CHRIST CHURCH GRAMMAR SCHOOL

YEAR 12

PHYSICS STAGE 3

TRIAL EXAMINATION 2012

Solutions

1		
2		
3		
Total		/ 180 = %

Time allowed for this paper
Reading time before commencing work: ten minutes
Working time for paper: three hours

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens (blue/black preferred), pencils (including coloured), sharpener, eraser, correction tape/fluid, ruler, highlighters

Special items: non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers	12	12	50	54	30%
Section Two: Problem-Solving	8	8	90	90	50%
Section Three: Comprehension	2	2	40	36	20%
				Total	100

Instructions to candidates

1. Write your answers in this Question/Answer Booklet

2. Working or reasoning should be clearly shown when calculating or estimating answers.

3. When calculating numerical answers, show your working or reasoning clearly. Give final answers to three significant figures and include appropriate units where applicable.

   When estimating numerical answers, show your working or reasoning clearly. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. The Formulae and Data booklet is **not** handed in with your Question/Answer Booklet.

YEAR 12
PHYSICS STAGE 3
TRIAL EXAMINATION 2012

Section One: Short Response

This section has **twelve (12)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **50 minutes**.

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Question 1 **(4 marks)**

Transperth B-series trains are capable of speeds up to 142 kmh^{-1} and are 2.90 m wide from wheel to wheel. Calculate the emf induced in the axle of such a train on the Joondalup line (travelling North) and state which side of the train would be at the higher potential. Assume the Earth's magnetic field in Perth is 5.50 x 10^{-5} T at 66° to the ground.

$142\ kmh^{-1} = 39.4\ ms^{-1}$

$\varepsilon = v\ell B$ (1)

$= (39.4)(2.90)(5.50 \times 10^{-5} \sin 66)$ (1)

$= 5.74 \times 10^{-3}\ V$ (1) *right hand side of train or East side* (1)

Question 2 **(4 marks)**

The compound **ninhydrin** is a fluorescent compound used to visualize fingerprints. Latent fingerprints are treated with the ninhydrin solution, which when illuminated with ultra violet light, turns the amino acid finger ridge patterns purple and therefore visible. Explain this phenomenon

- The ninhydrin absorbs ultraviolet photons.
- The UV photons have high energies and so excite the ninhydrin molecules to high-lying energy levels.
- The decay process may take place in a number of smaller steps which release lower energy photons.
- These lower energy photons have a longer wavelength and are more likely to be in the visible (purple) part of the spectrum.

Question 3 **(5 marks)**

You need to move a 50 kg bag of fertiliser from one end of the garden to the other. To assist you in your task you decide to use a wheelbarrow, as shown in the diagram below. Estimate the minimum magnitude of force that must be applied to the handles to lift the wheelbarrow (you can assume the bag of fertiliser has the same dimensions as the tray of the wheelbarrow). State clearly any estimations you make. Assume the mass of the wheelbarrow is 25 kg and the length from the handle to the centre of the wheel is 1.6 m.

1 mark each:
Centre of mass from pivot = 0.7 ± 0.1 m (± 0.2 m 0.5 marks)
Angle between vertical and handles = 110° ± 5° (± 10° 0.5 marks)

(0.5) (0.5)

$$\sum \tau = 0 \quad \tau = rF \quad \textit{Take wheel as pivot}$$

$$\sum \tau_{cw} = (1.6)(F_{app})(\sin 110) \text{ (0.5)}$$

$$\sum \tau_{cw} = (0.7)(25+50)(9.8)(\sin 70) \text{ (0.5)}$$

$$(1.6)(F_{app})(\sin 110) = (0.7)(25+50)(9.8)(\sin 70)$$

$$F_{app} = 320\,N \quad (\textit{answer to } 2sf)$$

(1)

Question 4 **(7 marks)**

Silicon films become better conductors of electricity when illuminated by infrared photons with energies of 1.14 eV or greater. This behaviour is called photoconductivity.

(a) What is the wavelength of these photons?

(4 marks)

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

$$(1)\quad (1.14 \times 1.6 \times 10^{-19}) = \frac{(6.63 \times 10^{-34})(3 \times 10^{8})}{\lambda} \quad (1)$$

$$\lambda = 1.09 \times 10^{-6}\ m \quad (1)$$

(b) Could visible light also cause this photoconductivity? Explain your reasoning.

(3 marks)

- Yes
- The energy of a photon is proportional to its frequency (and inversely proportional to its wavelength; E=hf).
- Visible light has higher frequencies than infrared light (or lower wavelengths) therefore will have energies greater than the 1.14 eV required for photoconductivity to occur.

Question 5 **(1 mark)**

According to the standard model of the fundamental particles, what is the same about quarks and leptons?

- They appear to have no internal structure.

Question 6 **(3 marks)**

A lot of particles that are created through collisions of cosmic rays with particles in our upper atmosphere have very short lifetimes (e.g. muons). Many of these particles, however, can still be detected at sea level, even though their lifetimes would suggest that they should have decayed prior to reaching sea level. Explain why we are able to detect these particles.

- The particles are moving at relativistic speeds (close to the speed of light).
- An observer on earth will measure time dilation for the particles.
- The life time of the particle will be extended due to the relative motion between the particle and the observer and the observer on earth will see it last for a longer period of time.

Or

- particles moving towards the earth see the distance to earth decreasing due to length contraction.
- The particle has a shorter distance to travel and can travel this in their lifetime, allowing them to be detected by an observer on Earth.

Question 7 **(6 marks)**

The piccolo shown below has an air column of length 18.5 cm. When it is blown, the air column vibrates in its third harmonic at 2.70 kHz.

(a) What is the wavelength of the sound produced by the piccolo? Assume the piccolo is an open pipe. Include a diagram in your answer.

(3 marks)

$$\lambda = \frac{2L}{3} \quad (0.5)$$

$$= \frac{(2)(0.185)}{3} \quad (0.5)$$

$$= 1.23 \times 10^{-1}\ m \quad (1)$$

(b) What is the speed of the wave in the piccolo?

(3 marks)

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

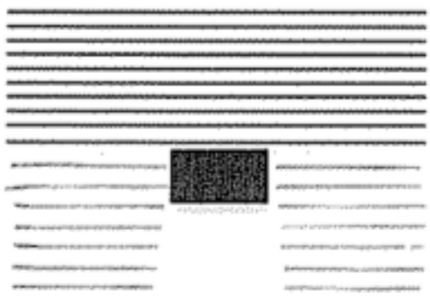
$$= (2700)(1.23 \times 10^{-1}) \quad (1)$$

$$= 332\ ms^{-1} \quad (1)$$

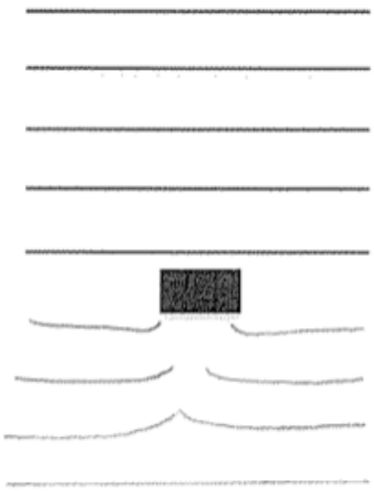
Question 8 **(4 marks)**

Complete these diagrams;

(a) **Light** incident on an object.



(b) Water waves incident on an object.



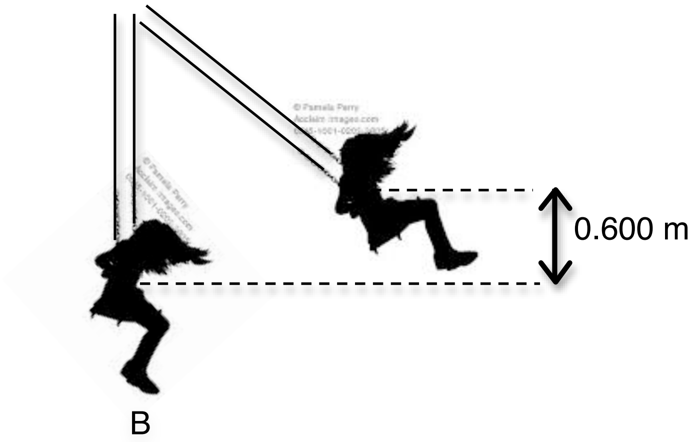
Question 9 **(4 marks)**

Explain why the classical Rutherford 'planetary' model of the atom predicts that atoms should collapse?

- As the electrons orbit the nucleus, they are accelerating (centripetal acceleration).
- Accelerating charged particles emit electromagnetic energy.
- This would mean that the kinetic energy of the electron would decrease, hence also its speed.
- As the speed of the electron decreases, its orbital radius will decrease and it would eventually spiral into the nucleus.

Question 10 **(6 marks)**

A child of mass 40.0 kg sits on a swing of negligible mass. The swing is pulled back so that the child's centre of mass is raised through a vertical height of 0.600 m as shown in the diagram below (diagram, not to scale). The chain length is 3.20 m.



(a) Determine the speed of the child as she moves through position B. (3 marks)

$$\sum E_i = \sum E_f$$

$$E_{Ki} + E_{Pi} = E_{Kf} + E_{Pf}$$

$$E_K = \frac{1}{2}mv^2 \quad (0.5) \quad E_P = mgh \quad (0.5)$$

$$0 + (40)(9.8)(0.6) = \frac{1}{2}(40)(v^2) + 0 \quad (1)$$

$$v = 3.43\ ms^{-1} \quad (1)$$

(b) Determine the size of the normal force acting on the child as she moves through position B.

(3 marks)

$$\sum F = ma_c$$

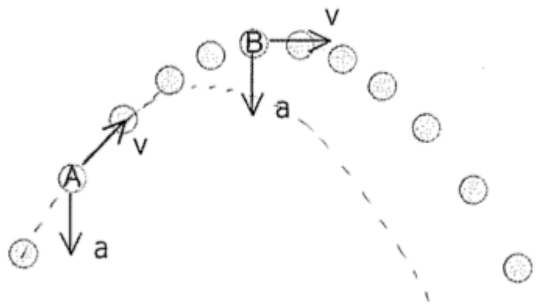
$$\sum F = F_N - mg = \frac{mv^2}{r} \quad (1)$$

$$F_N = \frac{(40)(3.43)^2}{3.20} + (40)(9.8) \quad (1)$$

$$= 539\ N \quad (1)$$

Question 11 **(6 marks)**

The following questions refer to the diagram below which shows the motion of a ball undergoing projectile motion from the left to the right;



(a) Draw and label vectors to represent the acceleration and the velocity of the ball at points A and B.

(4 marks)

(b) Sketch the path of the ball if air resistance is now taken into account.

(2 marks)

Question 12 **(4 marks)**

If a motor is switched on and left to run with no load attached, the current flowing through the coil decreases. Explain why this is so.

- As the motor turns there is a changing magnetic flux through the coil.
- There is an induced emf and current associated with this changing magnetic flux proportional to the rat of change of magnetic flux (Faraday's Law).
- The direction of the induced emf and current will be such so as to oppose the change that caused it.
- The induced emf (back emf) will be in the opposite direction to the applied emf, this reduces the net emf across the coil and hence the current that flows.

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Section Two: Problem-Solving

This section has **eight (8)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **90 minutes**.

NAME:____

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Question 1 **(10 marks)**

A car of mass 800 kg travels around a circular corner of radius 100 m at a speed of 50.0 kmh^{-1}.

(a) Determine the net force acting on the car.

(3 marks)

$$50\ kmh^{-1} = 13.9\ ms^{-1}$$

$$F_c = \frac{mv^2}{r} \quad (1)$$

$$= \frac{(800)(13.9)^2}{100} \quad (1)$$

$$= 1.55\ kN \quad \textit{towards the centre of the circle} \quad (1)$$

(b) Explain why curves are often banked to improve safety for motorists in wet or icy conditions.

(3 marks)

- Due to the banked curve a component of the cars normal force points to the centre of the curve.
- This horizontal force provides the centripetal force required for the car to maintain a circular path.
- This means the car does not need to rely on friction which is reduced in wet or icy conditions.

(c) Determine the angle at which this corner would need to be banked so that no friction is required for a car to travel around it at 50.0 kmh^{-1}.

(4 marks)

$$\sum F_H = F_N \sin\theta = \frac{mv^2}{r}$$

$$\sum F_V = F_N \cos\theta = mg$$

$$\frac{mg}{\cos\theta} = \frac{mv^2}{r\sin\theta}$$

$$\tan\theta = \frac{v^2}{rg} = \frac{13.9^2}{(100)(9.8)}$$

$$\theta = 11.2^\circ$$

Question 2 **(11 marks)**

In the diagram below S_1 and S_2 are two water wave sources in a ripple tank. They are vibrating at the same frequency and amplitude. There is a maximum disturbance at A, a minimum at B, another maximum at C and so on. For each of the scenarios below state how will the pattern of maxima and minima will change.

(a) The two sources are moved closer to each other.

(1 mark)

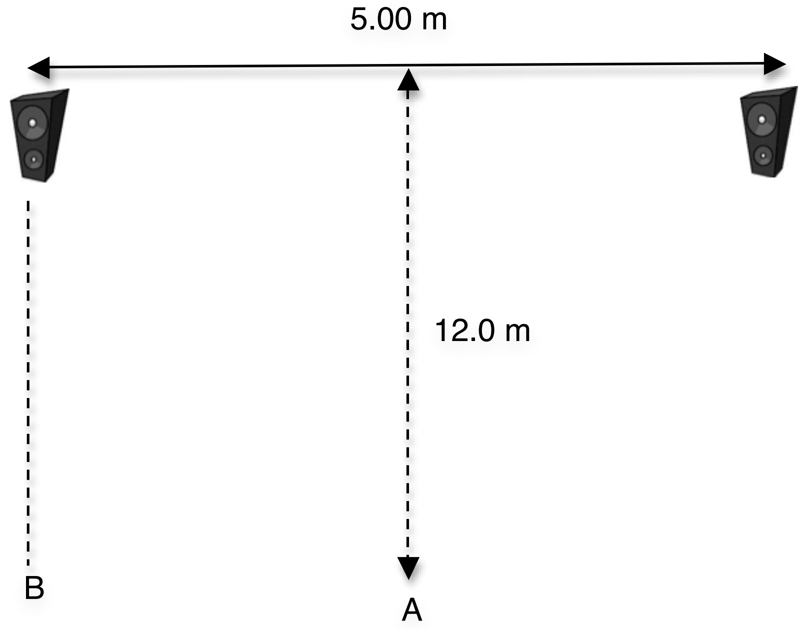
- A, B, C, D etc will move closer together.

(b) The speed of the ripples is decreased (by reducing the depth of the water in the tank). Explain your reasoning.

(3 marks)

- A, B, C, D will move further apart.
- If the speed of the ripples decreases and frequency stays the same, wavelength must increase.
- A greater path differences will required for the waves to go in and out of phase, meaning the loud and soft spots will move further apart.

Two loudspeakers of a stereo system are separated by 5.00 m. They are connected to a single frequency generator and are placed so that face outwards as shown in the diagram below. The speakers are playing a frequency of 1000 Hz. Assume the speed of sound in air is 333 ms^{-1}.



(c) What would the person at A (midway between the two speakers) hear? Explain your reasoning.

(3 marks)

- A loud spot (louder than either of the two individual speakers)
- The path difference from both speakers to A is the same, so the same number of wavelengths will fit into each path.
- The waves will arrive in phase and hence undergo constructive interference.

(d) If the person now moves to point B, what position would they be standing at? State whether it will be a loud or a soft spot and which number it will be.

(4 marks)

$$Path\ Difference = \sqrt{12^2 + 5^2} - 12$$
$$= 1.00\, m$$
$$v = f\lambda$$
$$333 = (1000)(\lambda)$$
$$0.333\, m$$

$$\frac{1}{0.333} = 3.00 \quad 3rd\ loud\ spot$$

Question 3 **(10 marks)**

A physicist working in a laboratory wears a necklace enclosing 1.00 x 10^{-2} m^2 and with a resistance of 0.010 Ω. The magnetic flux density in the laboratory starts at 2.00 T but due to a systems failure decays to 1.00 T in 1.00 ms.

(a) What is the current induced in the necklace?

(4 marks)

$$\varepsilon = \frac{\Delta\phi}{\Delta t}$$
$$= \frac{(1-2)(1\times10^{-2})}{1\times10^{-3}}$$
$$= 10.0\ V$$

$$V = IR$$
$$10 = (I)(0.01)$$
$$I = 1000\ A$$

(b) What is the total power dissipated by the necklace?

(3 marks)

$$P = VI$$
$$= (10)(1000)$$
$$= 1.00\times10^{4}\ W$$

(c) What is the total energy transferred to the wearer's neck?

(3 marks)

$$P = \frac{E}{t}$$
$$1.00\times10^{4} W = \frac{E}{1.00\times10^{-3}}$$
$$= 10.0\ J$$

Question 4 **(16 marks)**

The Hubble Law relates the recessional velocity of a galaxy and its distance from the Earth.

$$v = H_0 d$$

The redshift (z) of a galaxy is given by;

$$z = \frac{\lambda - \lambda_0}{\lambda_0} = \frac{v}{c}$$

(a) Explain what is meant by the term 'redshift of a galaxy' and what is causing the redshift.

(3 marks)

- Redshift is where the spectral lines emitted from galaxies in the universe are shifted towards the red end of the spectrum.
- This is because the space between observers on Earth and the galaxies is increasing.
- Because the speed of light must be constant, the wavelengths of the spectral lines stretch to fit the space and their wavelength increases.

A galaxy in the constellation Pisces is 5210 Mly from the Earth.
1 pc = 2.06 x 10^6 AU.

(b) Convert the distance to the constellation Pisces to Mpc.

(3 marks)

$$1pc = 2.06 \times 10^6 AU = (2.06 \times 10^6)(1.50 \times 10^{11})$$
$$= 3.09 \times 10^{17} m$$
$$1\ell y = (365)(24)(60)(60)(3 \times 10^8) = 9.46 \times 10^{15} m$$
$$\frac{(5210)(9.46 \times 10^{15})}{3.09 \times 10^{17}}$$
$$= 126\ Mpc$$

(c) Calculate the speed at which this galaxy is receding from Earth. Assume H_0 = 70 kms^{-1}/Mpc. If you could not answer (b) use a value of 140 Mpc.

(2 marks)

$$v = H_0 d$$
$$= (70 \times 10^3)(126)$$
$$= 8.82 \times 10^6\ ms^{-1}$$

(d) What redshift ratio is expected for light from this galaxy?

(2 marks)

$$z = \frac{v}{c}$$
$$= \frac{8.82 \times 10^8}{3 \times 10^8}$$
$$= 2.94 \times 10^{-1}$$

(e) Some galaxies in the Local Group (a group of about 30 galaxies that includes the Milky Way Galaxy, the Andromeda Galaxy and the Large and Small Magellanic Clouds) exhibit blueshifted spectral lines. Why is this so?

(3 marks)

- If the spectral lines are blueshifted the galaxies must be moving towards us.
- This is due to gravitational attraction between the galaxies.
- The space between the galaxies is decreasing, speed of light is constant so the wavelengths shrink to fit the space.

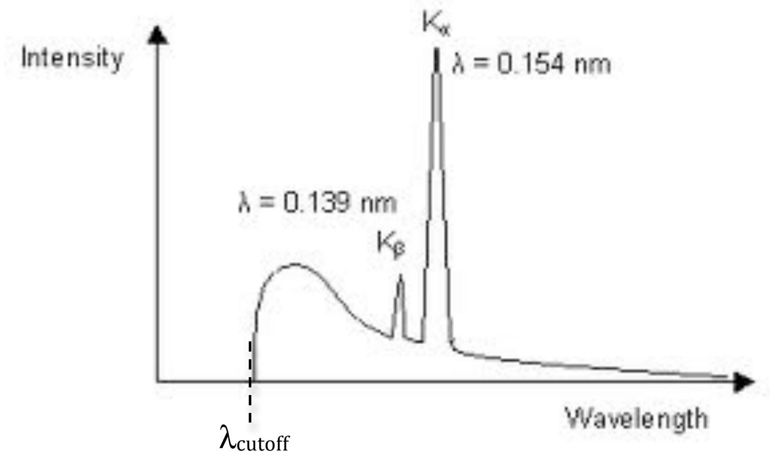
(f) What three pieces of evidence suggest our Universe evolved from a 'Big Bang'?

(3 marks)

- The uniform expansion of the universe
- The relative abundances of hydrogen and helium in the universe
- The presence of the cosmic microwave background.

Question 5 **(10 marks)**

The figure below shows the spectrum of X-rays produced when a voltage source of 25.0 kV is used.



(a) Show on the diagram the position of the cut-off wavelength.

(1 mark)

(b) Determine the magnitude of the cut-off wavelength.

(4 marks)

$$E = qV$$
$$= (1.6\times10^{-19})(25\times10^{3})$$
$$= 4.00\times10^{-15}\ J$$

$$E = \frac{hc}{\lambda}$$
$$4.00\times10^{-15} = \frac{(6.63\times10^{-34})(3\times10^{8})}{\lambda}$$
$$\lambda = 4.97\times10^{-11} m$$

(c) Explain the occurrence of the two distinct peaks on the spectrum.

(3 marks)

- If a high speed electron passes close to an inner shell electron it can knock that electron out of the atom.
- This leaves the atom in a highly excited state and higher level electrons drop down to fill the inner shells.
- When the electrons drop down a photon equal in energy to the difference between energy levels is released.

(d) If the operating voltage were to change, state **two** aspects of the X-ray spectrum that would also change.

(2 marks)

- The cutoff wavelength
- The height of the characteristic peaks
- The production of β lines

Question 6 **(12 marks)**

A transformer connected to a 240 V AC line is to supply 13.0 kV for a neon sign. To reduce the shock hazard, a fuse is to be inserted in the primary circuit. The fuse is to 'blow' when the current in the secondary circuit exceeds 8.50 mA.

(a) State whether a step-up or a step-down transformer should be used and calculate the ratio of turns in the transformer.

(3 marks)

- Step-up

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

$$\frac{N_S}{N_P} = \frac{13000}{240}$$

$$1:54.2$$

(b) What power must be supplied to the transformer when the secondary current is 8.50 mA?

(3 marks)

$$P = VI$$

$$= (13 \times 10^3)(8.50 \times 10^{-3})$$

$$= 111\,W$$

(c) What current rating should the fuse in the primary circuit have?

(3 marks)

$$P = VI$$

$$111 = (240)(I)$$

$$I = 4.63 \times 10^{-1}\ A$$

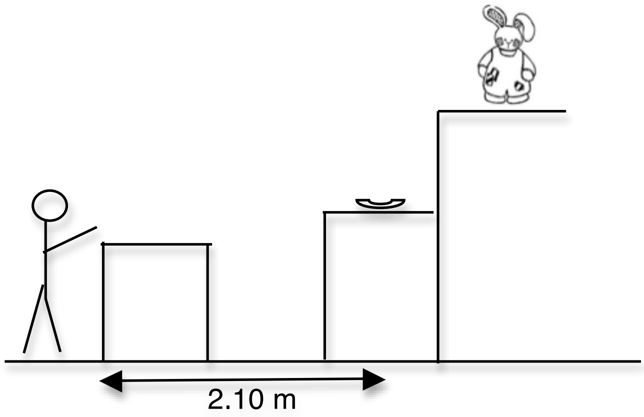
(d) The transmission of power over long distances would not be economical without the use of step-up transformers. Explain why.

(3 marks)

- By stepping up the voltage the current through the lines is reduced: $P=VI$.
- This reduces the amount of power lost due to resistive heating: $P=I^2R$.
- Also reduces the voltage drop across the lines: $V=IR$, meaning there is more available voltage at the end of the lines.

Question 7 **(11 marks)**

In a stall at the Royal Show you can win a stuffed animal if you toss a 20 c piece into a small plate. The plate is on a shelf above the point where the 20 c piece leaves your hand and is 2.10 m horizontally from this point. If you toss the coin with a speed of 6.40 ms^{-1} at an angle of 60° above the horizontal, and the coin lands in the plate, determine;



(a) The time the coin is in the air for.

(3 marks)

$$s = tv$$
$$2.10 = (6.40\cos 60)(t)$$
$$t = .656\ s$$

(b) The height of the shelf above where the coin leaves your hand.

(3 marks)

$$s = ut + \frac{1}{2}at^2$$
$$= (6.40\sin 60)(0.656) + \frac{1}{2}(-9.8)(0.656)^2$$
$$= 1.53\ m$$

(c) The velocity of the coin just before it lands in the plate.

(5 marks)

$$v = u + at$$
$$= (6.40\sin 60) + (-9.8)(0.656)$$
$$= -0.886\ ms^{-1}$$

$$v = \sqrt{(6.40\cos 60)^2 + 0.886^2}$$
$$= 3.32\ ms^{-1}$$
$$\tan\theta = \frac{opp}{adj} = \frac{6.40\cos 60}{0.866}$$
$$\theta = 74.9^\circ$$
$$3.32\ ms^{-1} \quad 74.9^\circ\ below\ the\ horizontal$$

Question 8 **(14 marks)**

Soviet cosmonaut Major Yuri A. Gagarin was the first man to orbit Earth. In his spacecraft Vostok 1, Gagarin made a single orbit of the Earth on April 12, 1961. His flight lasted 1 hour and 48 minutes. The apogee (the farthest point in the orbit from Earth) was about 327 km above sea level and his orbital speed was 27.3 x 10^3 kmh^{-1}.

(a) Determine the acceleration due to gravity on Vostok 1 and Gagarin at the apogee of the orbit.

(3 marks)

$$g = G\frac{M}{r^2}$$

$$= (6.67\times10^{-11})\frac{5.97\times10^{24}}{(327\times10^3 + 6.38\times10^6)^2}$$

$$= 8.85\ ms^{-2}$$

(b) Choose one method to calculate the distance that Gagarin would have travelled had he remained at the orbit of 327 km above sea level for the duration of his flight.

(3 marks)

$$27.3\ kmh^{-1} = 7.58\ ms^{-1}$$

$$s = tv$$

$$= (108\times60)(7.58)$$

$$= 49.1\times10^6\ m$$

$$C = 2\pi r$$

$$= (2\pi)(327\times10^3 + 6.38\times10^6)$$

$$= 42.1\times10^6\ m$$

(c) Determine what the period of the orbit would have been if Gagarin had remained at the apogee for the entire orbit.

(4 marks)

$$F = G\frac{m_1 m_2}{r^2} \quad F = \frac{m_1 v^2}{r}$$

$$G\frac{m_g m_e}{r^2} = \frac{m_g v^2}{r}$$

$$v^2 = G\frac{m_e}{r}$$

$$\frac{4\pi^2 r^2}{T^2} = G\frac{m_e}{r}$$

$$T = \sqrt{\frac{4\pi^2 r^3}{Gm_e}}$$

$$= \sqrt{\frac{4\pi^2(327\times10^3 + 6.38\times10^6)^3}{(6.67\times10^{-11})(5.97\times10^{24})}}$$

$$= 5.47\times10^3\ s$$

(d) What does your answer to (c) tell you about the shape of Gagarin's orbit. Include a sketch in your answer and discuss changes in the speed of Vostok 1 in terms of its energy.

(4 marks)

- The orbit was not circular, it was elliptical.
- As the shuttle was closer to the earth it had less gravitational potential energy and more kinetic energy and so was moving faster.
- This means it would have been travelling faster at some places in the orbit, accounting for the lower total time.

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PHYSICS STAGE 3
MID YEAR EXAMINATION 2012

Section Three: Comprehension

This section has **two (2)** questions. Answer **all** questions. Write your answers in the space provided.

Suggested working time for this section is **40 minutes**.

NAME:____

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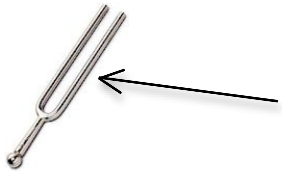
Question 1 **(19 marks)**

Tuning Forks

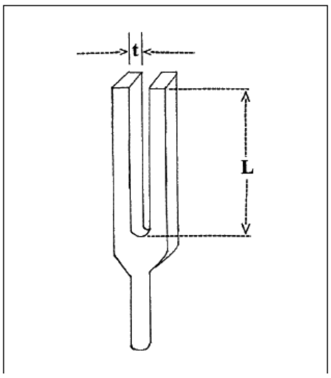
A tuning fork has two metal tines that flex alternately toward one another and away from one another.



The natural frequency of a vibrating system is determined by its physical shape and material of construction. In the case of a tuning fork, the length of the tines determines the natural frequency as well as the material of which it is made.

The equation that can be used to predict the fundamental resonant frequency of a tuning fork is given by;

$$f = \frac{(1.194)^2\pi}{8L^2}\sqrt{\left(\frac{EK^2}{\rho}\right)} \quad - ①$$



Where, L is the length of the tines
E is Young's Modulus of the material
ρ is the density of the bar metal
K is the radius of gyration of the bar = $\frac{t}{\sqrt{12}}$
Where t is the thickness of the time.

The speed of sound in the bar, v, can be substituted for $\sqrt{\frac{E}{\rho}}$.

(a) Rewrite equation ①, substituting in v.

(1 mark)

$$f = \frac{(1.194)^2\pi}{8L^2}v\sqrt{K^2}$$

A group of students conducted an experiment with a set of steel tuning forks to determine the values of m and B. They placed tuning forks of differing frequency near to a microphone connected to a cathode ray oscilloscope. They then struck each of the tuning forks in turn with a small rubber mallet.

The tuning forks used were all made from stainless steel and had a tine thickness (t) of 1.00 cm.

The period of each tuning fork was then measured from the oscilloscope screen. The results from this experiment are given below.

L (m)	f (Hz)	$1/L^2$ (m^{-2})
0.19	261	28
0.17	330	35
0.16	392	39
0.15	440	44
0.13	523	59

(b) Process the collected data so you are able to plot a graph of;

$$\mathrm{f\ vs\ } \frac{1}{\mathrm{L}^2}$$

(2 marks)

(c) Plot a graph of $\mathrm{f\ vs\ } \frac{1}{\mathrm{L}^2}$ including a line of best fit.

(5 marks)

(d) Determine the gradient of your graph.

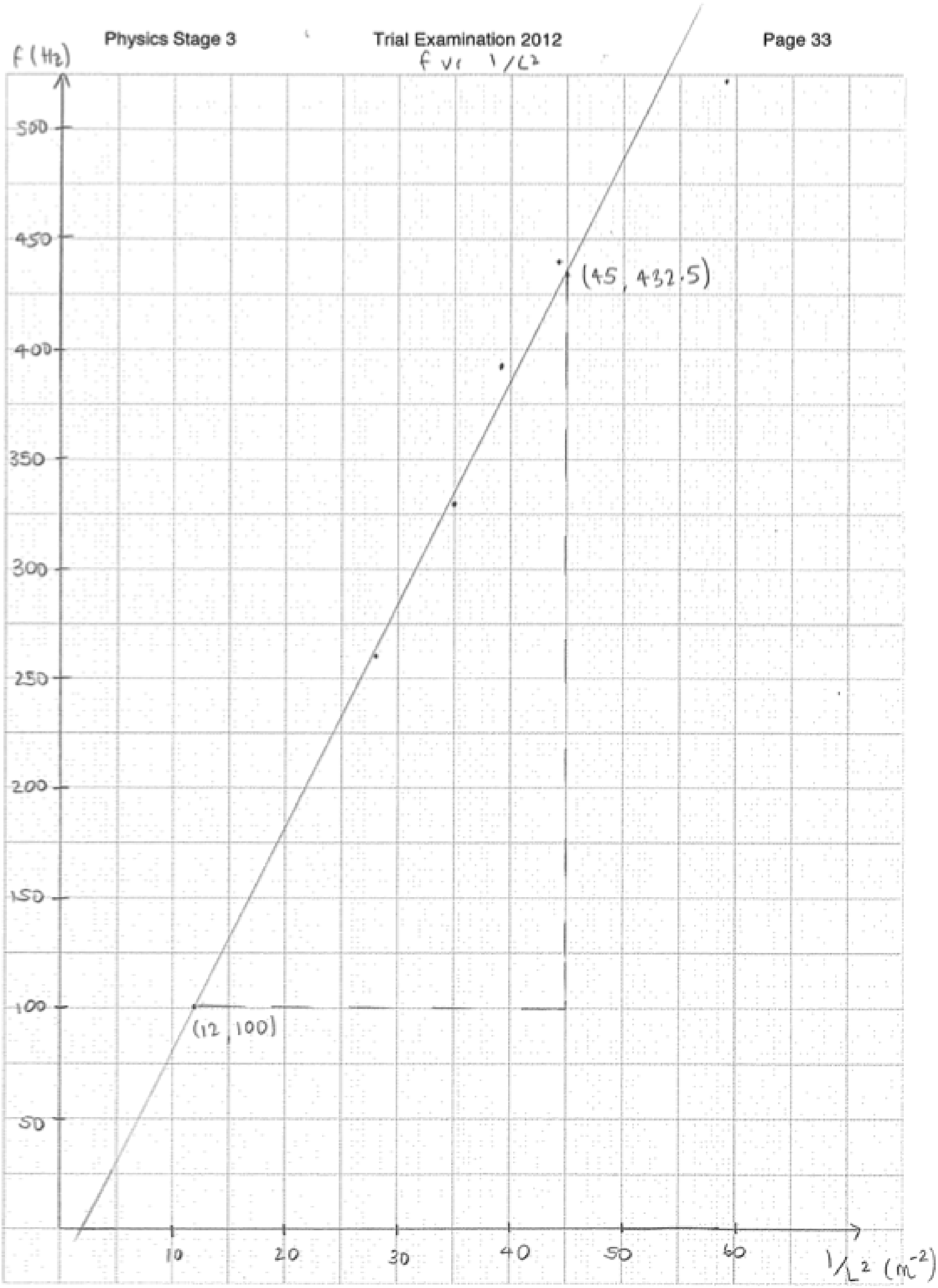
(3 marks)

$$gradient = \frac{rise}{run} = \frac{432.5 - 100}{45 - 12}$$
$$= 10.1\ Hz\, m^2$$

(e) Use your answer from (d) to determine the value of v, the speed of sound in the stainless steel tuning fork.

(3 marks)

$$gradient = \frac{(1.194^2)\pi}{8} v\sqrt{K^2}$$
$$10.1 = \frac{(1.194^2)\pi}{8} v\sqrt{8.33 \times 10^{-6}}$$
$$v = 6.25 \times 10^3\ ms^{-1}$$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Page 33
f vs 1/L²
f (Hz)
500
450
400
350
300
250
200
150
100
50
(45, 432.5)
(12, 100)
10
20
30
40
50
60
1/L² (m⁻²)

(f) The accepted value for the speed of sound in stainless steel is 5800 ms^{-1}. Determine the percentage error in your result.

(2 marks)

$$\frac{6250 - 5800}{5800} = 7.76\ \%$$

(g) Explain why tuning forks with long tines will vibrate at lower frequencies than short-tined forks?

(3 marks)

- The long tined tuning forks will have greater mass.
- This means they will have a greater inertia and their acceleration back to equilibrium will be at a lesser rate than for a tine with less mass.
- As the acceleration back to equilibrium has decreased, the tine will move slower and as tine speed as decreased, frequency will decrease also.
  (NB this answer is **not** linked to part (e).

Question 2 **(15 marks)**

Mechanical Oscillations and Resonance in a Tuning Fork

Theory

Standing waves can also be set up in rods and plates (as well as in string and pipes). The sound from a tuning fork is produced by the vibrations of each of its tines. A tuning fork can be made to sound be striking it with a rubber mallet, in which case it will oscillate at its natural frequency **or** can be forced to oscillate at the same frequency as an external source by physically moving the tines in and out.

(a) In the second scenario for making the tuning fork oscillate, what condition must be met for the tuning fork to have large amplitude oscillations (i.e. to resonate)?

(1 mark)

- The frequency of the external source must be the same or close to the natural frequency of the tuning fork.

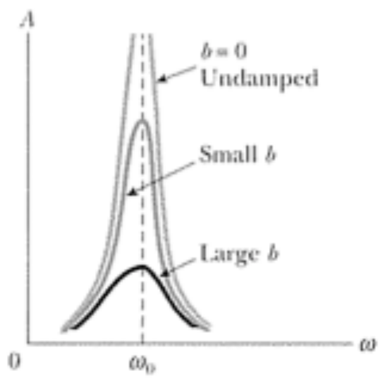
In everyday life, we often see damped oscillatory motion. Examples are the swinging of a pendulum, the bouncing of a car's front-end suspension (particularly visible if the `shocks' are worn out), the vibration of a string of a guitar. In these real systems, dissipative forces, such as friction, retard the motion. Consequently, the mechanical energy of the system diminishes in time and the motion is said to be **damped**.

One common type of retarding force is where the force is proportional to the speed of the moving object and acts in the direction opposite to the motion. This retarding force (R) is often observed when an object moves through the air and can be expressed as;

$$R = -bv$$

Where b is a constant called the damping coefficient.

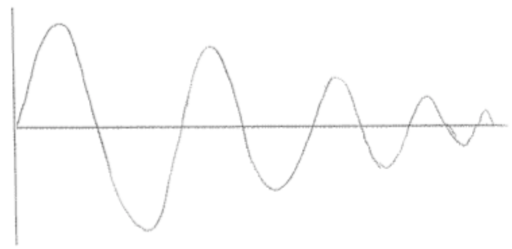
When a resonant system (such as an oscillating tuning fork) is damped, the shape of the resonance curve will change as shown in the diagram below (ω is a symbol used for frequency);



(b) State and sketch a diagram to show how you would expect the frequency and amplitude of a sound wave to change if its source is damped.

(3 marks)

- The amplitude of the wave would diminish but the frequency of the wave would not change.



(c) Explain why the shape of the resonance curve depends on the damping coefficient by making reference to energy transfer during resonance.

(2 marks)

- In resonance energy transfer between the driving force and the resonating system is most efficient (which is what leads to large amplitude oscillations)
- As the damping coefficient increases, the amplitude of the oscillations decreases as some of the energy is transferred to do work against the retarding force rather than go to the resonating system.

(d) If a tuning fork were struck in the vacuum of space, would you expect damping to occur?

(2 marks)

- Yes
- There is still friction between particles (hysteresis), (so although it will not occur as quickly) damping will still occur.

Experiments to determine the nature of damping for a resonant system are often performed with large tuning forks, in which two massive prongs can vibrate towards and away from each other, as shown in the diagram below.

(http://www.faraday.physics.utoronto.ca/IYearLab/tunfk.pdf)

A ferrite (iron) magnet is placed on the end of one prong of the tuning fork, which moves with the prong in front of a coil of wire which is connected to an ammeter. This coil is referred to as the 'pick-up' coil and is used to determine the speed of oscillation of the tuning fork.

(e) Explain how the magnet and 'pick-up' coil system would be used to determine the speed of oscillation of the tuning fork.

(3 marks)

- As the magnet moves in front of the coil of wire, the magnetic flux through the coil will change.
- As the magnetic flux changes, there will be an induced emf in the coil proportional to the rate of change of flux (Faraday's Law).
- As the tine moves faster, the rate of change of magnetic flux will be greater and hence so will the induced emf providing a measure of the speed of the tine.

The tuning fork can also be damped additionally by mounting a plate of copper to the other prong of the fork (not the one with the magnet on it). The copper plate can then be surrounded by an external magnet.

(f) Explain how the inclusion of the copper plate and magnet setup would increase the damping of the tuning fork.

(4 marks)

- As the copper plate moves through the external magnet, there will be a changing magnetic flux through the copper plate.
- As the magnetic flux changes, there will be an induced emf in the copper plate proportional to the rate of change of flux (Faraday's Law).
- This induced emf will be in such a direction as to oppose the direction of the motion of the copper plate (lenz's law).
- The magnetic field associated with the induced current in the copper plate will exert a force on the external magnet which will exert an equal and opposite force on the copper plate (in the opposite direction to its motion, slowing it down).

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