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Physics

2006 TEE Solutions*

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*These solutions are not a marking key. They are a guide to the 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.

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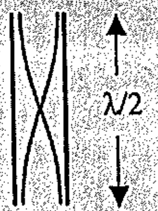
STAWA TEE Solutions Physics 2006

Section A

1. An example of beats would be playing the same note on two musical instruments which are slightly out of tune; a 2-engined aeroplane with both engines running.
   The conditions for this would be: 2 sound waves with similar frequencies occurring at the same time.
   Examples of diffraction: Water waves passing through a gap; sound waves passing through a gap such as a doorway.
   Conditions: Waves pass a barrier or go through a gap. Significant diffraction occurs when the wavelength is large compared with the barrier or similar in size to the gap.

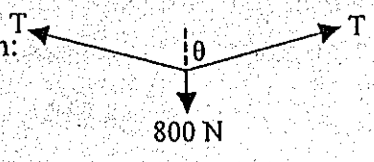
2. $\lambda = 2 \times 3 = 6$ m Assume $v = 346\ ms^{-1}$
   $f = v/\lambda = 346/6 = 58$ Hz

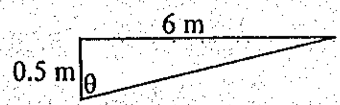


3. It would be easier to loosen the screw with Q because it has a handle with a larger radius.
   Torque = F x r so Q would give a larger torque for the same applied force.

4. Dam A is less likely to collapse because the water exerts a force on the dams but in A it creates a compressive force whereas in B it creates a tensile force. Concrete is stronger under compression and so will withhold more water.

5. Vector diagram:





$\tan \theta = 0.5/6 \quad \theta = 85.2^0$

Equating vertical components in the vector diagram: $2T \cos 85.2 = 800$
So $T = 4.82 \times 10^3$ N

6. A is true as shown by this calculation of g at the top of Everest:

$$g = \frac{GM}{R^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.37 \times 10^6 + 8.85 \times 10^3)^2} = 9.80\ ms^{-2}$$

   This value is almost the same as that at sea level which is 9.83 for the given values.

7. Force T acts at a greater distance from ground level and the chair's centre of mass (c of m), which will provide a large torque about the opposite corner and can cause it to topple: T = Fr.

   A force at M will give a very small turning torque because the radius from the pivot (far corner) is small – too small to overcome the torque due to the (c of m) for rotation, but the force may be large enough to overcome friction on the ground - in which case it will slide.

8. A 360^0 rotation would represent a turning time of 24 hours.
The angle turned in the picture from the star track is about 27^0 which gives an exposure time of about $t = \frac{27}{360} \times 24 = 1.8$ hours, approximately

If a protractor is not available or it is difficult to estimate an angle then arc lengths and radii can be measured from the photograph.(Largest radii will give most accurate results)

$$t = \frac{(l_{arc} \times 24)}{2\pi r} = \frac{(18 \times 24)}{2\pi 38} = 1.8 \text{ hours, approximately}$$

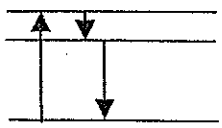
9. a) Power input = power output (no losses) so $V_1I_1 = V_2I_2$
So if V changes, I must change also.

b) $P_{OUT} = 0.9 \times P_{IN}$
$50 = 0.9 \times 240 \times I_{IN}$
$I_{IN} = 0.231$ A

10. A: $F = mg = 1.25 \times 10^3 \times 9.8 = 1.23 \times 10^4$ N

B: $F = mg - \frac{mv^2}{r} = 1.23 \times 10^3 - \frac{1.25 \times 10^3 \times 20^2}{80} = 6.00 \times 10^3$ N

11. λ will be longer because the photons emitted in fluorescence will have less energy than UV as they are visible
E = hf so f will be lower and λ will be longer since Energy, E, is less.

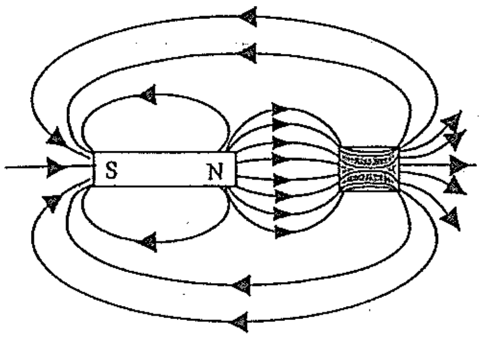


12. Area = $\pi(1 \times 10^{-3})^2 = 3.14 \times 10^{-6}$ m^2 L = 30×10^{-2} m

$$E = \frac{F}{A} \Big/ \frac{\Delta L}{L} \quad so \Delta L = \frac{FL}{EA}$$

$$\Delta L = \frac{250 \times 30 \times 10^{-2}}{(5.04 \times 10^9) \times (3.14 \times 10^{-6})} = 4.74 \times 10^{-3} \text{ m}$$

13.



NB. The iron concentrates the magnetic lines of force and the field will return around the outside to the S-end of the magnet.

"Too many field lines RH end"
"should match LH end"

14. The electrons will strike section A because the electric field will attract the electrons to the left and the magnetic field will deflect the electrons upward (by the right-hand "slap' rule).

15. Option (a) will be more likely to prevent him from hitting the barrier.
Reasons: To reduce the velocity of the car towards the barrier, a force is needed that acts directly away from the barrier. In braking, the frictional force from the tyres is always acting away from the barrier. However, when moving in a curve, the frictional (centripetal) force from the tyres acts inwards, towards the centre of the circle, which, at the point shown, is towards the left and not away from the barrier. The centripetal force only has a component acting away from the barrier at one particular time (when the car moves parallel to the barrier) and so the tyre friction would need to be greater in this case. In braking, the force is always opposing the car's forward direction and so must reduce the velocity of the car towards the barrier faster.
or Using Calculations

Let r = distance of car from barrier
u = initial velocity of car
a = required deceleration so that car misses barrier.

Circular motion

$F_c = ma_c$ towards centre

$$F_c = \frac{mu^2}{r}$$

Straight Braking

$F_b = ma_b$

since $v^2 = u^2 + 2as$

$\therefore \quad 0 = u^2 + 2a_b r$

$\therefore \quad a_b = \frac{-u^2}{2r}$

$\therefore \quad F_b = \frac{-mu^2}{2r}$

Therefore $F_b = 0.5\, F_c$ ie. only half the force is needed for direct braking

Section B

1. (a) A high-pitched, ultrasonic sound is one where the frequency is high and above human hearing.

   (b) $v = f\lambda \qquad 346 = 18{,}000\lambda \qquad$ so $\lambda = 1.92 \times 10^{-2}$ m

   (c) As the mosquitoes are on the ceiling, assume all the sound is emitted into a hemisphere of area $2\pi r^2 = 2\pi 3^2 = 56.54\ m^2$

$$I = \frac{P}{A} = \frac{2 \times 5}{56.54} = 0.177\ Wm^{-2}$$

$$L = 10\log\left(\frac{0.177}{10^{-12}}\right) = 112\ dB$$

2. (a) 4500/60 = 75 Hz frequency $\qquad r = 0.10$ m

$$v = 2\pi r f = 2\pi \times 0.1 \times 75 = 47.1\ ms^{-1}$$

   (b) $$a = \frac{v^2}{r} = \frac{47.1^2}{0.1} = 2.22 \times 10^4\ ms^{-2}$$

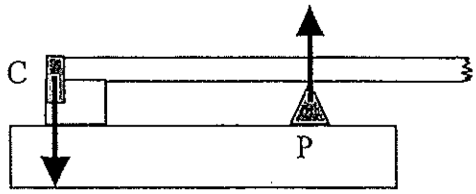
   (c) $F_{max} = 8 \times 10^{-3}$ N $m = 89 \times 10^{-9}$ g $= 89 \times 10^{-12}$ kg

$$a = \frac{F}{m} = \frac{8 \times 10^{-3}}{89 \times 10^{-12}} = 8.99 \times 10^7\ ms^{-2}$$

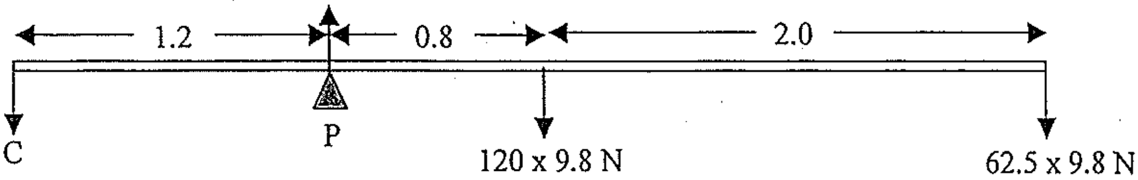
$$a_c = \frac{v^2}{r} \quad \text{so } v = \sqrt{ra} = \sqrt{0.1 \times 8.99 \times 10^7} = 3000\ ms^{-1}$$

$$f = \frac{v}{2\pi r} = \frac{3000}{2\pi \times 0.1} = 4.77 \times 10^3\ Hz$$

3. (a) Forces:



(b)

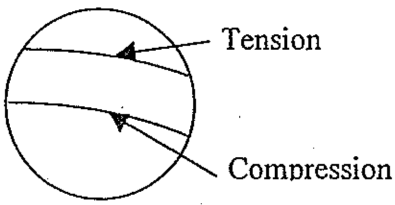


Taking torques about P: $\Sigma ACT = \Sigma CT$

$(0.8 \times 120 \times 9.8) + (2.8 \times 62.5 \times 9.8) = 1.2\ C$
$C = 2.21 \times 10^4$ N

Equating vertical forces: $P = 2.21 \times 10^4 + (120 \times 9.8) + (62.5 \times 9.8)$
$P = 4.00 \times 10^4$ N

(c) (i)



(ii) Standing: The force on the board = diver's weight which will cause the board to bend elastically so as to provide an equal force upwards, according to Hooke's Law.
Bouncing: When the diver lands his kinetic energy is absorbed by the board as it bends and is stored as elastic potential energy.

(iii) The board's breaking stress must be high so it doesn't break under large forces
The Young Modulus of the board must not be too high or too small so that it is not too rigid or does not bend downwards too far in a dive.

4. (a) (i) Important variables: Width, length or area of coil
Current in coil
Field strength of the magnet
Number of turns on the coil

(ii) Only current can be varied easily and quickly.

(b) Graph B is correct for the coils starting in the position shown (C does not represent a complete revolution.)

(c) Power output = $0.68 \times 200 \times 10^3 = 1.36 \times 10^5$ W

$$P = \frac{KE}{t} = \frac{mv^2}{2t} \text{ So } v^2 = \frac{2 \times 1.36 \times 10^5 \times 4}{4.4 \times 10^3}$$

$v = 15.7\ ms^{-1}$

(d) (i) With ordinary brakes, KE is converted to heat, which is dissipated into the atmosphere. In a regenerative system the KE from the wheels is used to turn the motor, which acts as a generator, to produce electrical energy which is stored in the battery for later use by the electric motor in moving the bus.

(ii) At low speeds only a small braking force would be available, which is no good in an emergency. Also, the degree of braking force can be better controlled with conventional brakes and will still work if the electrical system fails.

(e) $60\ kmh^{-1} = 16.7\ ms^{-1}$ Estimate N = 100 turns and a square coil of side 0.35 m
diameter of bus wheels 1.0 m i.e. radius 0.5m

Time for 1 revolution: $T = \frac{2\pi r}{v} = \frac{2\partial \times 0.5}{16.7} = 0.19\ s \therefore f = 5.3Hz$

1/4 Turn Method (This is an average emf not a maximum)

$$E = -N\frac{\ddot{A}(BA)}{\ddot{A}t} = \frac{100 \times 2 \times (0.35)^2}{\frac{1}{4} \times 0.19} = 5.2 \times 10^2\ V$$

Maximum emf Method (when wires move perpendicular to magnetic field)

$$E_{max} = 2NxBlv = 2NxBlx2\pi rf = 2\pi BANf = 8.2 \times 10^2\ V$$

These values are too high as back emf must be less than the applied voltage (even if batteries placed in series the applied voltage normally does not exceed 120V)

5. (a) (i) The radiation would need a large enough energy to ionize atoms – hence very short wavelength.

(ii) Yes, X-rays do have sufficient energy, as they have a very short wavelength and high energy.

(b) (i) $32\ eV = 32 \times 1.6 \times 10^{-19} = 5.12 \times 10^{-18}\ J$

$$\lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{5.12 \times 10^{-18}} = 3.88 \times 10^{-8}\ m$$

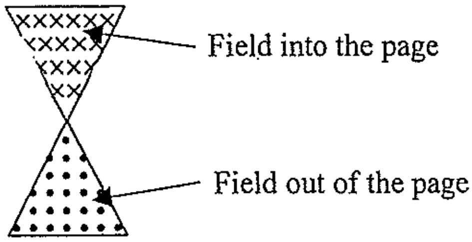
(ii) This wavelength applies to the ultraviolet region of the spectrum.

(c) (i) Atoms have fixed (quantized) energy levels which are the only allowed positions for electrons. The energy absorbed from a photon must exactly match the difference between energy levels for an electron to move from one level to another. Since photon energy is quantized only photons of specific frequency will be absorbed.

(ii) The excess energy appears as the KE of the ejected electron.

(iii) No, waves in the microwave region are not likely to cause cancers as their wavelengths are too long and their energies are too small - much lower than that required to cause ionization (e.g for $f = 10^9$ Hz, $E = 2 \times 10^{-6}$ eV).

6. (a) (i)

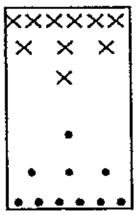


(ii) An electromagnetic force acts on an electron in the field making it move in the arc of a circle. The longer the electron stays in the field the greater its deflection, so the outer electrons (top and bottom) will be deflected through a greater angle than those near the centre because they pass through more area of the field during their motion.

(b) $F = Bqv$

$$B = \frac{F}{vq} = \frac{4.59 \times 10^{-14}}{2.05 \times 10^{6} \times 1.6 \times 10^{-19}} = 0.140\ \text{T}$$

(c)



The field needs to be into the page at the top and out of the page at the bottom

The field needs to be stronger at the top and bottom edges (larger deflection) decreasing to zero in the centre.

(d) Examples of applications:
Auroras – charged particles deflected in the Earth's field
TVs – electrons are deflected onto the screen to make a picture
Mass spectrometer – ions are deflected by the field to land in specific positions, depending on their mass and charge.

7. (a) $v_v = 40\sin60 = 34.64\ \text{ms}^{-1}$ $\qquad v_h = 40\cos60 = 20\ \text{ms}^{-1}$

Vertically: $v^2 = u^2 + 2as$
$0 = 34.64^2 - 19.6s$
$s = 61.2$ m

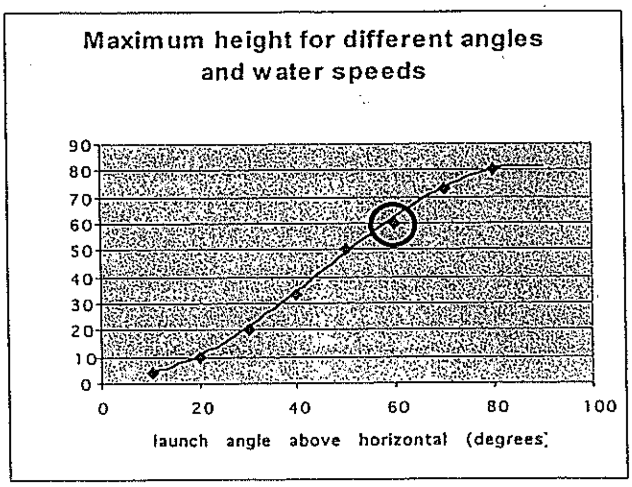
$v = u + at$ so $0 = 34.64 - 9.8t$
$t = 3.53$ s to the top $\qquad$ Total time of flight $= 3.53 \times 2 = 7.06$ s

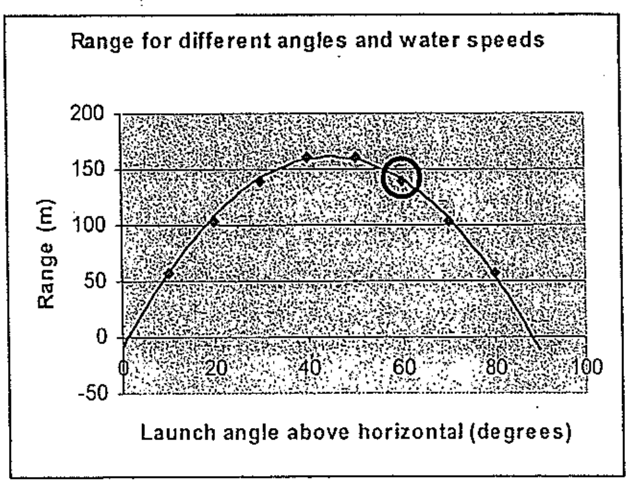
Horizontally: $\quad s = ut = 20 \times 7.06 = 141$ m

(b) $s_h = 150$ m $\qquad v_h = 22\ \text{ms}^{-1}$
Horizontally: $\quad t = s/v = 150/22 = 6.82$ s

Vertically: $\quad s = ut + ½at^2 = 0 + ½ \times 9.8 \times 6.82^2 = 228$ m

(c) (i)



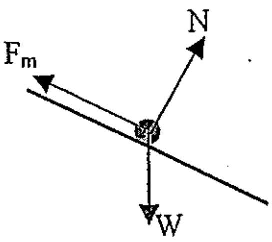


(ii) Best angle = 60^0 Best velocity = 30 ms^{-1}

Explanation – points to consider:
From the diagram, estimate that max height = 35 m, range = 80 m
A water speed of 20 ms^{-1} will not reach 35 m so 30 or 40 ms^{-1} must be used (top 2 lines on graphs)
From left graph, to obtain a 35 m height an angle of 60 – 65^0 must be used at 30 ms^{-1} because 40 ms^{-1} gives too great a height.
From right graph, if speed = 40 ms^{-1} at 60^0 height is too large.
So optimum at 60^0 and 30 ms^{-1}.

Section C

1. (a) (i)



W = weight of rod
N = normal reaction
F_m = magnetic force on rod

(ii) As the rod moves faster down the plane the current induced in it becomes greater in a direction which will oppose the motion (Lenz's Law). Eventually F_m up the plane will equal the weight component (resultant) force down the plane and the rod will therefore will move at constant speed.

(b) Down the plane: $F = mg\sin\alpha$ but $F_m = BIL$

So $\text{mgsiná} = BIL$ but $I = V/R$

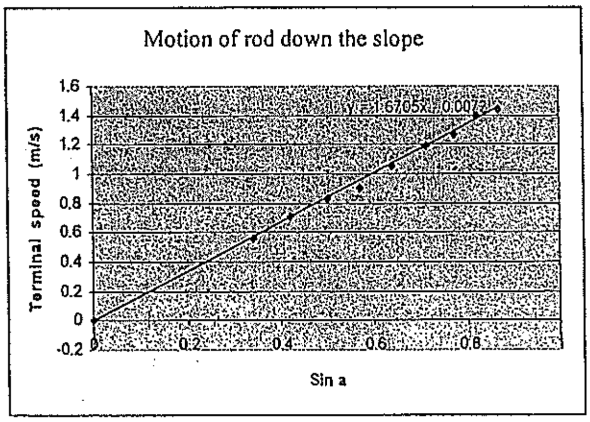
So $\text{mgsiná} = B\frac{V}{R}L$ but induced voltage $V = BLv_{ts}$

So $\text{mgsiná} = B\frac{(BLv_{ts})}{R}L$

Hence $v_{ts} = \frac{\text{mgsiná}R}{B^2L^2}$

(c)

Angle (α)	Terminal speed (cm/s)	Sin α
20	0.56	0.34
25	0.71	0.42
30	0.83	0.5
35	0.9	0.57
40	1.05	0.64
45	1.19	0.71
50	1.27	0.77
55	1.4	0.82
60	1.44	0.87



(i) Calculator: $v_{ts} = (1.68)\sin\alpha - 0.014$ (using values of sinα rounded to 2 S.F)

$v_{ts} = (1.71)\sin\alpha - 0.031$ (using precise values of sinα)

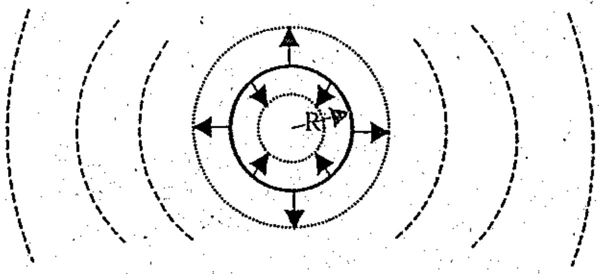
(ii) Graph: gradient = 1.67 cms^{-1} or 0.0167 ms^{-1}

(d) Gradient $0.0167 = \frac{mgR}{B^2L^2}$

$$B^2 = \frac{mgR}{0.167L^2} = \frac{44 \times 10^{-3} \times 9.8 \times 1.4 \times 10^{-4}}{0.167 \times 0.2^2}$$

B = 0.30 T

2. (a) (i)



Oscillating bubble emitting high pressure pulses

(ii) $$f_o = \frac{1}{2\pi}\sqrt{\frac{3 \times 1.4 \times 100 \times 10^3}{1 \times 10^3 \times (3 \times 10^{-3})^2}} = 1.09 \times 10^3 \text{ Hz}$$

(b) (i) f = 300/60 = 5 Hz v = 14 ms^{-1}

v = $2\pi rf$ so $14 = 2\pi \times r \times 5$

R = 0.45 m

(ii) The tips of the blades will be most likely to suffer cavitation damage as it is the point where the propeller is moving at the greatest velocity relative to the water.

(c) (i) From figure 1, r = 3.6 mm at maximum

(ii) From figure 1, the time to go from maximum radius to zero is about 0.3 ms

(iii) A high pressure pulse is produced when the bubble collapses (about 60 kPa change). The shock wave from this pressure change stuns or kills small creatures in the water.