Paper 1: Multiple Choice

1	2	3	4	5	6	7	8	9	10
A	A	C	D	Voided	D	B	A	D	C
11	12	13	14	15	16	17	18	19	20
B	B	C	A	B	C	A	C	C	D

Paper 2: Structured Questions

1 **(a)** Taking upwards as positive,

$u_y = 20.0 \sin 30°$ (substitution of values must be shown)

$= 10.0\ m\ s^{-1}$ **A1**

A number of candidates did not provide an explanation on how they arrived at their final answer.

(b) (i) Using $s = ut + \frac{1}{2}at^2$

$s = (10.0)(4.0) + \frac{1}{2}(-9.81)(4.0)^2$

$= -38.5\ m$ **M1**

The bomb will be 38.5 m below the point of release.

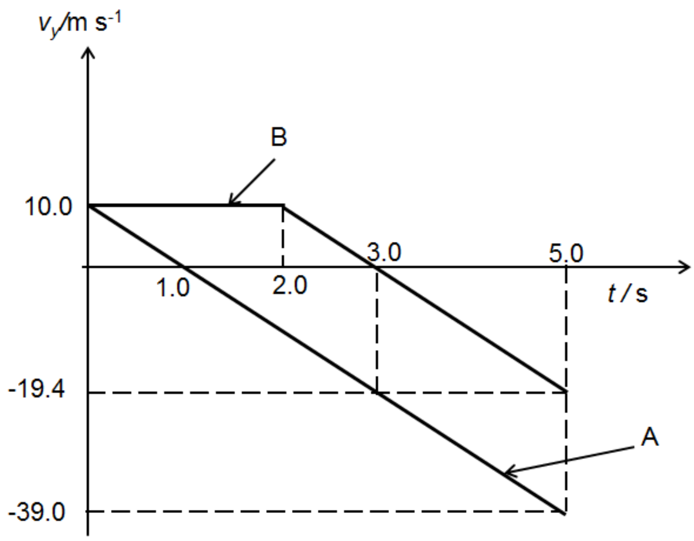
A handful of candidates were not careful when using the kinematics equation and neglected the signs of the values involved.

(b) (ii) When the bomb is falling, the helicopter is rising at the same time,
In 4.0 s, the helicopter rise a vertical distance = $(10.0)(4.0) = 40.0\ m$ above the point where the bomb is released.

Total distance from the helicopter = 40.0 + 38.5 = 78.5 m **M1**

The majority of the candidates got this question correct.

(c)



Correct Gradient of graph **B1**
Correct starting points of the graphs **B1**
Correct axis labels **B1**

A number of candidates did not read the question properly and did not start drawing the graph for B at *t* = 0s. Many also got the gradient of the graph wrong or did not label the axis of the graph, which resulted in a loss of marks.

(d) For first bomb, after $t = 5.0\ s$

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

$$s_1 = (10.0)(5.0) + \frac{1}{2}(-9.81)(5.0)^2$$
$$= -72.6\ m$$

For second bomb,

Displacement, s_2 = area under *v-t* graph.

$$= (10.0)(2.0) + \frac{1}{2}(10.0)(1.0) - \frac{1}{2}(19.4)(2.0)$$
$$= 5.6\ m$$ **M1**

Hence total distance between them = 72.6 + 5.6 =78.2 m. **A1**

The majority of the candidates did badly for this question by being unable to apply the concept that the area under a *v-t* graph gives the change in displacement. A large number of candidates did not realise that the area below the *t*-axis is actually considered negative displacement.

(e) As the bombs are being released at different timings, the second bomb will continue to travel forward after the first bomb hits the ground. Hence, it will land at a spot further away from where the first bomb lands. **M1**

The bombs will not hit the same spot when they hit the ground. **A1**

A large number of candidates incorrectly mentioned that the helicopter and the first bomb will have different horizontal displacements; the 2 bombs will have the same horizontal displacement in flight.

Total: 10 marks

2 **(a)** The ***Principle of Conservation of Linear Momentum*** states that the total linear momentum of a system of interacting particles remains unchanged provided no net external force acts on the system. **B1**

The majority of the candidates lost marks for this question because of missing key words such as "total momentum" and "external resultant/net force".

(b) (i) By conservation of momentum,

$$(2.0)(3.5) = (2.0 + 5.0)v_0$$
$$v_0 = 1.0\ m\ s^{-1}$$ **B1**

The majority of the candidates got this question correct.

(b) (ii) Total kinetic energy $= \frac{1}{2}mv_0^2$

$$= \frac{1}{2}(2.0 + 5.0)v_0^2$$ **B1**
$$= \frac{1}{2}(7.0)(1.0)^2$$
$$= 3.5\ J$$

The majority of the candidates got this question correct.

(b) (iii) Some of the kinetic energy has been **converted to elastic potential energy** stored in the compressed spring. **B1**

Candidates lost marks as the idea of kinetic energy being converted to elastic potential energy was not clearly articulated in their answers. Quite a handful gave default answers such as "energy is lost as heat and sound" which is not relevant to the context of the question.

(c) As the collision is elastic,
relative speed of approach = relative speed of separation
Taking → as positive,

$u_A - u_B = v_B - (-v_A)$
$3.5 = v_B + v_A$ ------------(1) **M1**

By conservation of momentum,
$m_A u_A = m_B v_B + m_A(-v_A)$
$(2.0)(3.5) = 5.0v_B - 2.0v_A$ ------------(2) **M1**

Solving Equation (1) and (2),
$v_A = 1.5\ m\ s^{-1}$ **A1**
$v_B = 2.0\ m\ s^{-1}$ **A1**

Candidates were careless in their algebraic manipulation which resulted in the failure to obtain the correct answers. Many answers also lacked explanations on how the numerical equations used were formed.

Total: 8 marks

3 **(a)** 98.1 N **B1**

(b) As the cupboard is in equilibrium, the horizontal forces acting on it must be zero. Hence X and P must have equal magnitudes. **B1**

A handful of candidates mentioned incorrectly that the reason for X and P to be equal in magnitude is to ensure that sum of torque / moment has to be zero.

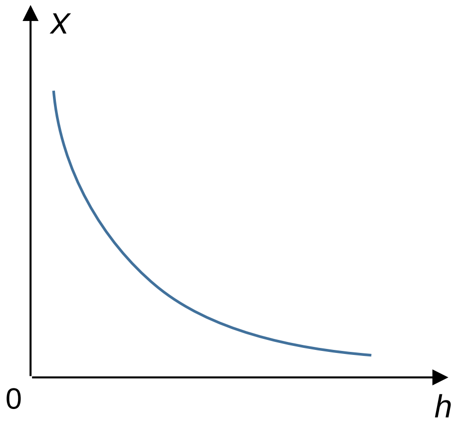
(c) Since the cupboard is in equilibrium,

$$\sum \tau = 0$$ **M1**

$$98.1(0.15) = X(0.60)$$

$$X = 24.5 \text{ N}$$ **A1**

(d)



Candidates who lost the mark for this question failed to note the salient point when sketching a $y = \frac{1}{x}$ graph; the rectangular area of each point on the graph are equal.

Correct shape of $\left(y = \frac{1}{x}\right)$ graph **B1**

Total 5 marks

4	(a)	It means that the oscillation has an acceleration that is always directly proportional to its displacement from the equilibrium position and	B1
		the acceleration is always directed towards the equilibrium point (or is always directed opposite to its displacement)	B1
		This part question was well done by the majority of the candidates. A handful of candidates did not include the reference position for which displacement was taken against.	
	(b) (i)	8.0 cm	B1
	(ii)	From the equation, $\omega = 220$ rad s^{-1}	C1
		Hence, $2\pi f = 220$	
		$f = 35.0$ Hz	A1
	(iii)	line drawn midway between AB and CD (allow ± 1mm)	B1
	(iv)	$v_o = \omega x_o$	M1
		$= (220)(0.040)$	
		$= 8.80$ m s^{-1}	A1
	(v)	$\lvert F_o \rvert = \lvert -m\omega^2 x_o \rvert$	M1
		$= (1.5)(220)^2(0.040)$	
		$= 2900$ N	A1
		A handful of candidates were not mindful that X_o was in centimetres which resulted in a loss of marks for parts (iv) and (v).	
	(c) (i)	line drawn at quarter mark 9 mm below CD (allow ± 1 mm)	B1
	(ii)	arrow pointing upwards	B1
		The majority of candidates got either or both parts to this question wrong. For part (i), candidates need to be aware that the position needs to be scaled relative to the given diagram.	

Total 12 marks

5 **(a)** The frictional force provides the centripetal force for circular motion of the mass. **B1**

$$0.78W = md\omega^2$$ **M1**

$$0.78mg = m(0.35)(2\pi f)^2$$

$$f = 0.74 \text{ Hz}$$

$$= 44.6 \text{ min}^{-1}$$ **A1**

(b) As the radius of the circular motion increases, the required centripetal force to keep the mud in circular motion increases. **B1**
Hence mud at the edge will leave the plate first. **B1**

A large number of candidates incorrectly mentioned that the centripetal force overcomes the frictional force when it is the latter that provides for the former.

Total 5 marks

6 **(a)** **(i)** vibrations in one direction (normal to direction of propagation) **B1**

Many candidates mentioned that the wave propagates in one plane/direction. What many failed to realize is that it is the oscillations that is in one plane.

(ii) I α $\cos^2\theta$ **M1**

We require that $\frac{I}{I_0} = (\frac{\cos\theta}{\cos 0})^2 = 20\% = \frac{1}{5}$

$$\cos\theta = \frac{1}{\sqrt{5}}$$

$$\theta = 63.4°$$ **A1**

Some candidates incorrectly used *I* α cosθ instead of *I* α $\cos^2\theta$.

(b) e.g. both transverse/longitudinal/same type meet at a point,
same direction of polarisation or unpolarised, etc.......1 each, max 3 **B2**

(c) **(i)** **1.** allow 0.3 mm → 3 mm **B1**

Some stated expressions like a << D or a ≈ λ instead of a value as required by the question. Most got the value wrong.

2. λ = ax/D (allow any subject) **B1**

(ii) **1.** separation increased **B1**
less bright **B1**

2. separation increased **B1**
less bright **B1**

3. separation unchanged **B1**
fringes brighter **B1**

further detail, i.e quantitive aspect in (ii)1 or (ii)2 **B1**
(in (b), do not allow e.c.f. from (b)(i)2)

Some students did not consider both factors required by the question, e.g. they missed out on the change in maximum brightness. Some could have assumed that nothing should be written if there are no changes.

(d) **(i)** 2.5λ = 78.0 cm **C1**
v = fλ
v = $(1.07\times10^3)\times(31.2\times10^{-2})$ **C1**
= 334 m s^{-1} (allow 330, not 340) **A1**

Candidates who got this question incorrect could not recognise the value of one wavelength.

(ii) Stationary wave formed by interference / superposition / overlap of either wave travelling down tube and its reflection **B1**

or two waves of same (type and) frequency travelling in opposite directions **B1**

speed is the speed of the incident / reflected waves **B1**

Some candidates did not explain according to the context of the question and missed out on the part where the wave travelling in the opposite direction is due to the reflection at the boundary. A number of candidates described the speed as the speed of the wave, instead of clearly specifying that the speed is the speed of the progressive waves (incident, reflected). Others described the speed as the speed of the stationary wave or particles (oscillating or travelling along the pipe). Some mentioned that it is the speed of sound (as indicated in (d)(i)), not seeing the need to further distinguish the speed as the speed of the progressive wave).

Total: 20 marks

7. (a) (i) When the work done per unit mass by the external agent to bring the point mass from infinity to a point in the gravitational field of one of the planet, the direction of the external force and the displacement are in opposite direction. Hence this work done per unit mass which is the gravitational potential is negative. **B1**

The resultant gravitational potential at that point is the sum of the individual negative values of gravitational potential due to each planet. **B1**

Very few candidates could provide the required answer and lengthy irrelevant answers were often seen. Definition of gravitational potential were often given but not utilised for the answer to the question. Very few candidates realised that the negative work done by the external agent comes from the fact that the external force and the displacement of the mass are in opposite direction. Candidates could not understand the requirement with regards to how the graph is derived.

(ii) The resultant gravitational force acting on an object at a point can be found by multiplying *m* and **B1**
the negative of the gradient of the tangent drawn at that point on the graph. **B1**

Many candidates wrote that the gradient of the graph in Fig .6.1 provides the gravitational field strength. However, they missed out the key point of "*gradient of the tangent drawn at that point.*"

(iii) **1**. When the acceleration of free all is zero, the gravitational field strength is zero. This is given by the turning point on the graph, i.e. $g = -d\phi/d(d) = 0$.

Hence the distance, d= 13.6 x10^6 m. **A1**

Explanations were often poor. Many candidates wrote the answer without the factor of 10^6 which is a gross error. They did not check the magnitude of the variable given in the axes. They should have noticed that a distance of 13.6 m or 14 m in planetary terms is ridiculous.

2. Gradient of the graph

$= (-29.580-(-29.830))\times10^{6} \;/\; (16.00 - 20.00)\times10^{6}$ **M1**

$= 0.25/ (-4.00)$

$= - 0.0652$

Acceleration of free fall on the surface of Charon

$= - d\phi/d(d)$

$= -(0.0652)$

$= 0.0652 \text{ m s}^{-2}$ **A1**

The level of explanation can be improved in this part. Presentation is often poor; short forms such as max, min, Fg, @ were often used. Gradient triangle and coordinates were often missing. Some candidates simply took values from the graph while many read the coordinates wrongly.

(iv) **1.** By Principle of conservation of energy:

Loss in gravitational potential energy = gain in kinetic energy

$m (\phi i- \phi f) = ½ mv^2 - 0$,

where v is the minimum speed of impact on pluto

$5 (-29.565 - (-30.000)) \times10^{6} = ½ \times 5 \times v^2$ **M1**

$v = 933 \text{ m s}^{-1}$ **A1**

Many candidates wrote the calculation without the factor of 10^6. Some candidates found the speed of impact on Charon instead while some used the gravitational potential of Charon's surface as the starting point. Many candidates attempted solving this questions by incorrectly using the concept of escape velocity or the orbital energy equation.

2. The loss in the gravitational potential energy from the maximum gravitational potential energy point to the surface of the planet equals the gain in kinetic energy of the mass, resulting in the minimum speed of impact. **B1**

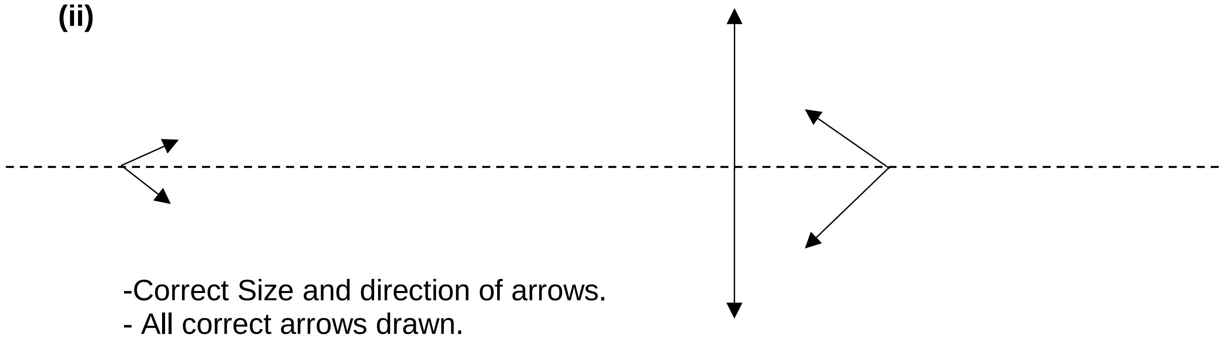
The kinetic energy of the rock on impact on Charon will be lesser as the loss in gravitational potential energy from the maximum gravitational potential energy point to the surface of Charon is less than the loss in gravitational potential energy from the maximum gravitational potential energy point to the surface of Pluto. Thus the minimum speed of impact on Charon will be smaller. **B1**

This question is poorly attempted by most candidates. Most answers centred on conversion of gravitational potential energy to kinetic energy. The energy transformation were often left out.

(c) (i) *The gravitational force of attraction between any two point masses in the universe is directly proportional to the product of their masses and inversely proportional to the square of their separation, and it acts along the line joining the two point masses.* **B1**

Key words such as "product" of the masses and "square" of the distance were often left out. Some candidates used the word radius instead of distance while others used the word "divided by" instead of "inversely proportional".

(ii)

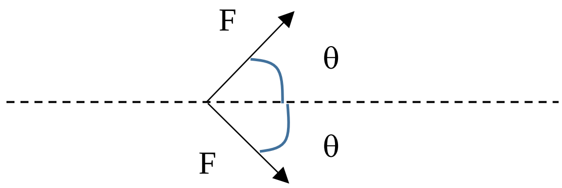


-Correct Size and direction of arrows.
- All correct arrows drawn.

This question was generally well done by most candidates except for those who did not take the magnitude and direction of the arrows into consideration.

(iii) **1.** Let r be the distance from P to either of the 2 planets X and Y.

Gravitational force acting on mass m due to planet X by Newton's law of Gravitation:



$F = GMm/r^2$
Resolving F into the direction of AB, $F' = F\cos\theta$

The vertical component of F will cancel with the vertical component of the force on m due to the planet Y. **B1**

Hence the resultant force acting on m will be the sum of the horizontal components due to the 2 planets X and Y.

Hence $F_G = 2F\cos\theta$
$= 2(GMm)\cos\theta/r^2$
$= 2GMm(x/\sqrt{(x^2+L^2)})\ /\ (x^2+L^2)$ **M1**
$= 2GMm\,x/(\sqrt{(x^2+L^2)})^{3/2}$ (shown)

This questions was poorly done by most in terms of presentation. Many candidates either incorrectly tried to find the resultant using the vector triangle method or to add vectors numerically. Those who resolved the forces failed to account for the vertical forces and also the magnitude of the resolved angle.

2. The resultant force on mass m, $F = 2GMm\,x/(\sqrt{(x^2+L^2)})^{3/2}$
$F = m(GMm\,x/(\sqrt{(x^2+L^2)})^{3/2})$

By Newton's 2nd law, $F_{net} = ma$,
the acceleration, $a = GMm\,x/(\sqrt{(x^2+L^2)})^{3/2}$ [1] **B1**
Comparing with Simple Harmonic (SHM) Equation : $a = -\omega^2 x$,
For SHM, a is proportional to -x
The acceleration, a, found in equation [1]
is proportional to $x/(\sqrt{(x^2+L^2)})^{3/2}$ and not to x. Hence the subsequent motion of the mass is not simple harmonic. **B1**

Answers to this question was disappointing. Only the very capable candidates where able to give acceptable answers. Comparing between acceleration of the mass due to the gravitational forces and due to a simple harmonic motion was often missing. Statements on SHM are given without making comparison with the equation in the previous questions was often seen.

Total: 20 marks