Answers to examination-style questions

Answers	Marks	Examiner's tips
1 (a) *Arrowed lines drawn to show:* • two components at right angles • vertical component in line with weight	**2**	These lines should form two sides of a rectangle, with F as the diagonal of the rectangle. For both marks, the lines must start from the • in the centre of the kite.
(b) (i) Horizontal component of T is $T \cos 60 = 25 \times 0.5 = 12.5$ N or 13 N to 2 significant figures.	**1**	These answers should really be quoted to 2 significant figures i.e. 13 N and 22 N, since the data is given to only 2 significant figures. Scale drawing would be more tedious and is less accurate.
(ii) Vertical component is $T \cos 30$ $= 25 \times 0.866$ $= 21.65$ or 21 N to 2 significant figures	**1**	
(c) (i) Vertical component is $2.5 + 21.65$ $= 24.15$ N	**1**	The kite is stationary and the forces acting on it are therefore balanced in all directions. The vertical component of F must be equal to the total downwards vertical force i.e. the vertical component of T + the weight.
(ii) Horizontal component is equal to $T \cos 60$ i.e. 12.5 N	**1**	The forces also balance horizontally.
(iii) Magnitude of F is $F = \sqrt{12.5^2 + 24.15^2}$ $= \sqrt{156.25 + 583.22}$ $= \sqrt{739.47}$ $= 27.19$ or 27 N to 2 sig. figs.	**1**	Throughout this question, you should retain 3 signficant figures when carrying out the calculations but only quote final answers to 2 significant figures. Part (iii) could also be done by scale drawing, for which a final result of 27 ± 2 N would be acceptable.
2 (i) use of $E_y = \dfrac{FL}{A\Delta L}$	**1**	The Young modulus equation is given in the Data Booklet. To find the extension, you have to rearrange it and then substitute values into it. Be careful with the powers of 10.
gives extension $\Delta L = \dfrac{FL}{E_Y A}$ $= \dfrac{125 \times 2.0}{2.0 \times 10^{11} \times 2.5 \times 10^{-7}}$	**1**	
$= 5.0 \times 10^{-3}$ m	**1**	
(ii) extension ΔL is proportional to $(1/E_Y)$ and E_Y for brass is $\frac{1}{2}$ of E_Y for steel ∴ extension of brass wire would be 10 mm	**1**	The tension in the brass wire must also be 125 N, because the weight of the bar is 250 N. Note that the bar AB cannot be horizontal when suspended in this way. It simply appears to be horizontal because there is only 5 mm difference between the heights of the ends A and B.
end A would be 5 mm lower than end B	**1**	
3 (a) (i) gradient = acceleration	**1**	Acceleration $a = \dfrac{\Delta v}{\Delta t}$ = gradient of the v–t graph. The ball experiences the acceleration of free fall, g, (which is constant) all the time it is moving in the air.
(ii) both AB and CD represent the acceleration of free fall (or the same acceleration)	**1**	

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(iii) the area under AB is equal to the height above the ground from which the ball was dropped	1	Area under v–t graph = distance travelled. The time corresponding to AB represents the time of the first fall to the ground.
(iv) the velocity at C is negative because the ball now starts to move upwards instead of downwards	1	B represents ball's arrival at the ground, whilst C represents its departure upwards after the direction of its velocity has been reversed.
(v) the speed at C is less than that at B because the ball loses some of its kinetic energy when it strikes the ground	1	Every time the ball strikes the ground some of its energy is converted into thermal energy.
(b) **(i)** use of $v^2 = u^2 + 2as$ gives $v^2 = 0 + (2 \times 9.81 \times 1.2)$	1	When the ball is moving upwards it is accelerating downwards, making the acceleration negative.
$\therefore\ v = 4.9\ \text{m s}^{-1}$	1	**Alternatively** you could answer **(b)** by using conservation of energy:
(ii) use of $v^2 = u^2 + 2as$ gives $0 = u^2 + (2 \times -9.81 \times 0.75)$	1	$m\,g\,\Delta h = \frac{1}{2}\,m\,v^2$ where (since it is the same) m cancels out.
$\therefore\ u = 3.8\ \text{m s}^{-1}$	1	
4 **(a)** *Relevant points include*: • force on driver is given by $F = m\,a$, where a is the deceleration • a larger deceleration produces a larger force • in a collision, Δv is always the same but the time of deceleration Δt can be different • use of the air bag increases the time Δt during which the driver decelerates and reduces the deceleration $\frac{\Delta v}{\Delta t}$ • thereby producing a smaller force, and reducing injuries	4	Other approaches are possible when answering part **(a)**, e.g. *Energy*: • air bag absorbs E_K of the driver • over a greater distance • ΔE_K = force × distance • so force is reduced *Effect of pressure*: • air bag increases contact area • force on driver acts over a larger area • pressure (force per unit area) on driver is reduced
(b) use of $v^2 = u^2 + 2as$ gives $0 = 18^2 + (2 \times a \times 2.5)$	1	On this occasion you are given the initial speed and the distance, rather than the time, over which the impact occurred.
gives $a = -65\ \text{m s}^{-2}$ and deceleration = $65\ \text{m s}^{-2}$	1	You are asked to calculate the deceleration, so there shouldn't be a minus sign in the answer.

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5 (a) (i) use of $v = u + a\,t$ gives $a = \frac{v-u}{t} = \left(\frac{60-0}{25}\right) = 2.4\ \text{m s}^{-2}$	1	Careful reading should make you appreciate that this is a standard projectile question, but turned through 90°. The spacecraft continues upwards at constant speed in a gravity-free environment, whilst being accelerated at 90° to this direction by the thrusters.
(ii) use of $F = m\,a$ gives force of thrusters $= 5.5 \times 10^4 \times 2.4$	1	
$= 1.3 \times 10^5$ N	1	
(b) by vector addition, magnitude of resultant velocity V is given by $V^2 = 890^2 + 60^2$	1	This part involves adding the two perpendicular components of the velocity. The effect of the thrusters on the magnitude of the resultant velocity is slight, making it vital to show your working.
$\therefore\ V = 892\ \text{m s}^{-1}$ (= 890 m s^{-1} to 2 significant figures)	1	
(c) $\tan\theta = \frac{60}{890}$ gives $\theta = 3.9°$ where θ is the angle between the initial and final directions of travel	1	It may help to draw a right-angled triangle with 890 m s^{-1} in direction A and 60 m s^{-1} in direction B.
6 (a) *Relevant points include*: • initially the raindrop accelerates due to its weight • resistive forces increase as speed increases • eventually, resistive forces become equal to the weight • the resultant force on the raindrop is then zero • raindrop falls at constant velocity (or has no acceleration) because $F_{res} = 0$	4	This is a standard type of question to test your understanding of terminal speed. It may seem contrary to common sense that a raindrop can fall when there is no overall force acting on it. If you have understood Newton's first and second laws, you will appreciate that motion at constant velocity is equivalent to being at rest: in both cases there is no resultant force.
(b) (i) kinetic energy $E_K = \frac{1}{2} m v^2$ gives $E_K = \frac{1}{2} \times 7.2 \times 10^{-9} \times (1.8)^2$	1	Once it has reached the terminal speed, the kinetic energy of the raindrop remains constant.
$= 1.2 \times 10^{-8}$ J	1	
(ii) work done on raindrop = (weight) × (change in height) $= 7.2 \times 10^{-9} \times 9.81 \times 4.5$	1	Work is still being done on the raindrop by gravity, but all of it becomes thermal energy in overcoming the frictional forces. Alternatively, you could calculate part **(ii)** by using work done $= \Delta E_P = m\,g\,\Delta h$.
$= 3.2 \times 10^{-7}$ J	1	
(c) by vector addition, magnitude of resultant velocity V is given by $V^2 = 1.8^2 + 1.4^2$	1	Part **(c)** gives you further practice in finding a resultant vector from two perpendicular components. In this case the sideways wind causes a big change in the direction of travel of the raindrop.
$\therefore\ V = 2.3\ \text{m s}^{-1}$	1	
$\tan\theta = \frac{1.4}{1.8}$ gives $\theta = 38°$ where θ is the angle to the vertical	1	

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7 (i) volume of air passing over blades per second $= \pi r^2 L = \pi \times 22^2 \times 15 = 2.28 \times 10^4\ \text{m}^3\ \text{s}^{-1}$	**1**	In 1 s, the air moves a distance of 15 m; this is the length of the effective cylinder.
(ii) mass of air per second $= V\rho$ $= 2.28 \times 10^4 \times 1.2$ $= 2.74 \times 10^4\ \text{kg s}^{-1}$	**1** **1**	Just rearrange $\rho = m/V$.
(iii) kinetic energy E_K per s $= \frac{1}{2} m v^2 = \frac{1}{2} \times 2.74 \times 10^4 \times 15^2$ $= 3.08 \times 10^6\ \text{J s}^{-1}$	**1** **1**	This calculation shows that the power output of this large wind turbine would be around 3.0 MW if it could achieve perfect conversion from kinetic to electrical energy. Yet a typical nuclear power station gives an output of 1200 MW!
(iv) *Relevant points include*: • if the wind speed were decreased by half, the mass of air passing the blades per second would be halved • $E_K \propto v^2$ and v^2 would be reduced to $\frac{1}{4}$ of the original value • the power available would be only $\frac{1}{8}$ of the original value	**2**	The argument here shows you that the power output from a wind turbine is very low when the wind speed is low. At high wind speeds the power of the wind can be so dangerous that the blades of a wind turbine have to be stopped to prevent it from being damaged. Doubling the wind speed increases the power available from the wind by a factor of 8.
8 (i) area of water $= 120 \times 10^6\ \text{m}^2$ mass of sea water $= V\rho$ $= 120 \times 10^6 \times 10.0 \times 1100$ $= 1.32 \times 10^{12}\ \text{kg}$	**1** **1**	Conversion of 120 km^2 into m^2 is the first hurdle here: $1\ \text{km}^2 = 1000\ \text{m} \times 1000\ \text{m} = 10^6\ \text{m}^2$. The water involved is **sea** water, whose density is greater than $1000\ \text{kg m}^{-3}$.
(ii) use of $\Delta E_P = m g \Delta h$ gives $\Delta E_P = 1.32 \times 10^{12} \times 9.81 \times 5.0$ $= 6.47 \times 10^{13}\ \text{J}$	**1**	The water can be thought of as a liquid block of height 10 m, which collapses on to the ground. The **average** height through which the water falls is therefore 5m.
(iii) power available from the falling water $P_{in} = \dfrac{\text{energy converted}}{\text{time taken}} = \dfrac{6.47 \times 10^{13}}{6 \times 3600}$ $= 3.00 \times 10^9\ \text{W}$ use of efficiency $= \dfrac{P_{out}}{P_{in}}$ gives $P_{out} = 0.40 \times 3.00 \times 10^9$ $= 1.2 \times 10^9\ \text{W}$ (1200 MW)	**1** **1** **1** **1**	The whole of the water is assumed to flow out to sea over a period of 6 hours. The tide would be going out during this time. Over the next 6 hours the sea level would be rising as the tide came in, filling up the reservoir again. Your calculation shows that the output power could be as great as that of a nuclear power station, but it would only be available for (at most) 12 hours per day. The nuclear power would provide a continuous output.

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9 (a) input power $P_{in} = I\,V = 14 \times 230 = 3220$ W	1	If you prefer, you can calculate the efficiency from the ratio of input energy to useful output energy:
output power $P_{out} = \frac{mgh}{t} = \frac{160 \times 9.81 \times 5.0}{22} = 357$ W	1	$E_{in} = I\,V\,t = 14 \times 230 \times 22 = 7.08 \times 10^4$ J
efficiency $= \frac{P_{out}}{P_{in}} = \frac{357}{3220} = 0.11$ (= 11 %)	1	$E_{out} = mgh = 160 \times 9.81 \times 5.0 = 7.85 \times 10^3$ J; efficiency $= \frac{7.85 \times 10^3}{7.08 \times 10^4} = 0.11$
(b) (i) use of $E_Y = \frac{\text{tensile stress}}{\text{tensile strain}}$ gives	1	In **(i)** you have to recall that the Young modulus is the ratio of stress to strain. The stress is the force (not the mass) per unit cross-sectional area. Tensile strain is a ratio of lengths, so there is **no unit** in the final answer.
tensile strain $= \frac{\text{tensile stress}}{E_Y} = \frac{F}{A} \times \frac{1}{E_Y} = \frac{160 \times 9.81}{1.8 \times 10^{-4}} \times \frac{1}{2.1 \times 10^{11}}$	1	
$= 4.15 \times 10^{-5}$	1	
(ii) use of tensile strain $= \frac{\text{extension}}{\text{original length}}$	1	Whilst in **(ii)** you have to recall that tensile strain is the ratio of extension to original length.
gives extension $= 4.15 \times 10^{-5} \times 14 = 5.8 \times 10^{-4}$ m	1	
10 (a) $\lambda = 2\,L = 2 \times 38 = 76$ m	1	The aerial is transmitting short wave (high frequency) radio signals at the fundamental frequency of vibration of the aerial wire. Note that these are electromagnetic waves that travel at the speed of light.
use of $c = f\lambda$ gives $f = \frac{c}{\lambda} = \frac{3.00 \times 10^8}{76} = 3.95 \times 10^6$ Hz (= 3.95 MHz)		
(b) (i) angle θ between cable and ground is given by $\sin\theta = (12/14)$ $\therefore\ \theta = 59.0°$	1	The aerial support system must be in equilibrium. Resolving horizontally at a point at the top of the aerial mast leads to this result, because the tension in the cable P acts downwards along its length.
resolving horizontally, $T = 110 \cos 59.0° = 56.7$ N	1	
(ii) cross-sectional area of copper wire $A = \frac{\pi d^2}{4} = \frac{\pi \times (4.0 \times 10^{-3})^2}{4} = 1.26 \times 10^{-5}$ m^2	1	This calculation shows the importance of working to 3 significant figures **throughout** when you are expecting the final answer to be accurate to 2 significant figures. If you round up the values of F and A to 2 significant figures, the final answer becomes 4.4×10^6 Pa.
stress in copper wire $= \frac{F}{A} = \frac{56.7}{1.26 \times 10^{-5}}$	1	
$= 4.5 \times 10^6$ Pa (or N m^{-2})	1	
(iii) *Relevant points include*: • breaking stress is ≈ 67 × stress in wire (or much higher than it) • copper is ductile, or could extend much more before breaking • because of plastic deformation • extension to breaking point is unlikely	**any 2**	Ratio of stresses $= \frac{3.0 \times 10^8}{4.5 \times 10^6} = 67$. Movement of either mast outwards would increase the strain in the aerial wire, producing a corresponding increase in stress. Additional calculations would show that the copper wire would have to extend by about 10 cm before the breaking stress was reached.

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11 (a) microwaves from the transmitter are polarised (or vibrate in a certain plane or direction) rotating the transmitter rotates the plane of polarisation of the microwaves received signal becomes zero when receiver is perpendicular to the plane of polarisation of the microwaves	1 1 1	XY is the axis of the system and you can imagine the transmitter being rotated about this axis from a vertical to a horizontal position. The receiver detects microwaves that are polarised in a particular plane. Originally the plane of polarisation of the microwaves must have coincided with this plane.
(b) (i) use of $c = f\lambda$ gives $f = \frac{c}{\lambda} = \frac{3.0 \times 10^8}{0.12}$ $= 2.5 \times 10^9$ Hz	1	Microwaves are electromagnetic waves; they travel at the speed of light.
(ii) any food at nodes would not be heated because there is no energy (or intensity, amplitude, vibrations) at the nodes	1 1	This is why microwave ovens contain a rotating turntable, and/or a rotating reflector, to ensure that any object placed in them receives microwaves from more than one direction.
12 (a) (i) angle F is a critical angle	1	The critical condition arises when the refracted ray travels along the boundary between two media.
(ii) angle D is greater than angle B (or ray R_1 refracts away from the normal at the glass-water boundary)	1	You may need to use a ruler on the diagram to notice that this ray changes direction, because the bending effect is slight.
(b) (i) use of $\sin\theta_C = \frac{n_2}{n_1}$ gives $\sin 48.8° = \frac{1}{n_{water}}$ $\therefore$ refractive index of water $n_w = 1.33$	1 1	At the start of this calculation, you are forced to find n_{water} from angle F, because you are not given the refractive index value for the glass. You should know that the refractive index of air is taken to be 1.00.
(ii) $n = \frac{c}{c_s}$ gives $\frac{c_{water}}{c_{glass}} = \frac{n_{glass}}{n_{water}} = \frac{\sin\theta_{water}}{\sin\theta_{glass}}$ $= \frac{\sin 48.8}{\sin 42.9}$ $= 1.11$	1 1 1	Refractive index is a ratio of the speed of waves in different media, not just a ratio of sines. This rearrangement follows from $n_1 \sin\theta_1 = n_2 \sin\theta_2$. The **small** difference in these speeds is the cause of the **slight** bending noted in **(a) (ii)**.
(c) ray R_2 has a greater angle of refraction in the water than angle D and undergoes total internal reflection at the water-air boundary	1 1	The continuation includes the ray meeting the top boundary on the diagram. There is total internal reflection here because the angle of incidence for this ray will be greater than the critical angle (F).

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13 (a) *Completed graph to show*: • maxima of successively smaller intensity • subsidiary fringes that are equally spaced • subsidiary fringes are half the width of the central fringe • symmetrical pattern each side of the central axis	**4**	You need to be fully conversant with the principal features of this pattern. Do not confuse this with the Young's slits pattern, where all the fringes are of similar intensity to the central fringe and the fringes are all the same width.
(b) *Relevant points include in* **(i)**: • a narrower slit gives broader maxima (or a broader pattern) • that will also be dimmer *and in* **(ii)**: • the maxima are more closely spaced with green light • the pattern is green and dark instead of red and dark	**any 3**	The diffraction effect increases as the slit width decreases, but less light energy comes through the slit. Diffraction is greater for light of longer wavelength, and $\lambda_{green} < \lambda_{red}$. The second mark in **(ii)** is for noting the change in the colour of the pattern you would observe.
14 (a) (i) time between successive clap $= (20 / 47) = 0.426$ s	**1**	When each clap coincides with the previous clap, the sound wave is travelling from the student to the wall and back again in the time taken from one clap to the next. Sound travels at constant speed in air.
(ii) distance travelled by sound $=$ speed $\times$ time $= 340 \times 0.426$	**1**	
distance of student from wall $= \dfrac{340 \times 0.426}{2} = 72$ m	**1**	
(b) (i) use of $c = f\lambda$ gives $\lambda = \dfrac{c}{f} = \dfrac{340}{2400}$	**1**	A fence made from wooden strips can act as a plane transmission diffraction grating for sound waves. Note that the separation of the 'slits' is comparable with λ for the sound waves, as is usual for diffraction effects.
$= 0.142$ m	**1**	
(ii) use of $\lambda = d \sin \theta$ for the first order gives $d = \dfrac{0.142}{\sin 28°}$	**1**	
$= 0.302$ m	**1**	
(iii) highest order maximum is given by $n\lambda = d \sin 90° = d$	**1**	Part **(iii)** follows the same steps that you would use for a diffraction grating with light waves. As usual, you must select the highest whole number that is less than the numerical answer for n when θ is 90°, the highest conceivable angle of diffraction.
from which $n = \dfrac{d}{\lambda} = \dfrac{0.302}{0.142} = 2.13$, $\therefore$ the highest order is the 2nd	**1**	

Nelson Thornes is responsible for the solution(s) given and they may not constitute the only possible solution(s).