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Physics

1996 TEE Solutions*

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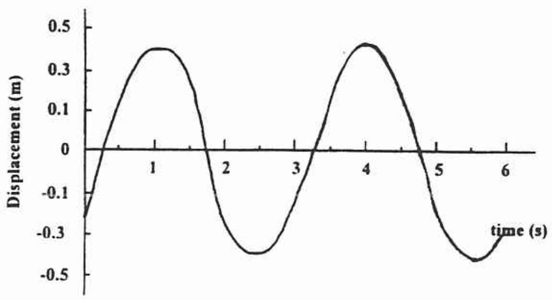
** These solutions are not a marking key. They are a guide to possible answers at a depth that might be expected of Year 12 students. It is unlikely that all possible answers to the questions are covered in these solutions.*

 STAWA appreciates the support of the Secondary Education Authority, which provided the marker's guides used as a basis for these solutions.

1996 TEE PHYSICS SOLUTIONS

SECTION A

1. If you just continue the trace you should get a maximum at 4.0 s, cross the axis at 4.75 s and get a minimum at 5.5 s.



2. The centre of mass of each object is low.
The centre of mass is over the centre of the base and the base is relatively wide.

3. This effect is called ***beats***. Beats occur when two slightly different frequencies are heard together. The two engines would be making sounds of similar but not identical pitch.

4. The sum of all of the forces on the body must be zero. The sum of all of the torques (moments) on the body must be zero.

5. The centripetal force is mv^2/r = 199 N if 8.5 m is used for r. A larger value for r could be estimated if you say Tarzan's mass is below the end of the 8.5 m rope. The tension in the rope must provide the centripetal force ***and*** support Tarzan's weight so the tension will be $mv^2/r + mg$ = 980 N.

6. Torque = rF = rmg = 2.2x5.5x9.8 = 119 N m

7. The current in AB will be unaffected by the magnetic field due to the current through XY because the magnetic field is parallel to the current.

8. The whiteners are fluorescent. They absorb UV from the incident light and emit visible light. The increase in the blue content of the emitted light makes the garments whiter or less yellow.

9. The "acceleration" due to gravity is Gm/r^2.
$g_{neptune} = 6.67\text{x}10^{-11}\text{x}17\text{x}5.98\text{x}10^{24}/(22.7\text{x}10^6)^2$
$g_{neptune} = 13.2 \text{ m s}^{-2}$

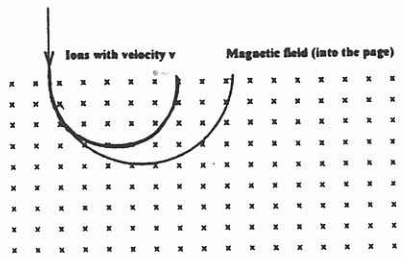
10. The speed of sound is $v = f\lambda$. This rearranges to give $\lambda = v\,{}^1/_f$ so a graph of λ against ${}^1/_f$ will have a gradient equal to v. The slope of the graph given is approximately 1500 m s^{-1}. From the data given with the examination paper you might guess that the medium is water or sea water.

11. Note that this question is asking you about the change in velocity. It is ***not*** asking you about the ***rate*** of change of velocity or acceleration. For the change in velocity described, the direction is E. The magnitude of the change in velocity is $v - u = \sqrt{(10^2 + 10^2)} = 14 \text{ m s}^{-1}$.

12.
$$Y = \frac{F/A}{\Delta l / l} = \frac{0.25\text{x}105\text{x}10^{-3}}{5\text{x}10^{-3}\text{x}\pi\text{x}(0.043\text{x}10^{-3}/2)^2} = 3.6\text{x}10^9 \text{ Pa}$$

13. High potential differences are more dangerous if people come into contact with the wires. There is a perception that higher voltage transmission lines create greater amounts of electromagnetic radiation and that this is dangerous. High voltage lines need larger support pylons and the lines need to be kept further apart and this would be unattractive in suburbia. High voltages are not useful in the home anyway as most devices work on quite low voltages that have been transformed down from 240 V.

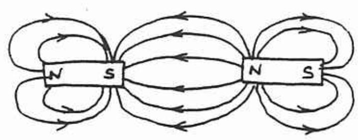
14. Force on the moving ion in the magnetic field is given F = qvB and since this force is centripetal we can write $qvB = mv^2/r$. Hence r = mv/qB. Since m, q, and B are constant in this situation we can say $r \propto m$. An ion of two thirds the mass will, therefore, follow a pathway of two thirds the radius.



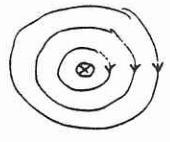
15. The centripetal force on the satellite is provided by its weight so $m_s v^2/r = G m_s m_p/r^2$. Using this and substituting $v = 2\pi r/T$ you can obtain $v^3 = G m_e 2\pi/T$.
Hence $v = ((6.67\text{x}10^{-11}\text{x}5.98\text{x}10^{24}\text{x}2\pi0/924\text{x}60\text{x}60))^{1/3}$
$= 3070 \text{ m s}^{-1}$

SECTION B

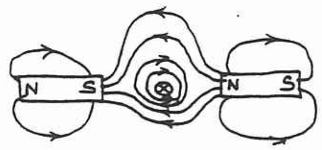
1(a)(i)



1(a)(ii)



1(a)(iii)



1(b) The current is perpendicular to B.
$F = liB = 6\text{x}30\text{x}10^{-2}\text{x}2.5 = 0.45$ N
The force is directed to the top of the page.

1(c)(i) As the coil in a generator is rotated, the magnetic flux linked by the coil changes. The rate of change of flux linked is proportional to the emf generated: emf = $-N\Delta\Phi/t$. The emf alternates from a maximum in one direction to zero to a maximum in the other direction and back again. (A good answer to this question should include a labeled diagram including magnetic field and slip rings.)

1(c)(ii) The generator is rotated by an externally supplied torque to create an ac current whereas a motor is driven by an externally supplied current to produce a torque.

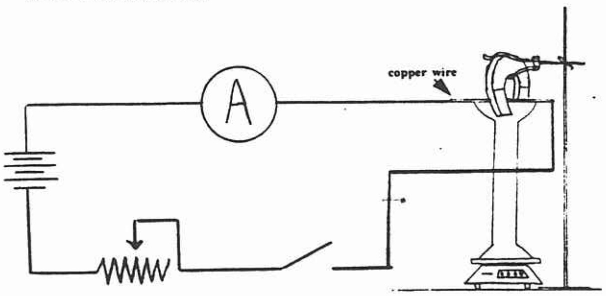
2(a) Calculate the time it takes to fall 6 m with no initial vertical velocity using $s = ut + \frac{1}{2}at^2$. If you use the "up is positive" convention then $s = -6$ m, $u = 0$, $a = -9.8$ m s^{-2}. Time taken to fall is 1.1 s.

2(b) She needs to travel 2.5 m horizontally in the 1.1 s it takes to fall. Her horizontal speed must be 2.3 m s^{-1}.

2(c) Her final vertical speed can be found using $v^2 = u^2 + 2as$. $v = \sqrt{(2as)} = \sqrt{(2 \times 9.8 \times 6)} = 10.8$ m s^{-1}. Her final velocity is the sum of 2.3 m s^{-1} horizontal and 10.8 m s^{-1} vertical. The vector sum of these is 11 m s^{-1} at an angle of 78° from the vertical.

3(a) $F = l\,i\,B$ or $F = k\,i\,B$ where k is a constant.

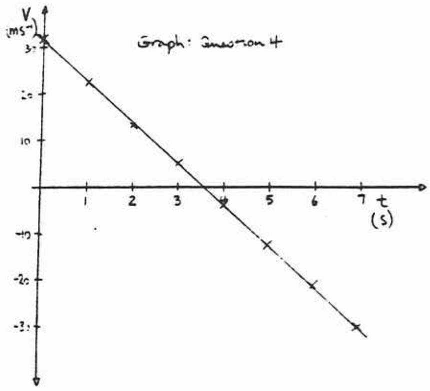
3(b) You would need to be able to measure the current through the copper wire. The following circuit would be suitable:



3(c) You would need to measure the magnetic force on the copper wire as well as the current in the wire. The ammeter in the above circuit will give you the current readings. If the balance is zeroed (tared) before you start then the readings on the electronic balance when multiplied by g give the force created by the magnet and the current. Typically around 5 to 10 readings would be reasonable in a Year 12 practical exercise.

3(d & e) If you graph I on the horizontal axis and F on the vertical axis then the gradient will be l B. If you divide the gradient by the length of the copper wire in the magnetic field then the result is B.

4(a) Points to consider when drawing the graph are that axes and scales must be sensible and well labeled, points must be plotted correctly, and a line of "best fit" should be drawn.



4(b)(i) At the highest point, the ball has no velocity. This corresponds to a time of 3.5 s.

4(b)(ii) g is the gradient of the graph, -8.83 m s^{-2}.

4(c) The equation involving velocity and displacement is $v^2 = u^2 + 2as$. A plot of v^2 on the vertical axis and s on the horizontal axis will give a line with gradient 2a and vertical intercept u^2.

4(d) The required values are 1024, 506, 174, 24.

5(a)(i) The cathode emits electrons.

5(a)(ii) The anode is positive.

5(a)(iii) A significant proportion of the energy of the bombarding electrons is converted to heat and the anode gets very hot.

5(a)(iv) X-rays are emitted in all directions but can be absorbed by lead. X-rays are potentially harmful and the lead shielding protects the people using the X-ray tube.

5(b)(i) Use $E = hf$ and hence $f = E/h$.
$f = [(-3.0)-(-69.6)] \times 10^3 \times 1.9 \times 10^{-19} / (6.63 \times 10^{-34})$
$= 1.61 \times 10^{19}$ Hz

5(b)(i) 69.6 kV

5(c) There are many possible answers for this question. Examples include X-ray astronomy, medical imaging, examination of welds, etc.

6A(a) Harmonics are integer multiples of the fundamental frequency.

6A(b) Closed tubes only vibrate at odd multiples of the fundamental. The next two modes of vibration would be 3x665 = 1995 Hz and 5x665 = 3325 Hz.

6A(c)

$$\begin{aligned} \text{decibel change} &= 10 \log_{10}(I/I_0) \\ \Rightarrow \quad 75-40 &= 10 \log_{10}(I/I_0) \\ \Rightarrow \quad \log_{10}(I/I_0) &= 3.5 \\ \Rightarrow \quad I/I_0 &= 3160 \end{aligned}$$

6B(a) Harmonics are integer multiples of the fundamental frequency.

6B(b) Closed tubes only vibrate at odd multiples of the fundamental. The next two modes of vibration would be 3x665 = 1995 Hz and 5x665 = 3325.Hz.

6B(c)

$$\begin{aligned} \text{decibel change} &= 10\log_{10}(I/I_0) \\ \Rightarrow \quad 65-30 &= 10\log_{10}(I/I_0) \\ \Rightarrow \quad \log_{10}(I/I_0) &= 3.5 \\ \Rightarrow \quad I/I_0 &= 3160 \end{aligned}$$

7A(a) When the weight is lifted from A to B, the centre of weight of the person and the weight is shifted forward. The person must lean back to counter this effect and keep the centre of weight above their feet.

7A(b) Assume that the 35 kg mass is being lifted by one arm. The anticlockwise torque supplied by the biceps must balance the clockwise torque supplied by the weight. The pivot is at the elbow.

$$\begin{aligned} 0.015 \times F_{biceps} &= 0.45 \times 35\ g \\ \Rightarrow \quad F_{biceps} &= 1.03 \times 10^4\ N \end{aligned}$$

7A(c) Estimate the mass of the arm at, say, 3 kg and its centre of mass, say, half way between the elbow and the hand:

$$\begin{aligned} 0.015 \times F_{biceps} &= 0.45 \times 35\ g + 0.225 \times 3\ g \\ \Rightarrow \quad F_{biceps} &= 1.07 \times 10^4\ N \end{aligned}$$

This is only slightly larger than the answer to part (a) and, since everything here is approximate anyway the difference is not significant.

7A(d) The upper arm bone is in compression. This can be seen if you imagine a pivot at the place where the muscle meets the forearm bone. The upper arm bone must be providing a downward force on that end of the forearm bone.

7B(a)The bricks hanging off the back may provide a large enough torque at the rear wheels and tip the truck. The torque due to the bricks at the "feet" will be less and the truck will not tip over. The weight of the truck will also provide a larger torque at the feet than at the back wheels.

7B(b) The anticlockwise torque supplied by the hydraulic ram must balance the clockwise torque supplied by the bricks. The pivot is at the top of the vertical member.

$$\begin{aligned} 0.15 \times F_{ram} &= 1.2 \times 1000\ g \\ \Rightarrow \quad F_{ram} &= 7.84 \times 10^4\ N \end{aligned}$$

7B(c) Estimate the mass of the lifting arm at, say, 20 kg and its centre of mass, say, half way between the pivot and the load:

$$\begin{aligned} 0.15 \times F_{ram} &= 1.2 \times 1000\ g + 0.6 \times 20\ g \\ \Rightarrow \quad F_{ram} &= 7.92 \times 10^4\ N \end{aligned}$$

This is only 1% larger than the answer to part (a). The difference is not significant.

7B(d) The vertical member is under tension. This can be seen if you imagine a pivot at the place where the hydraulic ram meets the lifting arm. The vertical member must be providing a downward force on the end of the lifting arm.

SECTION C

1(a) It is important to know the properties of the gas so that measurements of flow can be accurate. Small errors can make a big economic difference because of the very large total quantities involved.

1(b) The properties of the natural gas can be compared with the reference gas under the same conditions. The reference gas is selected because its properties are well known.

1(c) $400 \times 10^5 = 4 \times 10^6$ Pa

1(d) Resonance occurs when the frequency of a driving disturbance matches a natural frequency and causes a large amplitude oscillation. There are many everyday examples of this such as in organ pipes and other musical instruments, wobbling car wheels when the shock absorbers are ineffective, pushing a child on a swing, etc.

1(e)(i) Values are 406, 402, 398.

1(e)(ii) The relationship given is $v = k\sqrt{T}$ so $v/\sqrt{T}$ should be constant for all of the readings. In each case we get approximately 23.3 so the data is consistent with the given relationship.

2(a) The tether, which in this case is a long wire, is moving across the earth's magnetic field and consequently an emf is generated across its ends. Some would say that it is "cutting the magnetic field lines".

2(b)(i) An electron gun on the shuttle fires electrons back into the ionosphere.

2(b)(ii) The electrons flow from the satellite to the shuttle so the current is from the shuttle to the satellite. The power generated is 1.5 kW at 5 kV. Using P = VI, the current is 0.3 A.

2(b)(iii) The mechanical energy of the shuttle is converted into electrical energy. This will cause the total of kinetic and potential energy of the shuttle to decrease. The shuttle will gradually decrease its altitude. At lower altitudes the shuttle will be faster and its kinetic energy will be greater; its total energy, including potential energy, will be lower.

2(c) From the data sheet, the breaking stress of aluminium is 2.4×10^8 Pa.
Stress = F/A so F = Stress x A
$= 2.4 \times 10^8 \times \pi \times (2.5 \times 10^{-3}/2)^2 = 1.18 \times 10^3$ N

2(d) Both the shuttle and satellite must have the same period of revolution since they are tethered together. The satellite in a slightly larger orbit, would need to go slower than the shuttle and take longer to go around the earth if the only centripetal force was its weight. The tension in the cable provides the additional centripetal force to allow the satellite to be in a larger circular orbit but fast enough to keep up with the shuttle.