CHRIST CHURCH GRAMMAR SCHOOL

# YEAR 12 PHYSICS
# MOCK EXAMINATION 2009

SOLUTIONS

| | | |
|---|---|---|
| A | | |
| B | | |
| C | | |
| Total | | / 200 = % |

**TIME ALLOWED FOR THIS PAPER**

Reading time before commencing work: Ten minutes
Working time for paper: Three hours

**MATERIALS REQUIRED FOR THIS PAPER**

Pens, pencils, eraser or correction fluid, ruler, highlighter and a calculator satisfying the conditions set by the Curriculum Council.

**INSTRUCTIONS TO CANDIDATES.**

This exam consists of three sections. The *Physics: Formulae, Constants and Data Sheet* is provided separately.

Write your answers in the space provided and explain or justify all your answers where appropriate.

Marks will be awarded for clear working even if an incorrect answer is obtained. If you cannot do a section and the answer is needed for a subsequent part assume a value and show all working.

Marks will be deducted for absent or incorrect units.

Answers to numerical questions should be given to the correct number of significant figures [usually three]. Estimations should be given to the appropriate accuracy.

**SECTION A: Short Answer Section:** [60 marks]
This section contains fifteen [15] questions of **equal value** and is worth 30%.

**SECTION B: Longer Questions and Problems:** [100 marks]
This contains seven [7] questions **not of equal value** and is worth 50%.

**SECTION C: Comprehension and Interpretation Section:** [40 marks]
This section contains two [2] questions of **equal value** and is worth 20%.

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# SECTION A

1. In an experiment, a standing wave in a tube resonates to a driving frequency of 236 Hz at an air temperature of 25.0°C. You are able to place a tiny pressure sensitive microphone at any point in the tube without disturbing the standing wave.

(a) Explain how could you identify the location of displacement nodes.

[2]

- Pressure and Displacement are 90° out of phase (ie a pressure antinode is a displacement node).
- A loud spot heard with the microphone is a pressure antinode and hence will correspond to a displacement node.
- Move microphone until a loud spot is heard.

(b) Calculate the distance you would expect between successive displacement nodes.

[2]

$$distance\ between\ consecutive\ nodes = \frac{\lambda}{2}$$

$$v = f\lambda \quad (1)$$

$$\lambda = \frac{346}{236} = 1.466$$

$$\frac{\lambda}{2} = 7.33 \times 10^{-1} m \quad (1)$$

2. A 25.0 kV high voltage power line carries a current of 55.0 A in a southerly direction. If the power line experiences a force of magnitude 2.76 x $10^{-3}$ $Nm^{-1}$, determine;

(a) The direction of the force on the power line.

[1]

- West

(b) The magnitude of the Earth's magnetic field at this location if the field emerges from the Earth at 66.0° to the horizontal.

[3]

$$F = I\ell B\sin\theta \quad (1)$$

$$2.76 \times 10^{-3} = (55)(1)(B)(\sin 66) \quad (1)$$

$$B = 5.49 \times 10^{-5} T \quad (1)$$

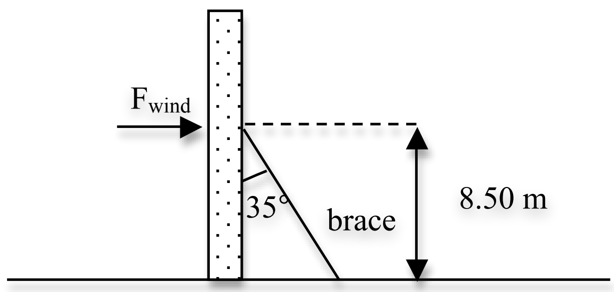
3. Astronauts and Cosmonauts on the International Space Station describe a feeling of weightlessness when the station is in orbit. Explain what causes these feeling and if it can be considered to be true weightlessness?

[4]

- The space station moves in an orbit around the Earth due to the Earth's gravitational field.
- As it orbits it falls towards the Earth and everything inside the station also falls towards the Earth at the same rate.
- This means there is no reaction force between the occupants of the space station and the space and hence they feel weightless.
- This is not true weightlessness as they are still under the influence of the Earth's gravitational field.

4. A 17.0 m high and 11.0 m long wall is under construction. For extra safety 10 braces have been placed along the wall. The wall is in stable equilibrium but can pivot about its base. Determine the force exerted by each of the braces if a strong wind exerts a horizontal force of 122 kN on the wall (assume the force of the wind acts at a point 8.50 m above the ground).

[4]




*Take base of wall as pivot*

$\tau = rF\sin\theta$ $\quad \sum \tau_{cw} = \sum \tau_{ccw}$ (1)

$\sum \tau_{cw} = (8.50)(122 \times 10^3)$ (1)

$\sum \tau_{ccw} = (8.50)(10T \sin 35)$ (1)

$(8.50)(122 \times 10^3) = (8.50)(10T \sin 35)$

$T = 21.3\ kN$ (1)

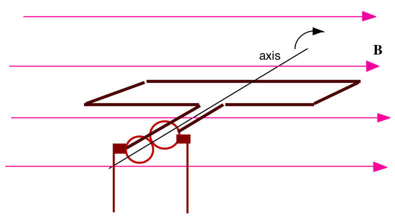
5. Low pressure mercury vapour lamps operate at low temperatures and emit primarily UV radiation.
Medium pressure mercury vapour lamps operate at considerably higher temperatures and emit a significant amount of visible wavelength radiation in addition to the UV radiation.
Explain why medium pressure mercury vapour lamps allow the emission of these visible wavelengths.

[4]

- In the medium pressure mercury vapour lamp the higher operating temperature means that atoms can be given sufficient energy to be excited to much higher levels.
- As the electrons decay back to the ground state, photons of energy are emitted. The greater the difference in energy levels, the greater the energy of the photon.
- When excited to higher levels, cascade decay can take place which is the emission of smaller energy photons.
- As photon energy decreases, the wavelength of the emitted radiation increases and moves from the UV region to the visible region.

6. The square generator coil below consists of 200 turns of wire with a 5.00 cm radius. It is placed in a uniform 1.25 T magnetic field in which it rotates through 90° in 15.0 ms. What is the maximum emf generated?

[4]




$$v = 2\pi r f = \frac{2\pi r}{T} = \frac{(2\pi)(0.05)}{(4)(15.0\times10^{-3})} = 5.24\,ms^{-1}$$ (1)

$$\varepsilon = 2Nv\ell B \; (or\; 2\pi BANf)$$ (1)

$$= (2)(200)(5.24)(0.10)(1.25)$$ (1)

$$= 262\,V$$ (1)

7. A flute is an instrument that behaves as an open pipe.

(a) If the effective length of a flute is 37.0 cm, calculate the frequency of the 3rd harmonic produced on a 25.0˚C day.

[3]

$\lambda_1 = 2L$

$v = f\lambda$ (1)

$346 = (f_1)(2)(0.37)$ (1)

$f_1 = 468\ Hz$

$f_3 = 3f_1 = 1400\ Hz$ (1)

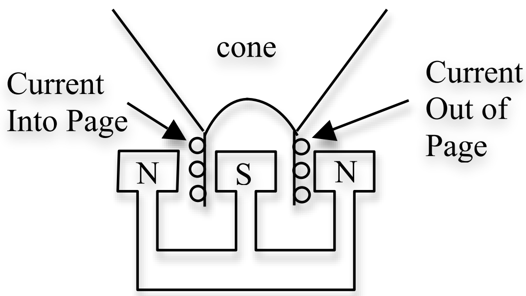
(b) On a colder day how will the fundamental frequency of the flute be altered?

[1]

- It will decrease.

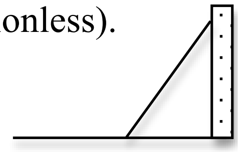
8. A diagrammatic representation of a moving coil loudspeaker is shown below. Alternating current (the frequency of which is proportional to the frequency of the sound) is fed into a coil, which is wrapped around the central pole piece. Explain how the alternating current will lead to motion of the cone and determine which way the coil and cone would move in this situation.

[4]




- The cone will move down the page.
- The current flowing in the coil will experience a force due to the magnetic field.
- When the direction of the current changes, the direction of the force will change.
- This means the cone will move in and out with a frequency the same as that of the AC.

9. A ladder is rested against a frictionless wall as shown in the diagram to the right (the floor, however, is not frictionless).



As a man climbs to the top of the ladder, is the ladder (circle the correct response);

(i) More likely to slip

(ii) Less Likely to Slip

(iii) Neither more nor less likely to slip

Explain your reasoning.

[4]

- As the man climbs higher up the ladder, the distance between where his weight acts and the pivot (the base of the ladder) increases, thus the clockwise torque on the ladder increases.
- Therefore an increased counter-clockwise torque will be required about the base of the ladder to keep it from tipping. This counter-clockwise torque must be provided by the normal force of the wall on the ladder.
- As the friction on the ground is equal (and opposite) to the normal force of the wall on the ladder when in equilibrium, the friction required increases and may not be provided by the floor – hence slippage may occur.

10. A compact disc drive rotates with a frequency of 10400 revolutions per minute. **Estimate** the magnitude of the centripetal acceleration of a point on the edge of a compact disc, stating any assumptions you make.

[4]

$f = 10400\ rev\ per\ minute = 173\ rev\ per\ second$ (1)

$r_{CD} = 6.00\ cm\ (accept\ 5.00 - 8.00\ cm)$ (1)

$v = 2\pi rf$

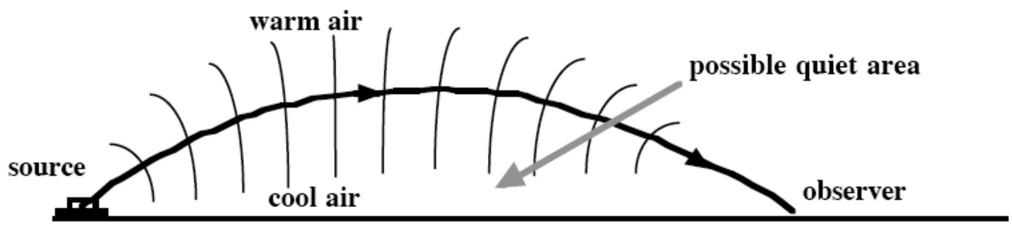
$= (2\pi)(0.06)(173)$

$= 65.2\ ms^{-1}$ (1)

$a_c = \frac{v^2}{r} = \frac{65.2^2}{0.06} = 7.09 \times 10^4\ ms^{-2}$ (1)

11. On a cold autumn night, a layer of cold air settles close to the ground. Mr. Tait is setting up a camp with a group of Year 9 boys on one side of a lake. Ranger Ned can hear Mr. Tait's whistles on the opposite side of the lake. A fisherman in the middle of lake, however, cannot hear the whistling. Name this phenomenon and with the aid of a diagram, explain what is occurring in this situation. [4]

- The phenomenon is total internal reflection (0.5 mark refraction).
- Sound waves travel faster in warm air than in cool air and hence as the sound waves move away from the source (Mr Tait) they are refracted away from the normal.
- At a certain height TIR will occur and the sound will be reflected back down to Ranger Ned.




12. Myles has unfortunately broken his fishing rod and must resort to a handline. If his lure has a mass of 50.0 g and he is swinging it in a vertical circle of radius 1.50 m at a constant speed of 8.00 $ms^{-1}$, identify where his handline is most likely to break and the tension in the handline at this point.

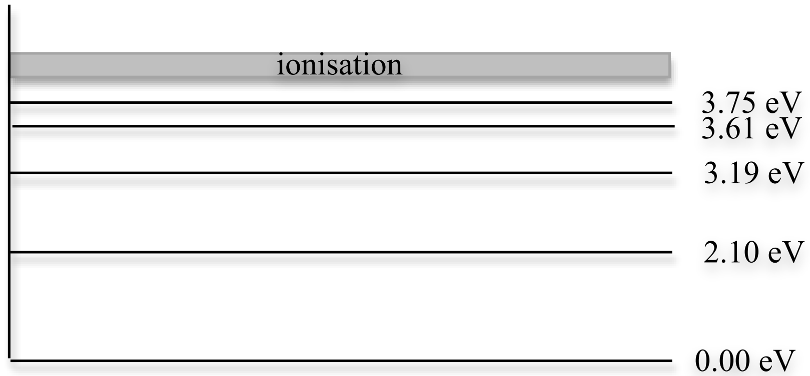
[4]

*most likely to break at the bottom* (1)

$$\sum F = T - mg = ma_c$$ (1)

$$T = mg + \frac{mv^2}{r} = (0.05)(9.8) + \frac{(0.05)(8^2)}{1.50} = 2.62\ N$$ (1) (1)

13. The diagram below shows some of the energy levels of the sodium atom.




(a) How many lines would you expect to see on a line emission spectrum for this atom if it is excited to the n = 4 level.

[1]

- 6

(b) What is the shortest wavelength photon that can be emitted and which transition does this correspond to?

[3]

$shortest\ \lambda = l\arg est\ \Delta E$

$n = 5\ to\ n = 1$ (1)

$\Delta E = \frac{hc}{\lambda}$ (1)

$(3.75)(1.60 \times 10^{-19}) = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{\lambda}$

$\lambda = 3.32 \times 10^{-7}\ m$ (1)

14. A 15.0 cm long animal tendon stretches 3.70 mm when a force of 13.4 N is applied. If the tendon is approximately round with an average diameter of 8.50 mm, determine its value of Young's modulus.

[4]

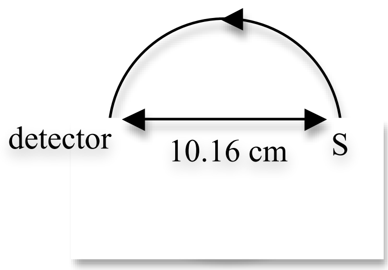
$$Y = \frac{\sigma}{\varepsilon} = \frac{F\ell_\circ}{A\Delta\ell}$$ (1)

$$= \frac{(13.4)(0.15)}{(\pi)(\frac{8.50 \times 10^{-3}}{2})^2(3.70 \times 10^{-3})}$$ (2)

$$= 9.57 \times 10^6\, Nm^{-2}$$ (1)

15. The percentage of helium in ordinary air is very small hence helium gas that is sprayed near a leak in a vacuum system will show up in the output of a vacuum pump very quickly. A mass spectrometer is designed to detect $He^+$ ions (helium atoms with a charge of +1e and a mass of 6.65 x $10^{-27}$ kg). If the ions emerge from the velocity selector with a speed of 1.00 x $10^5$ $ms^{-1}$ and are detected at a distance of 10.16 cm from the Slit 'S', determine the magnitude and direction of the magnetic field.

[4]




$$F = qvB = \frac{mv^2}{r}$$ (1)

$$B = \frac{mv}{rq} = \frac{(6.65 \times 10^{-27})(1.00 \times 10^5)}{(0.0508)(1.60 \times 10^{-19})}$$ (1)

$$B = 81.8\ mT$$ (1)

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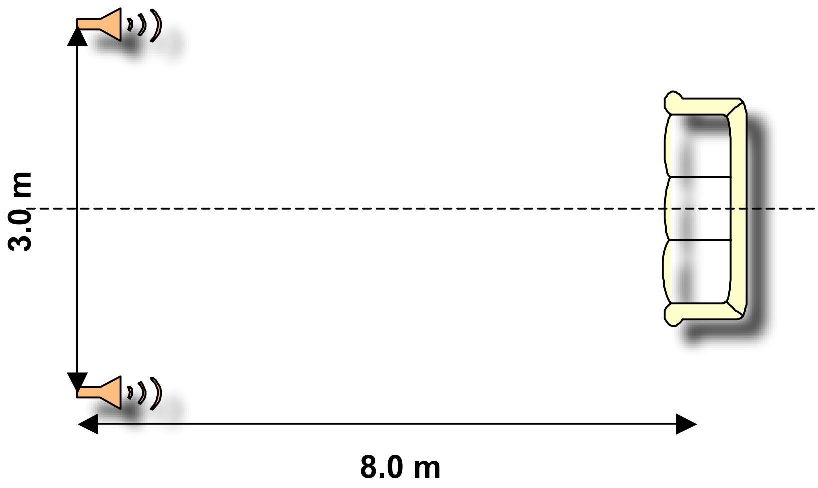
# SECTION B

**Name: ______________________________**

1. A girl is listening to sound through her stereo. Her stereo system has a speaker separation of 3.00 m and she is sitting on her sofa 8.00m from the wall on which the speakers are mounted (at head height). The speakers emit a constant tone. The girl notices that when she is sitting in the middle of her sofa, the sound is quite loud, but when she moves her head 35.0 cm to either side, the sound seems to disappear.




(a) Explain the girl's observation.

[3]

- In the centre of the sofa, the waves from each speaker must travel equal distances to the listener and hence arrive in phase.
- 35 cm to the side of the centre, the waves from each speaker have travelled different distances one wave travels half a wavelength more and the waves are now 180° out of phase.
- In phase – constructive interference – loud
  180° out of phase – destructive interference – soft

(b) Determine the frequency of the sound emitted.

[6]

$S_1 = \sqrt{8^2 + 1.85^2}$ (1)

$S_2 = \sqrt{8^2 + 1.15^2}$

$PD = S_1 - S_2 = 0.129\ m$ (1)

$1st\ softspot \therefore PD = \frac{\lambda}{2}$ (1)

$\lambda = 0.258\ m$ (1)

$v = f\lambda$ (1)

$346 = (f)(0.258)$

$f = 1340\ Hz$ (1)

(c) If the girl walks along a line equidistant from each speaker (the dashed line on the diagram above), describe what she would hear and explain this observation. The girl walks from the couch towards the speakers.

[3]

- On a line equidistant from each speaker she would hear a loud sound, which increases in intensity.
- Loud because the waves from each speaker travel the same distance ie path difference = 0 and are hence always in phase leading to constructive interference.
- The sound would get louder as I is inversely proportional to the square of distance from the source.

2. Ricky Ponting hits a ball over the covers at an angle of 24.0° to the horizontal at a speed of 40.0 $ms^{-1}$. At the instant that he hits the ball it is 0.20 m above the ground.

(a) Sketch the trajectory of the ball from the bat until it returns to the ground, without air resistance.

[1]

- Parabolic path: 0.5 mark
- Path ends below starting point: 0.5 mark

(b) On the same sketch you drew in (a) show how air resistance will affect the trajectory of the ball and label your diagram appropriately.

[2]

- Reduction in max height and label: 1 mark
- Reduction in max range and label: 1 mark

(c) Is there any time at which the ball will have zero acceleration, between the time it is hit and the time it takes to reach the ground? Explain your reasoning.

[2]

- No
- The ball is always within the earth's gravitational field and thus always experiences an acceleration of 9.80 $ms^{-2}$ towards the earth.

(d) Determine the maximum height reached by the ball.

[3]

$$v^2 = u^2 + 2as$$ (1)

$$0 = (40\sin 24)^2 + (2)(-9.8)(s)$$ (1)

$$s = 13.5 + 0.20 = 13.7\ m$$ (1)

(e) Determine the time the ball is in the air for.

[3]

$$s = ut + \frac{1}{2}at^2$$ (1)

$$-0.20 = (40\sin 24)t + (\frac{1}{2})(-9.8)(t^2)$$ (1)

$$t = 3.34\ s$$ (1)

(f) Determine the horizontal range of the ball.

[3]

$$s = tv$$ (1)

$$= (3.34)(40\cos 24)$$ (1)

$$s = 122\ m$$ (1)

3. A 1.05 m long rod of negligible weight is supported at its ends by wires A and B of equal length, as shown in the diagram below. Information pertaining to the wires is given in the table below. An object of mass 2.00 kg can be placed at any point along the rod.


| | Wire A | Wire B |
|---|---|---|
| Cross-Sectional Area | 2.00 mm$^2$ | 4.00 mm$^2$ |
| Young's Modulus | 1.80 x 10$^{11}$ | 1.20 x 10$^{11}$ |

(a) Derive a relationship relating the forces in wires A and B and the weight of the object.

[1]

$$\sum F_y = F_A + F_B - w = 0$$

(b) What must $F_A$ and $F_B$ be for there to be equal stress in wires A and B.

[3]

$$\sigma_A = \frac{F_A}{A_A} \qquad \sigma_B = \frac{F_B}{A_B}$$

$$\frac{F_A}{A_A} = \frac{F_B}{A_B} \quad (1)$$

$$F_B = \frac{(7.00)(4 \times 10^{-6})}{(2 \times 10^{-6})} \quad (1)$$

$$= 14\ N \quad (1)$$

(c) At what point along the rod should the weight be suspended to produce equal stress in wires A and B.

[4]

$F_A + F_B = 19.6$

$equal\ stress: \frac{F_A}{A_A} = \frac{F_B}{A_B} \therefore F_A = 0.5F_B$

$1.5F_B = 19.6$

$F_B = 13.1N\ F_A = 6.53N$

$\tau = rF\sin\theta \quad \sum\tau_{cw} = \sum\tau_{ccw}$ (1)

*Take A as pivot*

$\sum\tau_{cw} = (r)(19.6)$ (1)

$\sum\tau_{ccw} = (1.05)(13.1)$ (1)

$(r)(2.00\times 9.8) = (1.05)(13.1)$

$r = 0.70\ m\ from\ A$ (1)

marks allocated for correct use of torque about selected pivot – a number of correct answers were possible.

(d) If $F_A$ = 7.00 N what must $F_B$ be for equal strain in wires A and B.

[4]

$Y_A = \frac{\sigma_A}{\varepsilon_A} \qquad Y_B = \frac{\sigma_B}{\varepsilon_B}$

$\frac{F_A/A_A}{Y_A} = \frac{F_B/A_B}{Y_B}$ (1)

$F_B = \frac{F_A Y_B A_B}{Y_A A_A} = \frac{(7.00)(1.20\times10^{11})(4\times10^{-6})}{(1.80\times10^{11})(2\times10^{-6})}$ (2)

$= 9.33\ N$ (1)

(e) At what point along the rod should the weight be suspended to produce equal strain in wires A and B.

[4]

$F_A + F_B = 19.6$

$equal\ strain: \frac{F_A}{Y_A A_A} = \frac{F_B}{Y_B A_B} \therefore F_A = 0.75F_B$

$1.75F_B = 19.6$

$F_B = 11.2\ N\ F_A = 8.40\ N$

$\tau = rF\sin\theta \quad \sum\tau_{cw} = \sum\tau_{ccw}$ (1)

*Take A as pivot*

$\sum\tau_{cw} = (r)(19.6)$ (1)

$\sum\tau_{ccw} = (1.05)(8.40)$ (1)

$(r)(19.6) = (1.05)(9.33)$

$r = 0.45\ cm\ from\ A$ (1)

marks allocated for correct use of torque about selected pivot – a number of correct answers were possible.

4. A large power plant generates electricity at 12.0 kV. Its old transformer converted the voltage to 400 kV, but its secondary is being replaced so that its output can now be 500 kV.

(a) With the aid of a diagram, explain how a transformer works. [4]

- An alternating current in the primary coil induces a changing magnetic field in the iron core.
- The iron core links the primary and secondary coils
- and a changing magnetic field in the iron core induces a changing current and hence potential difference across the secondary coil.
- Diagram showing and labeling primary and secondary coils and soft iron core.

(b) What is the ratio of turns in the new secondary coil to the old secondary coil? [2]

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\frac{V_{S2}}{V_P} = \frac{N_{S2}}{N_P} \qquad \frac{V_{S1}}{V_P} = \frac{N_{S1}}{N_P}$$

$$\frac{N_{S2}}{N_{S1}} = \frac{V_{S2}}{V_{S1}} = \frac{500 \times 10^3}{400 \times 10^3}$$ (1)

$$= 1.25 : 1$$ (1)

(c) What is the ratio of the new current output to old current output for the same power?

[2]

*V is inversely proportional to I*

$\frac{1}{1.25} = 0.8$ (1)

$0.8 : 1$ (1)

(d) If the transmission lines still have the same resistance, what is the ratio of the new line power loss to the old?

[2]

$P_{loss} = I^2R$ (1)

$0.64 : 1$ (1)

(e) Explain why increasing the voltage across the secondary coil will make the transmission of power more efficient.

[3]

- If the transformer is 100% efficient then the greater the voltage the lower the current that will pass through the wires (P=VI)
- This means there will be less power loss due to resistive heating in the wires ($P=I^2R$).
- and less voltage drop across the wires (V=IR).

(f) If the voltage at the other end of the line (with the new transformer) is 498 kV and 0.60 MW of power is drawn by a factory, what is the resistance of the lines?

[4]

$P_{factory} = VI$ (0.5)

$0.6 \times 10^6 = (498 \times 10^3)(I)$ (0.5)

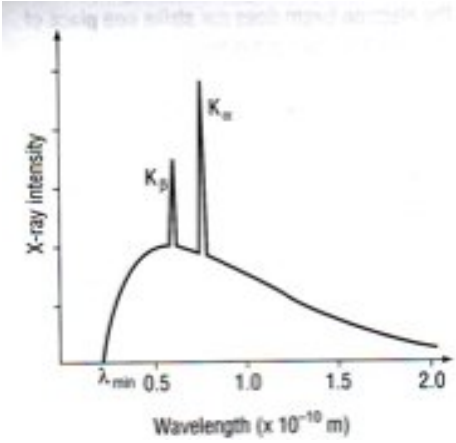
$I = 1.20\ A$ (1)

$V_{drop} = IR$ (0.5)

$(500 \times 10^3 - 498 \times 10^3) = (1.20)(R)$ (0.5)

$R = 1.67 \times 10^3 \Omega$ (1)

5. X-rays are produced when fast moving electrons strike a metal target. The X-ray spectrum produced consists of a continuous background and a line spectrum, as shown in the diagram below.




(a) Explain the formation of the characteristic peaks (the line spectrum) in an X-ray spectrum.

[4]

- Fast moving electrons have sufficient energy to knock tightly bound electrons from inner sub-shells.
- Electrons in higher energy shells drop down to fill the gap.
- In doing so the atom emits a photon of energy equal to the difference in energy between the levels.
- The characteristic peaks will only occur at these particular energies.

(b) State how the position of these peaks could be changed and explain why this change would lead to a shift in peak position.

[3]

- By changing the anode material.
- Every atom has different spacing of electron levels.
- The energy/position of the characteristic peaks depends on the spacing of these energy levels.

(c) What would be the minimum accelerating potential to observe X-rays of wavelength 0.063 nm from a sample of rhodium.

[4]

$$E = \frac{hc}{\lambda} \quad (0.5)$$

$$= \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{0.063 \times 10^{-9}} \quad (0.5)$$

$$= 3.16 \times 10^{-15}\, J \quad (1)$$

$$E = qV \quad (0.5)$$

$$3.16 \times 10^{-15} = (1.6 \times 10^{-19})(V) \quad (0.5)$$

$$V = 19.8\, kV \quad (1)$$

(d) If X-rays are to be used in a radiograph, an image produced when a part of the body is irradiated with X-rays (as shown below), which type of X-ray would be used, hard or soft? Explain your reasoning making reference to the differences between the two types of radiation.

[3]

- Hard X-rays
- Hard X-rays are produced using higher operating potentials and have higher energy and shorter wavelength – and hence are more penetrating.
- This allows the X-rays to pass through flesh (but not bone) to irradiate a photographic plate.)
  [Soft X-rays may not be able to penetrate flesh]

6. Pluto, recently demoted to a demi-planet, has a mass of $1.20 \times 10^{23}$ kg and a diameter of 3000 km. Pluto orbits the sun at an average distance of $5.90 \times 10^{9}$ km.

(a) Determine the magnitude of the acceleration due to gravity at the surface of Pluto.

[3]

$$g = \frac{Gm_p}{r^2} \quad (1)$$

$$= \frac{(6.67 \times 10^{-11})(1.20 \times 10^{23})}{(1500 \times 10^{3})^2} \quad (1)$$

$$= 3.56\ ms^{-2} \quad (1)$$

(b) Determine the acceleration of Pluto towards the Sun.

[4]

$$\frac{m_p v^2}{r} = \frac{Gm_s m_p}{r^2} \quad (1)$$

$$a_c = \frac{v^2}{r} = \frac{Gm_s}{r^2} \quad (1)$$

$$a_c = \frac{(6.67 \times 10^{-11})(1.99 \times 10^{30})}{(5.90 \times 10^{12})^2} \quad (1)$$

$$= 3.81 \times 10^{-6}\ ms^{-2} \quad (1)$$

(c) Determine the orbital speed of Pluto.

[2]

$$a_c = \frac{v^2}{r}$$

$$3.81 \times 10^{-6} = \frac{(v^2)}{5.90 \times 10^{12}} \quad (1)$$

$$v = 4740\ ms^{-1} \quad (1)$$

(d) What would be the length of a year on Pluto (in Earth Years)?

[4]

$$g = \frac{Gm_p}{r^2}$$

$$s = tv$$

$$v = \frac{2\pi r}{T} \quad (1)$$

$$4740 = \frac{(2\pi)(5.90 \times 10^{12})}{T} \quad (1)$$

$$T = 7.82 \times 10^{9}\,s \quad (1)$$

$$= 248 \textit{ Earth Years} \quad (1)$$

7. A sound technician is testing loudspeakers that will play music for a drama performance. He measures the sound level for one speaker at a distance of 3.00 m and obtains a reading of 114 dB.

(a) Determine the total acoustic power for this loudspeaker (assume a hemispherical distribution).

[4]

$$\beta = 10\log\left(\frac{I}{I_0}\right) \quad (0.5)$$

$$114 = 10\log\left(\frac{I}{1\times10^{-12}}\right) \quad (0.5)$$

$$I = 0.251\ Wm^{-2} \quad (1)$$

$$I = \frac{P}{A} \quad (0.5)$$

$$(0.251) = \frac{P}{2\pi(3^2)} \quad (0.5)$$

$$P = 14.2\ W \quad (1)$$

(b) Determine the sound level that would be registered by a performer sitting in the back row of the theatre, a distance of 20.0 m from the loudspeaker.

[4]

$$I = \frac{P}{A} \quad (0.5)$$

$$= \frac{14.2}{2\pi(20^2)} \quad (0.5)$$

$$I = 5.65\times10^{-3}\ Wm^{-2} \quad (1)$$

$$\beta = 10\log\left(\frac{I}{I_0}\right) \quad (0.5)$$

$$= 10\log\left(\frac{5.65\times10^{-3}}{1\times10^{-12}}\right) \quad (0.5)$$

$$\beta = 97.5\ dB \quad (1)$$

(c) Someone accidentally switches on another two identical speakers while the first speaker is on. Justify with appropriate calculation if the sound level has reached the threshold of pain where the sound technician is standing.

[3]

$$I = 3 \times 0.251 = 0.753\ Wm^{-2}$$ (1)

$$\beta = 10\log\left(\frac{I}{I_0}\right)$$

$$= 10\log\left(\frac{0.753}{1\times10^{-12}}\right)$$

$$= 119\ dB$$ (1)

- At Threshold of Pain (1)

(d) During the rehearsal, the performers backstage in the changing rooms hear the bass guitar more defined than the high pitched violins in a particular section of music. Explain why this is so.

[3]

- The bass guitar has a lower fundamental frequency than the guitars and therefore a longer wavelength.
- Longer wavelengths are more effective at diffracting around objects.
- Hence the bass guitar can diffract around the stage better than the high pitched violin and can be heard backstage.

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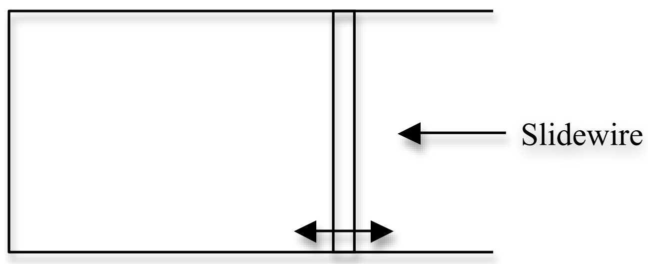
# YEAR 12 PHYSICS
# MOCK EXAMINATION 2009

# SECTION C

**Name: ________________________________**

1. Work and Power in a Slidewire Generator

A slidewire generator is shown in the diagram below. As the slidewire is moved across the U-shaped conductor, energy will be dissipated in the circuit due to the resistance of the circuit.




Let the resistance of the circuit at a given point in the slidewire's motion be R. The slidewire moves with a constant velocity v and has a length $\ell$. The whole apparatus is located in a magnetic field, B, directed out of the page.

(a) As the slidewire moves to the right, will the resistance increase or decrease?

[1]

- Increase

(b) As the slidewire moves to the right, which end (top or bottom)will be at the higher potential?

[1]

- Bottom end

(c) Show that the induced current in the circuit will be $I = \frac{v\ell B}{R}$.

[1]

$$\varepsilon = v\ell B$$

$$I = \frac{\varepsilon}{R} = \frac{v\ell B}{R}$$

(d) Show that the rate at which energy is dissipated in the circuit is given by

[1]

$$P_{dissipated} = \frac{v^2 \ell^2 B^2}{R}$$

$$P = I^2 R$$

$$= \frac{v^2 \ell^2 B^2}{R}$$

(e) For a situation where B = 0.5 T, and $\ell$ = 20.0 cm, the following set of data was collected.

| $P_{dissipated}$ (mW) | R (Ω) | 1/R ($\Omega^{-1}$) |
|---|---|---|
| 18 | 0.05 | 20.0 |
| 11 | 0.08 | 12.5 |
| 9.0 | 0.10 | 10.0 |
| 7.5 | 0.12 | 8.33 |
| 6.4 | 0.14 | 7.14 |
| 5.6 | 0.16 | 6.25 |

(d) What would you need to plot to obtain a straightline graph?

[1]

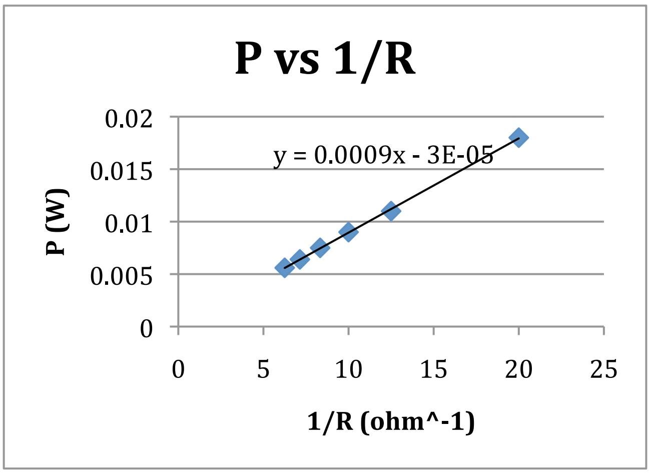
$$P \text{ vs } \frac{1}{R}$$

(e) Process the data in the table above so you are able to plot a straightline graph.

[2]

(f) Plot your graph on the graph paper provided.

[5]



(g) Determine the gradient of your graph.

[3]

- 0.5 mark triangle
- 0.5 mark
- 1 mark value
- 1 mark units 9.00 x $10^{-4}$ WΩ

(h) Use the gradient to determine the speed at which the slidewire is moved.

[2]

$$PR = v^2 \ell^2 B^2$$

$$9 \times 10^{-4} = (v^2)(0.2^2)(0.5^2)$$

$$v = 0.30\ ms^{-1}$$

- 1 mark value
- 1 mark units

(i) In this scenario we have discounted friction, if friction were present, what effect would this have on the graph? Explain your reasoning.

[3]

- If friction were present some of the work done on the slidewire to move it would go to overcoming the friction rather than generating current (alternatively, there will be a decrease in velocity).
- Net current in the circuit would decrease and the power dissipated by the circuit would decrease.
- Gradient would be reduced (ie flatter graph).

2. Atomic Clocks

Adapted from the article: Optical Clocks Gill P and Margolis H, Physics World, Vol 18 No 5 2005

It is 54 years since Louis Essen demonstrated the first caesium atomic clock at the National Physical Laboratory and set in motion the shift to atomic timekeeping. Back then, the second was defined in terms of the Earth's rotation, but this was found to fluctuate as our ability to measure time improved. Essen showed that atoms, which have a discrete set of energy levels, could provide a much more stable reference time interval. In 1967 the second was officially redefined by the *Comité International des Poids et Mesures* in terms of the gap between two specific energy levels in a caesium-133 atom.

Since Essen's pioneering work, the accuracy of a caesium clock has steadily improved by a factor 10 or so every decade, such that today's atomic clocks are better than one part in $10^{15}$. These improvements have lead to many scientific advances as well as technologies such as the Global Positioning System (GPS) and the Internet, which depend critically on time and frequency standards.

In a standard atomic clock, a beam of caesium-133 atoms is probed by microwaves that have a frequency of about $9.2 \times 10^{9}$ Hz. When the microwave frequency is adjusted to a value of exactly 9192 631 770 Hz, the photons have an energy that is equal to the energy difference between the two very closely spaced energy levels that make up the ground state of the caesium atoms. The atoms absorb the microwaves and a signal generated from the absorption is fed back to the microwave source, which stops it from drifting from this specific frequency.

The stability imposed on the microwave source by the atoms is what allows us to define the second as "the duration of 9192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom". Effectively we can consider that the caesium atoms oscillate from an excited to a non-excited state 9192 631 770 times in a second.

The clock that was developed 54 years ago used a beam of hot caesium atoms that had been evaporated from an oven. The atoms were probed using a technique developed by Norman Ramsey, for which he shared the 1989 Nobel Prize for Physics. It involved firing a short pulse of microwaves at one position along the beam of atoms, followed – a few milliseconds – later by another short pulse further along the beam. Interference between the excitation of the atoms by the two probe pulses creates a set of fringes (light and dark lines) as a function of the microwave frequency. The width of these interference fringes are inversely proportional to the interval between pulses and aid in enhancing the resolution of the clock.

During the 1990s a new type of caesium atomic clock known as an “atomic fountain” (see Figure 1) was developed by André Clairon and co-workers and was based on techniques that had been developed using lasers and magnetic fields to trap clouds of atoms that had been cooled to temperatures below 1 mK. In the fountain, cold caesium atoms are launched upwards to a height of about a metre before falling back under gravity. The atoms, which pass through a microwave cavity once on the way up and once on the way down, move so slowly that they interact with the microwaves for much longer periods than if they were hot. This arrangement gives the clock a much higher resolution and if the fluctuations in frequency of the clock are averaged over a day, it can measure time to better than $10^{-10}$ s per day.

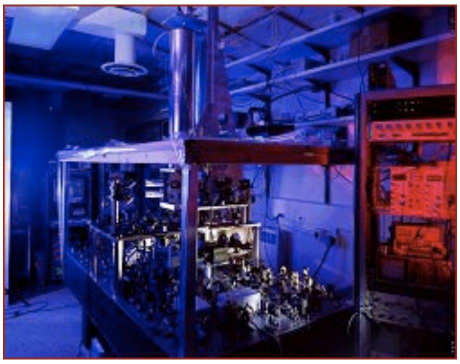


Figure 1: The Atomic Fountain Clock at NIST in Colorado.

Although caesium clocks are very accurate, there are limits to how much better they could get. First, collisions between cold caesium atoms and between atoms and the wall of the container in the fountain can shift the frequency of the atomic transition. Second, the stabilities of one part in $10^{15}$ are only possible by averaging the signal over the period of about a day.

(a) Why are atomic clocks so much more accurate for defining a second than using the Earth's rotation?

[2]

- The Earth's rotation period was found to fluctuate as measurement accuracy increased.
- The difference in energy between two levels in an atom cannot change/fluctuate and therefore is much more reliable for the determination of a time period.

(b) Determine the difference in energy levels between the hyperfine ground states of caesium in joules and electronvolts.

[3]

$$E = hf$$
$$= (6.63 \times 10^{-34})(9192631770)$$
$$= 6.09 \times 10^{-24}\ J$$
$$= 3.81 \times 10^{-5}\ eV$$

(c) What is the lifetime (the time a state stays excited for) of the hyperfine ground state of caesium?

[2]

$$E = hf$$
$$f = 9192631770\ Hz$$
$$T = \frac{1}{f} = 1.09 \times 10^{-10}\ s$$

(d) How can an atomic clock user be sure that they are locked to the correct microwave frequency?

[2]

- When not locked there will be no absorption of the microwave.
- There will be no feedback signal to the microwave source.

(e) What is the distinguishing feature between the original atomic clocks and the 'atomic fountain' clocks and what does this affect in the clock.

[3]

- In the original clock, a heated beam of caesium atoms is used.
- In the fountain clock the atoms are cooled 0.5 each
- In the cooled beam the atoms will be moving slower because
- T is proportional to ave KE and therefore to the v of the particles.

(f) Why is an "atomic fountain" clock so much more accurate than a standard atomic clock?

[4]

- The atoms are moving much slower
- Which means the time between pulses increases
- Therefore the width of the interference fringes decreases
- Which increases the resolution of the clock.

(g) Would an "atomic fountain" clock be able to reach accuracies of $10^{15}$ in real time? Explain why or why not.

[2]

- No
- These accuracies are only achievable when the frequency distortions are averaged over a whole day.

(h) The accuracy of "atomic fountain" clocks are limited by the collisions between atoms in the fountain with each other and the walls of the fountain. Why might these collisions affect the accuracy of the clock?

[2]

- These collisions may excite the atoms to higher energy levels.
- Thus the radiation emitted is not at the feedback frequency and may cause frequency variations.