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Physics

2003 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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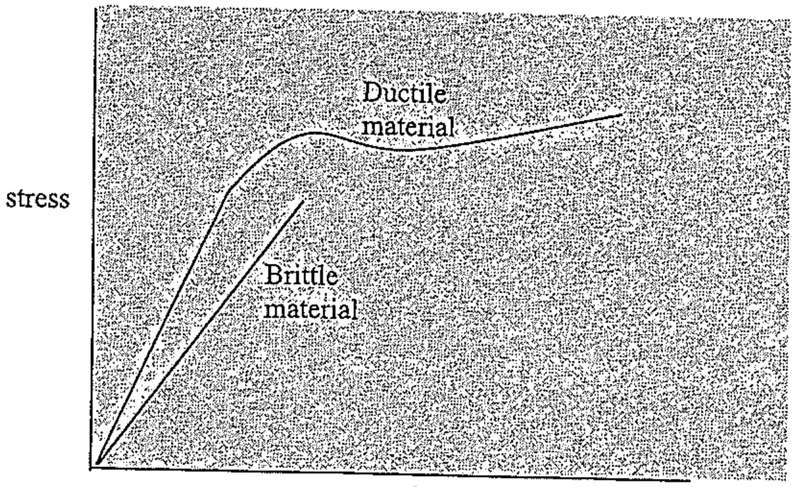
Section A

1. (a) **B**
   (b) **4 + 5** (weight and air resistance)

2. (NB Earth's magnetic field is actually 10 times the value stated in this question)
   Vertical component of Earth's field = $5.8 \times 10^{-6} \sin 66°$
   $= 5.298 \times 10^{-6}$ T
   emf = BlV = $5.298 \times 10^{-6} \times 30 \times 85$
   $= \mathbf{1.35 \times 10^{-2}}$ **V**

3. **C**

4. Ductile materials have a plastic region after the elastic limit is reached.
   Brittle materials do not have a plastic region but break when the elastic limit is reached.



5. The satellite can only orbit around the centre of mass of the earth (strictly, the CM of the earth-satellite system, but this is effectively at the CM of the earth). That is, the centre of the orbit must be the centre of the earth. The orbits in C do not meet this condition.

6. Distance travelled by sound = 2 x 43 m = 86 m
   Time taken = 0.25 s
   Speed of sound = s/t = 86/0.25
   $= \mathbf{3.44 \times 10^{2}}$ **m** $\mathbf{s^{-1}}$

7. **B**

8. (a) Fundamental wavelength = 4 x 1.5 = 6 m
   Third harmonic wavelength = 6/3 = 2 m
   Distance between node & adjacent antinode = $\lambda/4$ = **0.5 m**
   (b) $f = v/\lambda = 346/2 = \mathbf{1.73 \times 10^{2}}$ **Hz**

9. Fundamental wavelength on stretched string = 2 _ length of string = 2L
   $v = f\lambda$
   so $f = v/\lambda = v/(2L)$

10. Difference in level = 17 – 22 = -5 dB

so $10 \log(I_B/I_A) = -5$

$\log(I_B/I_A) = -0.5$

$I_B/I_A = 10^{-0.5}$

$= \mathbf{3.16 \times 10^{-1}}$

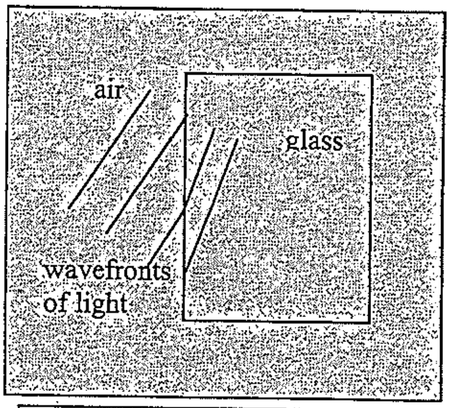
or

$22 = \log(I_A/I_o)$ so $I_A = 1.58 \times 10^{-10}$ Wm^{-2}

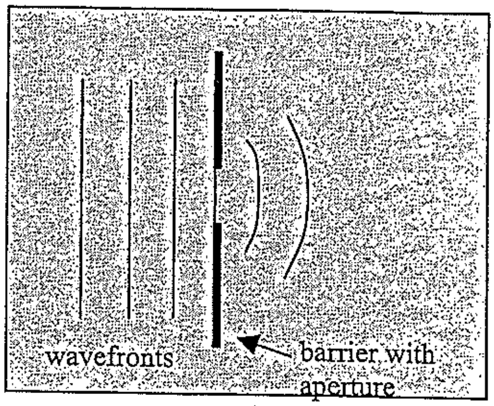
$17 = \log(I_B/I_o)$ so $I_B = 5.01 \times 10^{-11}$ Wm^{-2}

$I_B/I_A = 5.01 \times 10^{-11}/1.58 \times 10^{-10} = \mathbf{3.16 \times 10^{-1}}$

11.



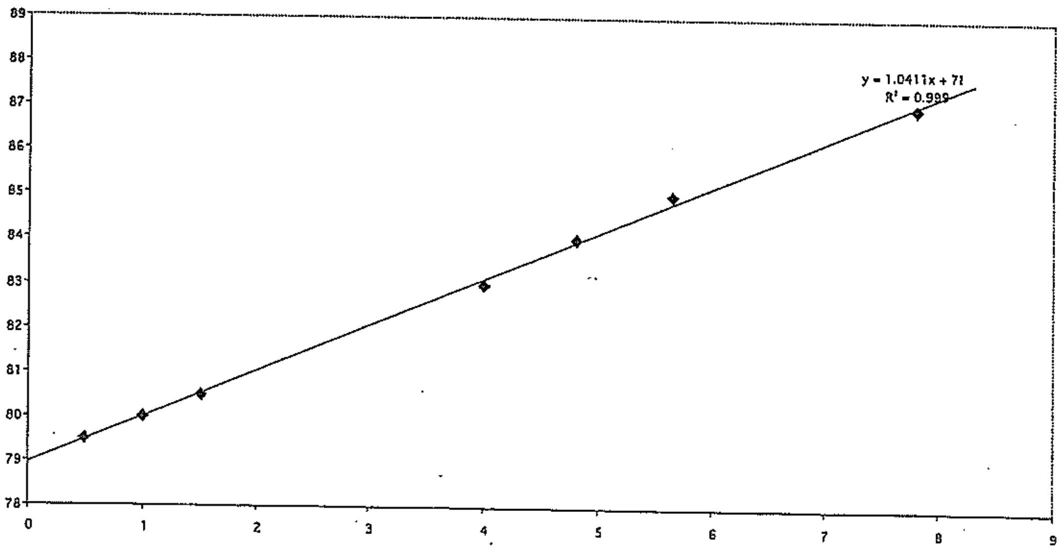
Refraction: wavefronts bending due to reduction in speed of wave



Diffraction: wavefronts bending as they pass an obstacle

12. The truck's rumbling forces the hanging items into vibration. The item that has a natural frequency equal to the frequency of the forcing vibration is driven into oscillations of large frequency as it is given energy at just the right part of each swing. This is resonance. It then has enough energy to continue swinging after the truck has gone.

13.



Slope of graph = Δlength/Δmass = 1.04 mm/g = 1.04×10^3 mm/kg = $\Delta L/\Delta m$

Y = stress/strain

$= FL/(A\Delta L) = \Delta mgL/(A\Delta L)$

so Y $= 9.8 \times 79.5/(\text{slope} \times 4.8 \times 10^{-7})$

$= \mathbf{1.56 \times 10^6}$ **Pa**

14. (a) Electric and magnetic fields at right angles. Suppose the electron is travelling in the positive x-direction: then a magnetic field into the paper will produce a force downwards (negative y-direction). An electric field directed upwards (positive y-direction) will also produce a force on the electron downwards (negative y-direction) This gives the maximum force on the electron.

(b) Electric force = $qE = 1.602 \times 10^{-19} \times 110$
$= 1.76 \times 10^{-17}$ N

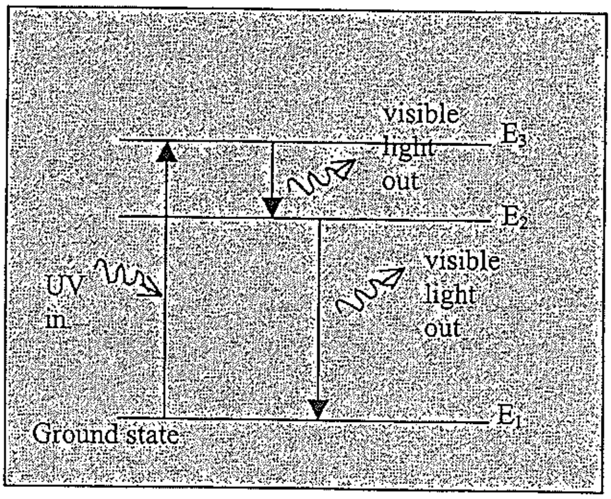
Magnetic force = qvB
$= 1.602 \times 10^{-19} \times 2.0 \times 10^{3} \times 0.5 \times 10^{-4}$
$= 1.60 \times 10^{-20}$ N

So, the **electric field** produces the greater force.

(alternative: $E/B = qE/(qvB) = E/vB = 110/(2\times 10^{3} \times 0.5 \times 10^{-4}) = 1100 > 1$)

15. In fluorescence, invisible ultra-violet light excites an electron into a higher energy level. From there it returns to its ground state via one or more intermediate energy levels, and in doing so it emits several photons of light of lower frequency than the exciting radiation. One or more of these photons is in the visible part of the spectrum, so the object glows visibly.

Example: fluorescent lights are coated internally with fluorescent materials. The mercury vapour in the tubes is excited electrically and emits UV light. This causes the coating to fluoresce and emit visible light.



Section B

1. (a) Power output = VI

$= 3.6 \times 335 \times 10^{-3}$ W

= 1.21 W

(b) This is 75% of the input power.

So input power = 75%1.206/0.75

= 1.61 W

(c) Primary: $P_{in} = V_{in} \times I_{in}$

o $I_{in} = 1.608/240$

= 6.7 mA

(d) Resistance in the transformer windings dissipates energy
Hysteresis losses in the transformer core dissipate energy as the core is repeatedly magnetised and demagnetised.

Eddy currents induced in the transformer core dissipate energy
(any two of the above)

2. (a) (i) Force in one side of coil = NBil = $40 \times 1.2 \times 1.5 \times 15 \times 10^{-2}$ N

= 10.8 N

Force in other side of coil is equal and opposite, so there is a couple

Torque = 2r.F

= 0.10 x 10.8

= 1.08 N m

(ii) since the perpendicular distance between the lines of action of the forces is now zero,

torque = 0.

(iii) r = 0.05 x sin 45°

torque = 2 x 0.05 x sin45° x 10.8

= 0.764 N m

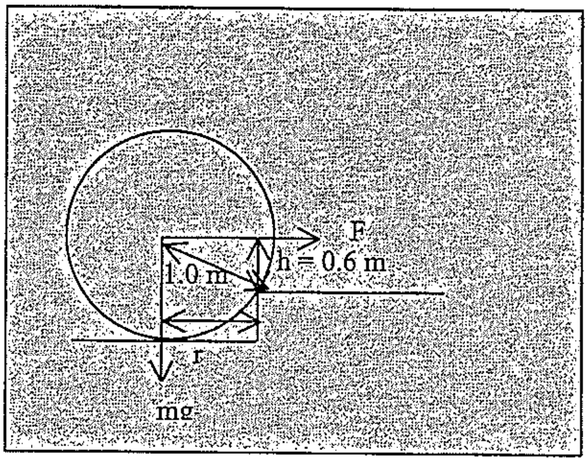
(b) (i) The torque fluctuates between 1.08 N m and 0 as the coil turns. Therefore the coil will rotate in a jerky manner.

(ii) Add another coil at right angles to the first, and replace the commutator with a 4-segment split ring. Now the torque fluctuates between 1.08 N m and 0.764 N m, so the average torque is greater and the rotation is smoother.

Or

Use curved pole pieces so that the coil cuts flux lines at 90° for a longer period.

3.



(a) Take moments about the top of the step.

CWM = ACWM

$$F \times h = mg \times \sqrt{(1 - 0.36)}$$

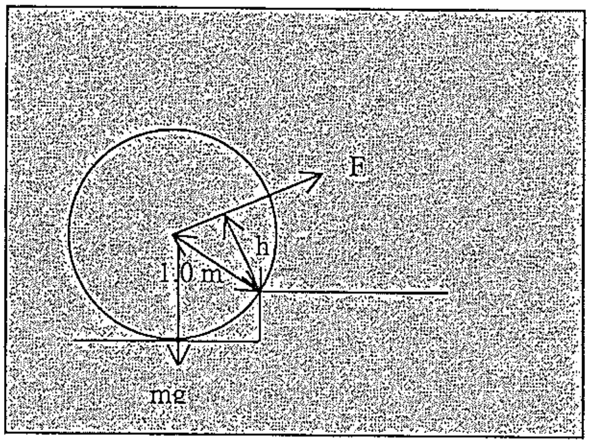
$$F \times 0.6 = 22 \times 9.8 \times \sqrt{(1 - 0.36)}$$

$$F = 22 \times 9.8 \times 0.8 / 0.6$$

$$\mathbf{F = 2.88 \times 10^2\ N}$$

(b) As the wheel rises, the perpendicular distance to the weight decreases so the moment of the weight decreases and h increases, so F decreases.

(c)



If F is now directed at 20° above the horizontal, the same moment can be supplied with a smaller force as h, the perpendicular distance from the pivot to the line of action of F, is now greater. So there is an advantage.

4. (a) Centripetal force = horizontal cpt of tension + horizontal cpt of lift

$= 22 \cos 35° + 34 \sin 35°$

$= \mathbf{3.75 \times 10^1\ N}$

(b) Vertical forces balance, so $mg + T\sin 35° = \text{lift} \times \cos 35°$

$m = (34 \times \cos 35° - 22 \times \sin 35°)/9.8$

$\mathbf{m = 1.55\ kg}$

(c) Centripetal force = mv^2/r

so $v^2 = (r \times 37.5/m)$

$v = \sqrt{(15 \times 37.5 / 1.55)}$

$= \mathbf{1.90 \times 10^1\ m\ s^{-1}}$

5. (a) The soccer ball is larger, so presents a greater cross-sectional area to the air. This increases the air resistance.

(b) As soccer ball has a smaller mass, the effect of the air resistance is greater.

(c) The range of the soccer ball is less because:

(i) the vertical acceleration is greater than g (it is $g+R/m$ downwards), so the ball does not rise as high and is in flight for a shorter time.

(ii) the horizontal acceleration is greater ($= -R/m$), so the ball has a smaller average velocity in the horizontal direction. Since its time of flight is also less, it cannot travel as far in the x-direction.

(d) Horizontal motion of ideal projectile: $u_h = u \cos 45°$ (for no drag)

$a = 0$

$s = 40.7$ m

$t = s/v_{av}$

$= 40.7/u \cos 45°$

Vertical motion: $u_v = u \sin 45°$

$a = -9.8\ m\ s^{-2}$

$s = 0$

$s = ut + 0.5at^2$

$0 = u \sin 45° \times 40.7/u.\cos 45° - 4.9\ (40.7/u.\cos 45°)^2$

$u^2 = 4.9 \times 40.7/\cos^2 45°$

$u = \sqrt{(4.9 \times 40.7 \times 2)}$

$= 19.97\ m\ s^{-1}$

$\mathbf{u = 2.00 \times 10^1\ m\ s^{-1}}$

6. (a) $F_G = F_C$

$GMm/r^2 = mv^2/r$

and $v = 2\pi r/T$

so $GM/r = 4\pi^2 r^2/T^2$

$M = 4\pi^2 r^3/GT^2$

$\mathbf{M = 2.27 \times 10^{37}\ kg}$

(b) $g = GM/r^2$

$\mathbf{g = 2.63 \times 10^{-2}\ ms^{-2}}$

(c) $g_0 = g(r/r_0)^2$

$g_0 = 2.63 \times 10^{-2} \times (2.4 \times 10^{14}/1000)^2$

$\mathbf{g_0 = 1.51 \times 10^{21}\ ms^{-2}}$

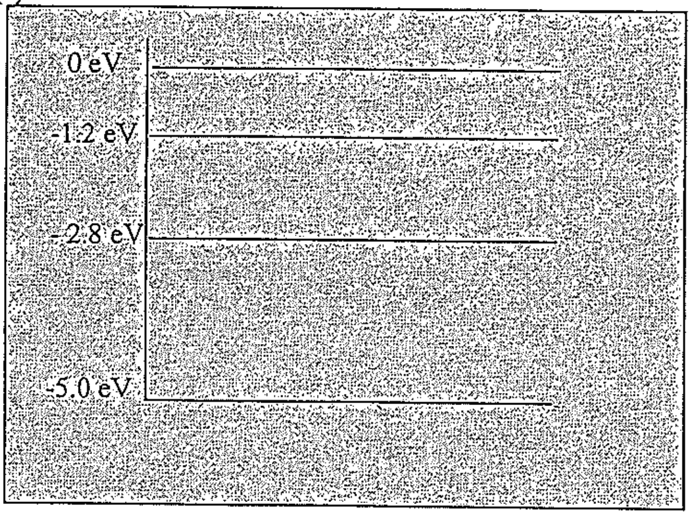
or

$g = GM/r^2$

$g = 6.67 \times 10^{-11} \times 2.27 \times 10^{37}/(1000)^2$

$\mathbf{g = 1.51 \times 10^{21}\ ms^{-2}}$

7. (a)



(b) $\Delta E = E_I - E_1$

$= (0 + 5)$

$= 5eV$

so ionisation energy $= 5.0 \times 1.60 \times 10^{-19}$ J

$\mathbf{= 8.00 \times 10^{-19}\ J}$

(c) $E = hf$

$E = hc/\lambda$

$\lambda = hc/E$

$\lambda_1 = hc/(E_2 - E_1)$

$\lambda_1 = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / ((-2.8 + 5) \times 1.6 \times 10^{-19})$ m

$= \mathbf{5.65 \times 10^{-7}}$ **m**

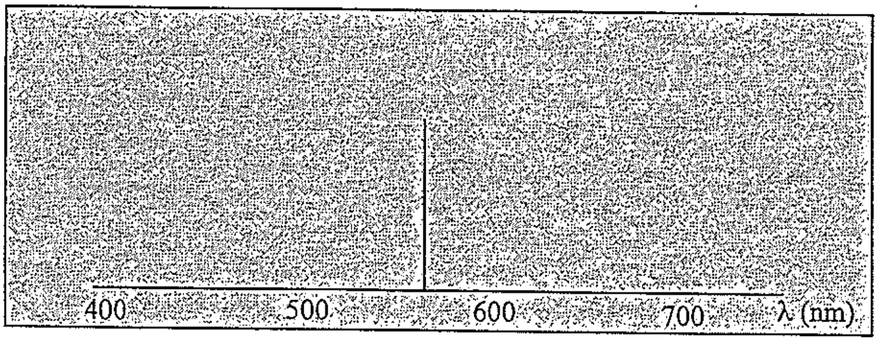
$\lambda_2 = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / ((-1.2 + 5) \times 1.6 \times 10^{-19})$ m

$= \mathbf{3.27 \times 10^{-7}}$ **m**

$\lambda_3 = 6.63 \times 10^{-34} \times 3.00 \times 10^8 / ((0 + 5) \times 1.6 \times 10^{-19})$ m

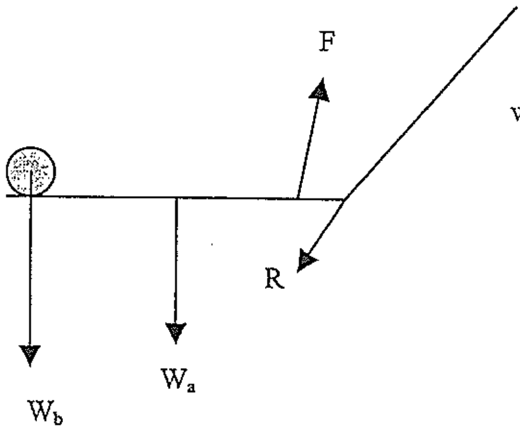
$= \mathbf{2.49 \times 10^{-7}}$ **m**

(d) Only 1 line is seen as the visible part of the spectrum is from 400nm to 700nm



The absorption spectrum would be a continuous spectrum with a single dark line in the yellow part of the spectrum, at $\lambda = 565$ nm.

8A. (i)



where: W_b = weight of ball
W_a = weight of arm
F = force from muscle
R = reaction force

(ii) Take moments about the elbow joint

assume: $r_b = 0.6$m, $r_a = 0.3$m, $r_m = 0.05$m, mass of arm = 1.5 kg, muscle angle = 90°

CWM = ACWM

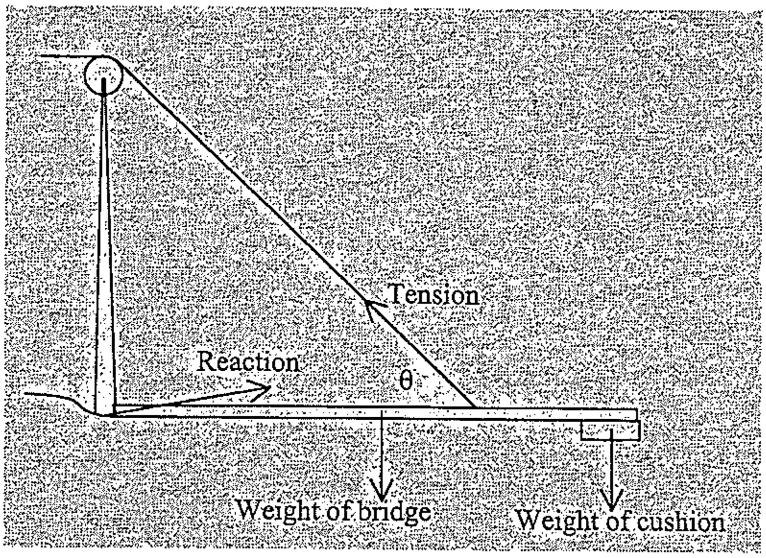
$F \times r_m = W_a \times r_a + W_b \times r_b$

$F \times 0.05 = 1.5 \times 9.8 \times 0.3 + 4.0 \times 9.8 \times 0.6$

F = 560N

so the force exerted by the muscle must be $\mathbf{5.6 \times 10^2}$**N**

8B. (i)



(ii) Assume pulley is 60 cm above ground, plank about 1.2 m long, pulley is frictionless.

$\sin\theta = 0.6/\sqrt{(0.6^2 + 0.67^2)}$
$= 0.6671$

Take moments about base of pulley support:
CWM = ACWM
$8 \times 9.8 \times 0.6 + 2.5 \times 9.8 \times 1.2 = T \times 0.67 \times 0.6671$
$T = 171\ \text{N}$

so the child needs to apply approx. **1.7×10^2 N**

Alternate:
Assume pulley is 75 cm above ground, plank about 1.5 m long, pulley is frictionless.
$\sin\theta = 0.75/\sqrt{(0.75^2 + 1.0^2)}$
$= 0.6$
Take moments about base of pulley support:
CWM = ACWM
$8 \times 9.8 \times 0.75 + 2.5 \times 9.8 \times 1.5 = T \times 1.0 \times 0.6$
$T = 160\ \text{N}$

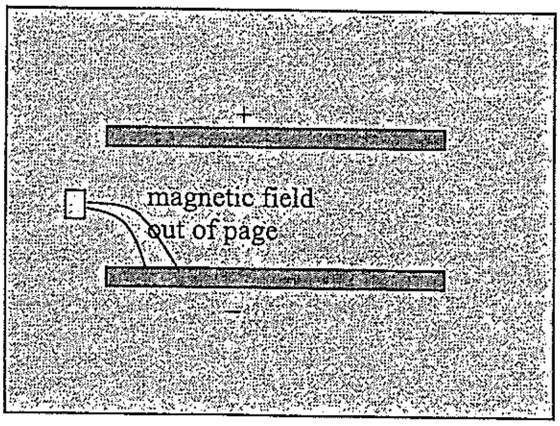
so the child needs to apply approx. **1.6×10^2 N**

Section C

1.

(a) The alpha particles collide with air molecules and have sufficient energy to knock an outer electron completely out of each atom struck, thus ionising them.

(b) Since alpha particles carry an electric charge, they will be deflected by a magnetic field. It is possible that they were deflected in such a way that they were collected by the negative plate and no longer ionised air molecules between the plates.



(c) The small ion current would have to be amplified by the detector; this would need circuitry that would require additional power, drawing extra current.

(d) Convert kWh to Joules

0.020 kWh = 0.020 x 1000 x 3600 J

= 72,000 J

W = VIt

= 24 x 45 x 10^{-6} x t

= 72,000

t = 72,000/(24 x 45 x 10^{-6}) s

t = 6.67 x 10^{7} s

t = 772 days

or about **once every 2 years.**

(e) Assuming inverse square law holds,

$I_2/I_1 = (r_1/r_2)^2$

$= 1/225$

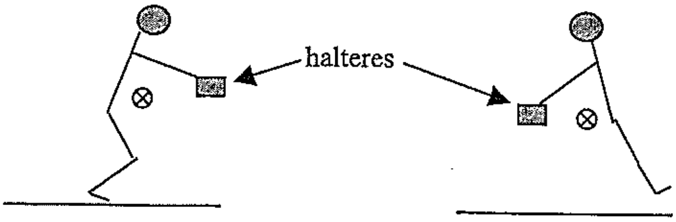
10log(1/225) = -23.52

so the level would be 80 – 23.52 = **56 dB**

2.

(a) The halteres enabled the athletes to increase their take-off velocity, by loading the leg muscles more, and they also enabled the athletes to alter their centre of mass so that it is further forward when jumping and further behind the feet when landing.

(b)



⊗ shows CM position

(c) A haltere mass of about 6 kg would give the greatest increase in take-off speed. Greater weights would enable a greater change of CM position, but at the expense of slowing the jump speed, so it is probable that the mass used was around **6 kg.**

(d) (i) Stress = force/area; the area is not changing

so $s_2/s_1 = F_2/F_1$

Percentage increase = $(F_2 - F_1)/F_1 \times 100\%$

$= 2 \times 12/76 \times 100\ \%$

(the 90% in the question is irrelevant because it will cancel)

= **32%** increase in stress

(ii) At the lowest point of the swing, the athlete must supply an upward force equal to the weight of the halteres plus the required centripetal force.

take mass = 12 kg

$F = mg + mv^2/r$

$F = 12 \times 9.8 + 12 \times 6.2^2/0.75$

$= 733\ \text{N}$

$F = 7.33 \times 10^2$ N on each haltere