of 2cm: 1, 2, 5, 10, 20, 50, 100, … • Scales must be chosen so that the plotted points occupy at least half the graph grid in both x and y directions. • Scales must be labelled with the quantity with unit that is being plotted. **ECF** • Scale markings should be no more than 2 large squares apart, including origin if data point falls within the box.	**1**
	Plotting: • All observations in the table must be plotted on the grid. • Diameter of plotted crosses must be $\leqslant$ half a small square (no "blobs"). • Points must be plotted to an accuracy of half a small square. • **for irregular scale, use scale markings encompassing the point**	**1**
	Line of best fit: • Judge by balance of all points on the grid about the candidate's line (at least 5 points). There must be an even distribution of points either side of the line along the full length. • Allow one anomalous point only if clearly indicated (i.e. circled and **labelled (optional)**) by the candidate. • Lines must not be kinked or thicker than half a square.	**1**
	Linearising Statement **Accept answer if quantities of y-axis, x-axis, gradient and y-intercept mentioned are mentioned on this page**	**1**
	Gradient: • The hypotenuse of the **triangle or lines (must draw)** must be greater than half the length of the drawn line. **(Accept non-dotted lines)** • Do not allow $\Delta x / \Delta y$. • Both read-offs must be accurate to half a small square in both the x and y directions (can drop off trailing zeros) • Accept 2 to 4 sf • **Accept if coordinates not stated but shown in gradient working substitution.** • **Correct calculation**	**B1**
	Value of a • correct relation to gradient **(optional to state)** • correct unit (e.g. cm^{-1}) • accept 2 to 4 sf	**B1**

	Value of b • correct relation to y-intercept • no unit • accept 2 to 4 sf • y-intercept: Either: ○ Correct read-offs from a point on the line substituted into y = mx + c or an equivalent expression. ○ **Correct calculation** ○ Read-offs must be accurate to half a small square in both x and y directions. OR ○ Intercept read directly from the graph, with read-off accurate to half a small square.	**B1**
2(d)(ii)	Correct justification of anomalous point • State coordinates of anomalous point or comment on absence • Follow/does not follow trend of best fit line • (Significantly) far/ not far from best fit line relative to other points	**1**

Total Marks: 17