PHYSICS **9749**

Multiple-Choice, Structured Questions and Practical
MARK SCHEME w/ EXAMINERS' COMMENTS
Maximum Mark

October 2020

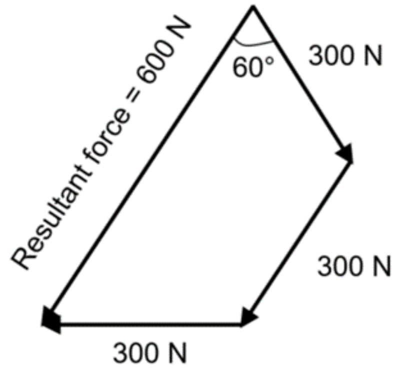
Paper 1 Solution

<table>
<tr><td>1</td><td>A</td><td>$Units\ of\ E = kg\ m^2\ s^{-2}$
$Units\ of\ c = ms^{-1}$

For equation to homogeneous, units of $(\alpha c^2)^2$ and $(\beta c)^2$ must be equal to units of E^2

<table><tr><td>$(units\ of\ E)^2$
$= (units\ of\ \alpha)^2(units\ of\ c)^4$
$(kg\ m^2\ s^{-2})^2 = [\alpha]^2(m^2\ s^{-1})^4$
$[\alpha] = kg$
Therefore, α represents mass.</td><td>$(units\ of\ E)^2$
$= (units\ of\ \beta)^2(units\ of\ c)^2$
$(kg\ \ ^2\ s^{-2})^2 = [\beta]^2(m\ s^{-1})^2$
$[\beta] = kg\ m\ s^{-1}$
Therefore, β represents momentum.</td></tr></table></td></tr>
<tr><td>2</td><td>B</td><td>$\rho = \frac{M}{V} = \frac{M}{lbt}$
$\frac{\Delta\rho}{\rho} = \frac{\Delta M}{M} + \frac{\Delta l}{l} + \frac{\Delta b}{b} + \frac{\Delta t}{t}$
$Percentage\ uncertainty\ of\ \rho = 1 + 1 + 2 + (\frac{0.4}{11.2} \times 100\%) = 7.6\%$

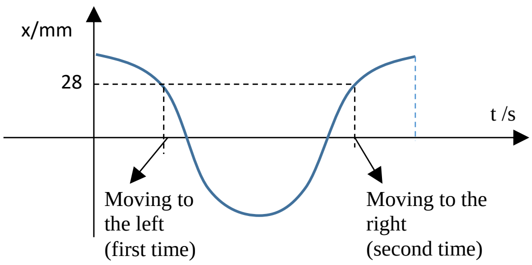
Refer to EJC 2020 Measurement tutorial Qn 7 for deeper understanding on handling percentage uncertainty when "stacking" is involved.</td></tr>
<tr><td>3</td><td>B</td><td>B will result in the voltmeter giving readings that are larger than the true value.</td></tr>
<tr><td>4</td><td>D</td><td>Option C is actually the velocity-time graph of the car. Note that the gradient at t = 0 for the displacement-time graph should be zero as the car starts from rest. Given that the area under the acceleration-time graph cancels out one another, the final velocity of the car is zero as change in velocity is zero. Hence gradient of displacement-time graph is zero at the end. Lastly, when acceleration is 0 between t and 2t, the car is travelling at constant speed. Hence gradient of displacement-time graph is constant.</td></tr>
</table>

5	**B**	As both the hammer and spanner are released from the same vertical height and have the same initial vertical velocity relative to the first floor they will land in the first floor at the same time as they experience the same acceleration.
6	**C**	Solution: the 12 N force will be exerted equally on all springs as they are being connected in series. Using Hooke's Law, *F* = *kx*, x_A = 12/2 = 6 m x_B = 12/3 = 4 m x_C = 12/6 = 2 m Therefore answer is 3 : 2 : 1.
7	**D**	Pressure at point A $= \rho_{water} g h + P_{atm}$ $= (1000)(9.81)(h) + P_{atm}$ $= 9810h + P_{atm}$ Pressure at point B $= \rho_{Hg} g h_{Hg} + \rho_{oil} g h_{oil} + P_{atm}$ $= (13600)(9.81)(0.05) + (800)(9.81)(h - 0.05) + P_{atm}$ $= 6278.4 + 7848h + P_{atm}$ Pressure at the same depth are equal at equilibrium. $6278.4 + 7848h + P_{atm} = 9810h + P_{atm}$ $h = 3.20\ m$
8	**A**	Team C and F alone gives a resultant force of 300 N along OF Team A and D gives a resultant force of 300 along OD Team B and E gives a resultant force of 300 N along OE Drawing the vector diagram gives resultant force of all teams to be 600 N along OE. Question can also be done by resolving resultant forces due to CF and AD along the direction OE. 

9	**B**	Taking 3M and 2M as one system, Resultant force upslope, 5ma = F – 5mgsin30 a = F/(5m) –gsin30 Considering FBD for 2M: F_{AonB} – 2mgsin30 = 2ma F_{AonB} = 2m(a + gsin30) Sub a into F_{AonB}, F_{AonB} = 2m(F/(5m) –gsin30 + gsin30) = 2F/5
10	**C**	Mass of air swept down per second = density of air x volume of air per second = 1.02 x cross sectional area of air x velocity of air = 1.02 x π x $(5.0/2)^2$ x (18) = 360.5 kg per second Force on air by blade = Δ(mv)/ Δt = 360.5(18-0) = 6490 N From Newton's Third Law, magnitude of force on blade by air = magnitude of force on air by blade = 6490 N
11	**C**	Change in momentum = area under the graph from 4 to 8 seconds = ½ (2+4) (12) = 36 Ns 36 = 3.0 (v_f – 12) v_f = 24 m s^{-1}

12	**C**	Using Conservation of linear momentum $2Mv+(M)(-2v)= (2M)v_2 - Mv_1$ $0= 2v_2 - v_1$ ---(1) Using relative speed of approach = relative speed of separation $v - 2v= v_2 - v_1$ $-v= v_2 - v_1$ ---(2) Solving (1) & (2) $v_2 = v$ $v_1 = 2v$ total E_k after collison = $\frac{1}{2}(2M)v^2 + \frac{1}{2}(M)(2v)^2 = 3Mv^2$
13	**B**	Application of Newton's 3rd Law. **A** is a violation of Newton's 3rd Law. For **B**, If the forces are in equilibrium, then crate will not accelerate. **D** will result in 0 resultant force on the crate → 0 acceleration.
14	**A**	Graph given is extension, e vs force applied F. Hence the elastic potential energy stored in spring is the shaded area X.
15	**B**	Output energy = change in GPE = (400)(9.81)(1200) = 4710 kJ Input energy = 4710/(0.8) = 5890 kJ Wasted energy = 5890 – 4710 = 1180 kJ Wasted power = 1180/[2(60)] = 9.83 kW
16	**C**	$v = r\omega$. Since the Earth rotates about its axis at constant ω, v is proportional to r.

17	**D**	At the top, the direction of linear momentum is to the left. GPE is max, KE is constant. At the bottom, the direction of linear momentum is to the right. GPE is min, KE is constant. Total mechanical energy = GPE + KE.
18	**B**	$\leftarrow +$: $g_{net} = \left(+\dfrac{GM}{R^2}\right) + \left(+\dfrac{G(2M)}{(2R)^2}\right) = \dfrac{3}{2}\dfrac{GM}{R^2}$ Option A: Found the difference between g_X and g_Y. Did not consider that g is a vector and here g_X and g_Y are in the same direction, thus should be added instead. Option C: Careless. Used $2R^2$ instead of $(2R)^2$. Option D: Used the formula for potential ϕ instead of for g.
19	**C**	$F = -\dfrac{dE_p}{dr} = -m\dfrac{d\phi}{dr} \approx -1 \times \dfrac{\Delta\phi}{\Delta r}$ Option A: Underestimated the gradient. Option B: Incorrectly used $g = \dfrac{\phi}{r}$ .which is applicable only for a radial field. Here the g-field is the vector sum of the g-field due to the moon and the g-field due to the planet. The net field is not radial. Option D: Overestimated the gradient.
20	**A**	$W = \Delta GPE = m\Delta\phi = 10[(-60)-(-20)] = -400$ MJ Option B: Did not multiply by m to find ΔGPE. Option C: Did not multiply by m to find ΔGPE. Did not calculate change as final value subtract initial value. Option D: Calculated the work done by the gravitational force instead, which is equal to the negative of the change in gravitational potential energy.

21	**D**	Option A: $\omega = \frac{2\pi}{T}$. Since T = 24 h is constant, ω is constant. Option B: $\frac{GMm}{r^2} = mr\omega^2 \Rightarrow r^3 \propto \frac{1}{\omega^2}$. Since ω is constant, r is constant. Thus $a = r\omega^2$ is constant. Option C: $\frac{GMm}{r^2} = mr\omega^2 \Rightarrow r^3 \propto \frac{1}{\omega^2}$. Since ω is constant, r is constant. Option D: $E_p = -\frac{GMm}{r} \propto m$ since r is constant. Thus GPE depends on the mass m of the satellite.
22	**D**	$v_{max} = \omega x_0 = 5\ ms^{-1}$ $x_0 = 7\ m$ Therefore, $\omega = \frac{5}{7} = 0.7143$ rad s^{-1} And $T = \frac{2\pi}{\omega} = 8.8\ s$
23	**C**	Equation, taking right to be positive: $x = 50\cos\frac{2\pi}{3}t$ When displacement is 28 mm while moving to the right,  $28 = 50\cos\frac{2\pi}{3}t$ $\frac{2\pi}{3}t = 2\pi - \cos^{-1}\left(\frac{28}{50}\right)$ $t = 2.5\ s$

24	**D**	After 1st polariser, by Malus' Law, $I_1 = I_0 \cos^2 40°$ After 2nd polariser, by Malus' Law, $I_2 = I_1 \cos^2 70°$ Therefore, $I_2 = \cos^2 40° \times \cos^2 70° \times I_0 = 0.0686 I_0$
25	**B**	P is moving to the right, but it is not at maximum speed. Q is moving to the left and since it is at equilibrium, it is at maximum speed. R is momentarily at rest, since it is at its amplitude. Its acceleration is at its maximum. S is moving to the right but its acceleration is zero at the equilibrium point.
26	**C**	Wavelength is from compression to compression. 100 m spans across 5 wavelengths. Therefore, $\lambda = 100 \div 5 = 20$ m Using $v = f\lambda$, $1200 = f(20)$ Therefore, frequency = 60 Hz
27	**C**	The sources are out of phase by π rad. This is because the path difference $S_2O - S_1O$ is zero but the waves are in antiphase at O, resulting in destructive interference and a minimum detected. Low signal | X Path difference = 2λ High signal | Path difference = $3\lambda/2$ Low signal | Path difference = λ High Signal | Path difference = $\lambda/2$ Low signal | O Path difference = 0

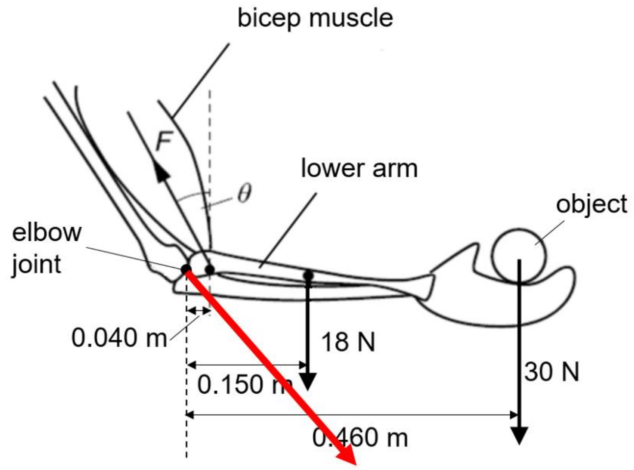
28	**B**	$x = \frac{\lambda D}{a}$ $x \propto D$ $\frac{1.0\ \text{mm}}{3.0\ \text{mm}} = \frac{D}{(D + 2.0)}$ $D = 1.0\text{m}$ $1.0 \times 10^{-3} = \frac{(600 \times 10^{-9})(1.0)}{a}$ $a = 0.6\ \text{mm}$
29	**B**	$s = r\theta$ $\theta \approx \frac{\lambda}{b}$ $\frac{s}{r} = \frac{\lambda}{b}$ $\frac{2.0}{r} = \frac{500 \times 10^{-9}}{3.0 \times 10^{-3}}$ $r = 12\ \text{km}$
30	**C**	$d \sin\theta = n\lambda$ $d \sin(15.4^o) = 1(5.30 \times 10^{-7})$ $d = (1.996 \times 10^{-6}) \sin(15.4^o) = 1(5.30 \times 10^{-7})$ $d = 1.996 \times 10^{-6}\text{m}$ $(1.996 \times 10^{-6}) \sin\theta_2 = 2(5.30 \times 10^{-7})$ $\theta_2 = 32.1^o$ $\Delta\theta = 32.1^o - 15.4^o = 16.7^o$

Paper 2 Mark Scheme

Question		Solution	Marks
1	(a)	$s_y = u_y t + \frac{1}{2} g t^2$ $= 20\sin(50°)(2.75) + \frac{1}{2}(-9.81)(2.75)^2$ $= 5.04\ m$	 **M1** **A0**
	(b)	$u_x t = 245 + x$ $20\cos(50°)\ (2.75) = 32 + x$ $x = 3.35\ m$	 **A1**
	(c)	Given that the water bomb took 2.75 s before it hits the intended target and the boy has got 0.20 s lag time. He is only left with 2.75 – 0.20 = 2.55 s left to run 5.0 m. Taking rightwards as positive, $s = ut + \frac{1}{2} a t^2$ $5.0 = 0 + \frac{1}{2} a (2.55)^2$ $a = 1.54\ m\ s^{-2}$	**C1** **A1**
	(d)	Horizontal distance covered depends on <u>initial horizontal velocity</u> and <u>time of flight.</u> Since the <u>vertical acceleration is independent of the mass of water bomb</u>, the time of flight was not affected. No change.	**B1** **M1** **A1**

Examiners' Comments

(a) Generally well done. A number of candidate failed to demonstrate clearly what substitution is being done to arrive at the final answer.
(b) Generally well done. Common mistakes includes forgetting to subtract 32 m away to determine *x*.
(c) Poorly attempted by the candidates. Common mistakes includes not recognising that the 0.2 s is the lag time and the boy will have less time to run. Some candidates used 0.2 s as the duration of acceleration which was conceptually wrong.
(d) Poorly attempted. Most candidates only stated the variables as being constant but did not mention explicitly what makes it constant. There is also a lack in most answers that mentioned about horizontal displacement depends on initial horizontal velocity and time of flight. Most uncredited answers as give vague statement without specifying clearly what they are referring to for e.g. velocity(horizontal or vertical) is constant.

Question		Solution		Marks
2	(a)	Taking moments about the elbow joint, Using principle of moments, (F cos 15.0°)(0.040) = (18)(0.150) + (30)(0.460) F = 427 N		 M1 A1
	(b)	(i)	 Correct direction of R *CONCURRENT FORCES of combined weight, R and F.* *R NEEDS TO BE LESS STEEP*	A1
		(ii)	'The rightward horizontal component of R is to balance the leftward horizontal component of F. <u>Taking moments about the point the muscle is attached to the bone,</u> the vertical component of R needs to act downwards to provide an anticlockwise moment to counter the clockwise moment provided by the 18 N and 30 N forces.' OR 'The rightward horizontal component of R is to balance the leftward horizontal component of F. The net vertical force due to the weights and tension is upwards, hence the vertical component of R must act downwards so that there is no net vertical force.' OR 'A vector diagram is draw in scale. Using drawn vector diagram in scale, we can deduce the direction of the force R should point rightward and downward.' OR 'The forces of 18 N and 30 N can be combined to form one downwards force which should be drawn between the two mentioned forces. Since the forces of R, F and combined force due to 18 N and 30 N should intersect at a point, we can deduce the direction of the force R should point rightward and downward.'	B1 B1 B1 B1 B1 B1 B1 B1
	(c)	**Curve is sloping upwards** and **does not start from origin**, where its asymptote is at 90°.		B1

	(d)	Both centre of mass of arm and object will be further away from the elbow joint hence giving a larger clockwise moment about the elbow joint. To remain in equilibrium, *F* will need to be larger to provide a large anticlockwise moment to balance out the increased clockwise moment. ALTERNATE ANS: Perpendicular distance from elbow joint to application point of F increases proportionately with the distance between weight and application point of F. Hence there is no change in F.	**B1** **B1**

Examiners' Comments

(a) Poorly done. A significant number of candidates are unable to apply Principle of Moments to tackle the problem and relied on the idea of equilibrium to solve the problem unsuccessfully.

(b) (i) Poorly attempted. Most candidates treated the problem as the force exerted on the elbow instead of the arm. There is a lack of understanding that the force needs to balance the leftwards horizontal force exerted by bicep muscle.

(ii) Poorly done. Many failed to explain clearly for the direction of the reaction force clearly. Many candidates only mentioned that horizontal force needs to be cancelled without discussing about the vertical forces. Some attempted to use moments to explain, but failed to state clearly the moments is taken about with point.

(c) Well done. Candidates knows the shape of the curve with the help of GC. However, many do not realise that the graph did not start at origin.

(d) Generally well done. Most are able to qualitatively describe and explain for the change. However, majority lose marks because of poor description of the change, for example failing to mention that the line of action of the weight is further away from the elbow joint and only state that moment is larger.

Question		Solution			Marks
3	(a)	The total momentum of a system before and after a collision is constant			B1
		provided no (resultant) external force is acting on it			B1
	(b)	(i)	1.	Since collision is elastic, $\frac{1}{2}$ m$(9.0 \times 10^5)^2 = \frac{1}{2}$ m $(4.5 \times 10^5)^2 + \frac{1}{2}$ m v^2 $v = 7.8 \times 10^5$ m s^{-1}	 M1 A1
			2.	By Principle of Conservation of Momentum in the vertical direction, $0 = m(4.5 \times 10^5) \sin 60^o - m(7.8 \times 10^5) \sin \theta$ $\theta = 30^o$	 M1 A1
		(ii)	In this scenario, the principle is applied to the system of particles A and B together. As particle B experiences a change in momentum because of the collision with A. In order for the principle to hold, particle A needs to experience a change in momentum of the opposite direction but equal in magnitude to that of B. Hence momentum of A cannot be conserved. Alt: As <u>particle A experiences a net resultant force due to B</u> it will experience a change in momentum Hence, its momentum cannot be conserved.		B1 B1 B1 B1

Examiners' Comments

(a) Significant number did not get the full two marks as they omitted the condition "provided no resultant external force is acting on it". Some students also tend to include statements irrelevant to the definition such as total energy must be conserved.

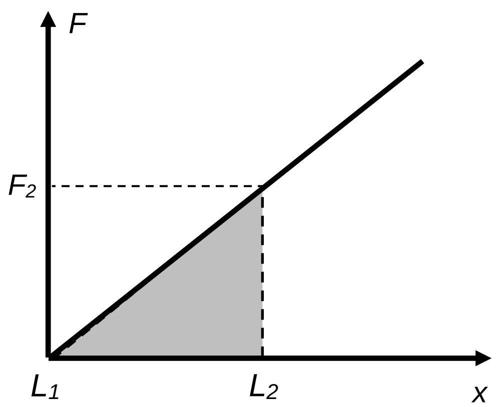
(b) (i) Some students determined the answers to parts 1. and 2. by resolving the conservation of momentum in the horizontal and vertical directions. However, students need to inculcate the good habit of writing out the principles that they used in determining the answer. Marks are deducted where students equate the sum of velocities before collision to sum of velocities after collision. They should insert the mass of the particles, m into the equations used.

i.e. $0 = m(4.5 \times 10^5) \sin 60^o - m(7.8 \times 10^5) \sin \theta$

instead of $0 = (4.5 \times 10^5) \sin 60^o - (7.8 \times 10^5) \sin \theta$

(c) Complete answers should include describing explicitly that the total momentum of the system consists of momentums of A and B. Answers should also describe how B's momentum was initially 0 and had an increase after the collision with A and where that increase comes about given that total momentum is conserved.

For answers that describes A experiencing a resultant force, they need to specify what is the source of this resultant force ie. It comes from B and how that resultant force causes A to change its momentum and hence momentum is not conserved.

Question		Solution		Marks
4	(a)	(i)	Work done by F = area under the F-x graph from 0 to 3.0 m = ½ (5 + 10) (1.0) + (3.0-1.0)(10) = 27.5 J	 A1
		(ii)	Gain in kinetic energy of box, ½ mv^2 = Work done by F for first 3.0 m – Work done against friction for first 3.0 m – (loss in energy due to work done against F and friction from 3.0 to 5.0 m) = 27.5 – (2.5 x 3.0) – (7.5 x 2.0) = 27.5 – 7.5 – 15 = 5.0 J Speed of box, v = $(5.0/[1/2(4.0)])^{1/2}$ = 1.6 m s^{-1}	 M1 C1 A1
	(b)		 straight line F-x graph sketched. Elastic potential energy stored $= \text{area under } F - L \text{ graph}$ $= \frac{1}{2}F_2(L_2 - L_1)$ $= \frac{1}{2}[k(L_2 - L_1)(L_2 - L_1)]$ $= \frac{1}{2}k(L_2 - L_1)^2$	B1 M1 A1

Examiners' Comments

4(a)(i) This is supposed to be an easy question. However, some careless mistakes include considering the net work done by the difference of external force applied F, and resistance.

(ii) Some wrong answers failed to see the concept that frictional force does not necessarily act opposite to the external force applied but will always be acting in the opposite direction to the motion of the object.

(b) Some students did not sketch the graph of Force against extension for the spring that would aid in the derivation of the expression. Instead, graph of elastic potential energy vs extension was drawn. Some derived the expression in terms of x, clearly indicating that they did not read the question properly. Some also sketch a non linear F-x graph even though Hooke's Law applies to the spring

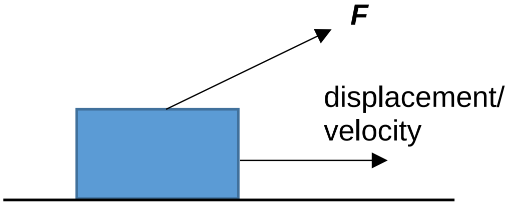
Question			Solution	Marks
5	(a)	(i)	The horizontal component of R provides the centripetal force. $\leftarrow +$: $F_{net} = ma$ $R\sin 60^{\circ} = m\left(\dfrac{v^2}{5.0\cos 30^{\circ}}\right)$ ……(1) $\uparrow +$: $F_{net} = 0$ $R\cos 60^{\circ} - mg = 0$ ……(2) $\tan 60^{\circ} = \dfrac{v^2}{(5.0\cos 30^{\circ})g}$ $v = 8.6$ m s^{-1}	 **B1** **B1** **M1** **A0**
		(ii)	R is always perpendicular to the velocity of the rider and motorcycle Thus R does no work on the rider and motorcycle.	**M1** **A1**
	(b)		At B the weight of the rider and motorcycle provides the centripetal force. There is no contact force if the rider is just able to complete the loop **AND** $\downarrow +$: $F_{net} = ma$ $mg = m\,v^2/r$ $v^2 = gr$ ……(1) From A to B, applying the Principle of conservation of energy, Gain in GPE = Loss in KE $mg\,(2r) = \frac{1}{2}mu^2 - \frac{1}{2}mv^2$ ……(2) Substitute (1) in (2) gives $u = \sqrt{5gr}$	 **B1** **M1** **A1**

Examiners' Comments

5 (a) (i) Some students have difficulty resolving vectors, either to obtain the centripetal force or the radius of the circular motion. On the whole, most students are able to obtain the answer.

(ii) A very common misconception is to think that no work is done by a force if the object does not move in the direction of the force.

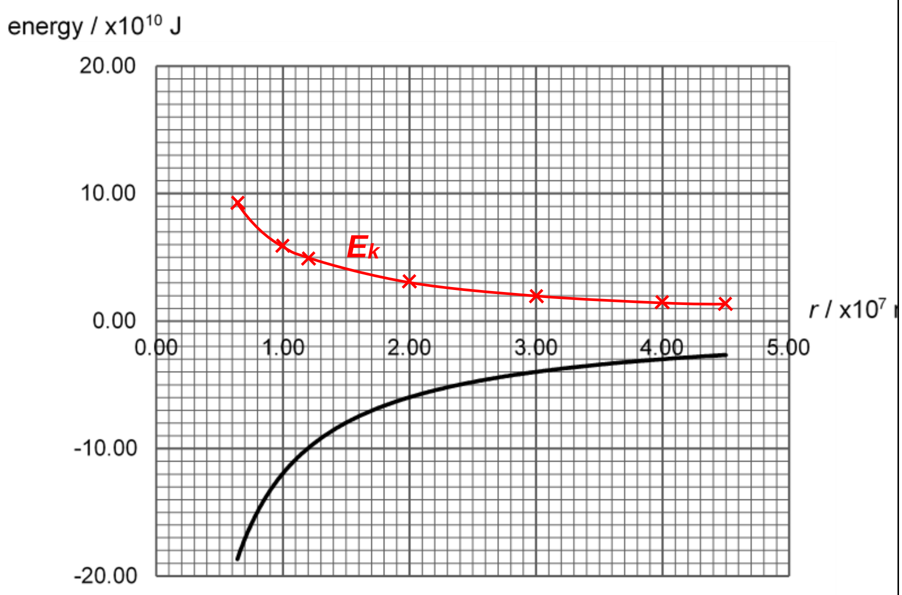
This is not true. As can be seen in the diagram, although the object did not 'move in the direction of *F*, but *F* does positive work on the object as the displacement of the object *has a component* in the direction of *F*.



We can only be sure that *F* does no work on the object if the velocity or displacement vector of the object is perpendicular to *F* at any instant

(b) Common mistake here include not explaining why the centripetal force at the top of the sphere is provided by gravitational force only. Students need to make clear that the normal contact force would be zero at the top if the rider is just able to complete the vertical loop.

Another common mistake is to assume that the speeds at A and B are the same, or to assume that the speed at B is zero.

Question		Solution		Marks
6	(a)	(i)	Gravitational force of Earth on m provides the centripetal force. By Newton's 2nd Law, $F_{net} = ma$ $\frac{GMm}{r^2} = m(\frac{v^2}{r})$ $E_k = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{GMm}{r}\right) = \frac{GMm}{2r}$	B1 M1 A1
		(ii)	$E_p = -\frac{GMm}{r} = -2E_k$  Points on E_k graph must be such that $E_k = -\frac{1}{2}E_p$.	B1
	(b)	(i)	1. From A to B, r increased, thus E_p increased since $E_p = -\frac{GMm}{r}$. E_k decreased since $E_k = \frac{GMm}{2r}$ $\left(\text{AND/OR } E_k \propto \frac{1}{r}\right)$.	B1 B1
			2. The thrust force from the rocket engines does positive total work on the satellite, thus total energy of the satellite increased.	B1
		(ii)	1. Orbital radius remains constant, thus $E_p = -\frac{GMm}{r}$ remains constant.	B1
			2. Thrust force from engines are perpendicular to tangential velocity/ orbital plane thus no work done. Direction of	B1

				velocity of satellite changes but magnitude remains constant.	

Examiners' Comments

6 (a) (i) Generally well-done, although some students lost marks by leaving out the mandatory statement of "Gravitational force provides/is the centripetal force." Note that it should not be gravitational force is "equal to" centripetal force, as this implies merely a mathematical equality, which does not convey the concept that the net force causes the circular motion.

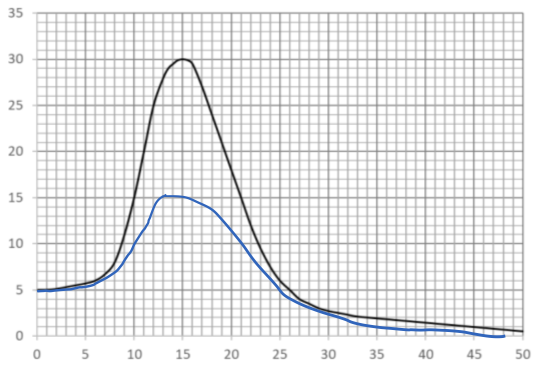
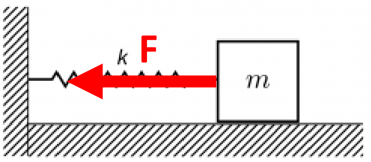
(ii) This is surprisingly badly done. Students should know that $E_k = -\frac{1}{2}E_p$ and since the graph is to be drawn on a grid, the graph must be accurate.

(b) (i)1. Many students simply claimed that E_k or E_p decreased/increased because the orbital radius r has increased, without providing the reason for the energy change. These answers gets zero credit.
Students should note that the full equations relating the physical quantities, in this case, the equations for gravitational E_k and E_p , must always be quoted to justify the decision on whether the physical quantity will change if one of the independent variables in the equations changes.

(i)2. Many students did not realise that the total energy of the satellite has actually increased as it goes to a higher orbital radius. Students need to identify how the extra energy is supplied.

(b) (ii)1. Same comment as in (b)(i)1.

(ii)2. It is insufficient to just state that the thrust force of the engine is perpendicular to the tangential velocity of the satellite. This must be followed by an explanation of why the tangential speed is not affected. Accepted answers would be the thrust force does not do any work to increase the tangential speed, or the thrust force will not cause any tangential acceleration.

Question		Solution			Marks
7	(a)	(i)	Resonance		A1
		(ii)	1.	15 Hz	A1
			2.	5 mm	A1
		(iii)	Peak is lower. Peak occurs at a lower (or same) frequency. Curve is less sharp. Curves should not intersect (bet 8 and 25 Hz). 		P1
	(b)	(i)	Natural frequency = 15 Hz (answer from (a)(ii)1.) Since mass is set into free oscillation, it oscillates at its natural frequency, $T = \frac{1}{f} = \frac{1}{15}$ $T = 0.067s$		C1 A1
		(ii)	 Let F be the force exerted by the spring on the mass, $F = kx$ When the mass is displaced to the right, $F_{net} = ma$ $kx = ma$ $a = \frac{k}{m}x$ Since $\frac{k}{m}$ **is a constant**, a is **directly proportional** to x. When the mass is displaced to the right, the spring is extended/stretched. The **<u>force</u> exerted by the spring** on the mass is to the left. Hence, acceleration is **opposite** to displacement, $a = -\frac{k}{m}x$.		M1 A1 A1

Examiners' Comments

7ai, ii A few students wrote "resonant frequency" instead of "resonance". Some students also wrote the phenomenon as "forced oscillation". Almost all students were able to identify the natural frequency of the system correctly. Most students were not able to identify the amplitude of the oscillator.

7aiii For the frequency response curve, many students drew a curve which intersects with the given curve. Some students also drew a curve which shifted to the right (or has its peak shifted to the right). Many students drew a curve where the peak remained at the same frequency, even in cases where the amplitude has reduced substantially. Some students also did not flatten the curve sufficiently.

7bi Some students did not realise that the system was the same as in part (a) and could not find the relevant information required. Those who did were able to do this question very well. A few still made mistakes in the calculations.

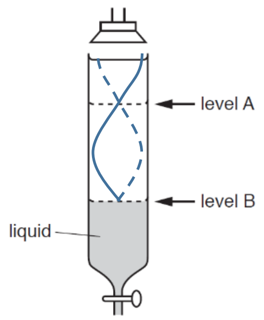
7bii Only a small number of students were able to obtain full credit for this question. Many students were not able to derive the mathematical relationship between acceleration and displacement. Some students who included friction in their free body diagram did not know to use an assumption (i.e. that friction is negligible) in order to proceed. Students also had difficulty deducing the two characteristics from the mathematical equation, with most of them merely stating the characteristics in their final statement.

<table>
<tr><th colspan="2">Question</th><th colspan="2">Solution</th><th>Marks</th></tr>
<tr><td>8</td><td>(a)</td><td colspan="2">When the string is plucked, progressive waves are formed and they propagate towards the two ends of the string and gets reflected at the ends.

The reflected wave overlaps another progressive wave

of the same frequency, speed and amplitude and hence, a stationary wave is formed.</td><td>B1

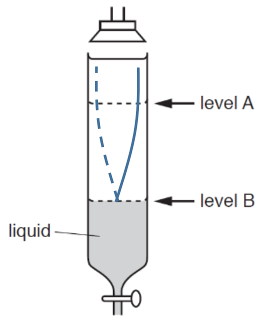
B1

B1</td></tr>
<tr><td></td><td>(b)</td><td>(i)</td><td>

Node at liquid surface and antinode at open end.

Node at level A</td><td>M1

A1</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>It is given that wavelength is 0.24m.

Distance between levels A and B = $\frac{1}{2}\lambda$ =0.12 m</td><td>A1</td></tr>
<tr><td></td><td></td><td>(iii)</td><td>At Level A or B</td><td>A1</td></tr>
<tr><td></td><td></td><td>(iv)</td><td>Length of level B below open end, considering (b)(ii)
$$L = \frac{3}{4}\lambda = 0.18\ m$$

When wavelength is increased, frequency decreases until it reaches fundamental mode.
$$L = \frac{1}{4}\lambda$$
$$0.18 = \frac{1}{4}\lambda$$
$$\lambda = 0.72\text{ m}$$</td><td>C1

A1</td></tr>
</table>

Examiners' Comments

8a A small proportion of students did not make any reference to the context (i.e. strings of a guitar) in their answer, and merely stated conditions for stationary waves to be formed. Many students described the waves being reflected in antiphase at the fixed ends, though it was not required in the answer. A handful of students then related the reflection being antiphase to the waves being stationary, with a few explicitly saying because the velocity/amplitude "cancels out each other".

8bi, ii, iii This question is generally well done. Most students had issues with (iii). Students who made errors in (ii) were given full credit for (iii) if the location is at the displacement node of the diagram drawn in (ii).

8biv Many students were not able to obtain full credit for this question. Some students did not understand the context; some students made errors in identifying the length of the tube; many students could not identify the standing wave which is formed. Some students found the next highest frequency rather than the next longest wavelength. Only about half of the students drew the diagram of the standing wave in order to solve this question – many just relied on the formula.

Question		Solution		Marks
9	(a)	Total energy = max $E_K = \frac{1}{2}m(\omega x_o)^2 = \frac{1}{2}(8.0)((5.0)(0.15))^2$ OR Total energy = max elastic E_P from equlibrium = $\frac{1}{2}kx_o^2 = \frac{1}{2}(200)(0.15)^2$ $= 2.25\ \text{J}$		M1 (M1) A1
	(b)	(i)	gain in kinetic energy = loss in gravitational potential energy $E_{k\ final} - E_{k\ initial} = mg\Delta h$ $\frac{1}{2}mv^2 - 0 = mg\Delta h$ $\frac{1}{2}v^2 - 0 = (9.81)(20)$ OR $v^2 = u^2 + 2as$ $v^2 = 0 + 2(9.81)(20)$ $v = 19.8\ \text{m s}^{-1} (\text{or } 20\ \text{m s}^{-1})$	B1 M1 (C1) (M1) A1
		(ii)	$F = \frac{\Delta p}{\Delta t}$ $F = \frac{m(v_f - v_i)}{\Delta t}$ $F = \frac{(8.0)(3.0 - 19.8)}{(0.75)}$ $F = 179\ \text{N (or } 180\ \text{N)}$	 M1 A1
		(iii)	Part of the kinetic energy (and gravitation potential energy) of the stone is transferred to the kinetic energy (or gravitational potential energy) of the water. Kinetic energy of stone is smaller transferring the energy to the water. Hence less work is needed for the stone to come to a stop	M1 A1
	(c)	(i)	Using $I \propto \frac{1}{r}$ and $I \propto x_o^2$, $x_o^2 \propto 1/r$ $\left(\frac{x_o'}{x_o}\right)^2 = \frac{r}{r'}$	

			$\left(\frac{x_o'}{4.0}\right)^2 = \frac{(0.50)}{(1.5)}$ $x_o' = 2.3$ cm	**M1** **A1**
		(ii)	energy is spread over a bigger area (or circumference) as the wave spreads hence no energy is lost. OR Intensity is inversely proportional to distance from the source Intensity is proportional to the square of the amplitude of the wave	**A1**
		(iii)	$v = f\lambda$ $2.0 = (8.0)\lambda$ $\lambda = 0.25$ m phase difference $= \frac{1.0}{0.25} \times 2\pi = 8\pi$ OR No of wavelengths between A and B = (1.5 – 1.0)/0.25 = 4 Hence they are in phase	 **C1** **M1** **(M1)** **A1**

Examiners' Comments

9 (a)(i) A common mistake is where candidates use the total extension to calculate total elastic potential energy and equate this to the total energy of the oscillation. Some also add up the kinetic, gravitational and elastic potential energies, wrongly taking the bottom of the oscillation as having zero GPE. There is a substantial number who carelessly left out the square of the angular frequency during calculation.

(b)(i) Students generally used either equations of motion or conservation of energy to solve this question. Amongst those who used equations of motion, about a third failed to see that the mass is instantaneously at rest when the spring broke at the lowest point of oscillation. Amongst those who used conservation of energy, a number of students included the elastic potential energy in the calculation, failing to see that that the mass is already detached from the spring and hence need not be considered. Some did not state the energies gained and lost by the objects.

(b)(ii) Most candidates approached the question correctly. A small number used the velocity given in the question as the change in velocity instead of subtracting from the velocity found in (b)(i). For those who did not manage to obtain an answer in (b)(i), they should indicate a value on the answer line and use that value for calculation in this question. Some used (change in momentum) x time to find force wrongly.

(b)(iii) This was poorly done. Most candidates did not specify the types of energy transformed and the specific objects transferring and receiving the energies. Some mentioned GPE is of the stone transformed but left out the kinetic energy. There is little mention of "less work done is needed" to decrease the kinetic energy of the stone.

(c)(i) About half the candidates got the wrong answer due to the wrong use of relation. They assumed that intensity is inversely proportional to square of the distance from the source.

(c)(ii) Wrong answers include damping and destructive interference. Some used wrong relations such as "intensity is proportional to amplitude" in their explanation.

(c))(iii) Most students received full marks for this part. However, presentation was not done well where algebraic manipulations were shown without explaining why they were done so.