UACE PHYSICS PAPER 2008 GUIDE

Instructions to the candidates:

Answer **five** questions taking at least one from each of the sections **A, B, C** and **D**, but not more than one question should be chosen from either section **A** or **B**

Any additional question (s) will not be marked.

Mathematical tables and squared paper will be provided

Non programmable calculators may be used.

Assume where necessary

Acceleration due to gravity, g	$9.81ms^{-2}$
Electron charge, e	$1.6 \times 10^{-19}C$
Electron mass	$9.11 \times 10^{-31}kg$
Plank's constant, h	$6.6 \times 10^{-34}Js$
Speed of light in the vacuum, c	$3.0 \times 108ms^{-1}$
Specific heat capacity of water	$4.200Jkg^{-1}K^{-1}$
Avogadro's number, N_A	$6.02 \times 10^{23}mol^{-1}$
The constant, $\frac{1}{4\pi\varepsilon_0}$	$9.0 \times 10^{9}F^{-1}m$
Permittivity of free space, μ_0	$4.0\pi \times 10^{-7}Hm^{-1}$
Permittivity of free space, ε_0	$8.85 \times 10^{-12}Fm^{-1}$
One electron volt	$1.6 \times 10^{-19}J$
Resistivity of Nichrome wire at 25^0C	$1.2 \times 10^{-6}\Omega m$

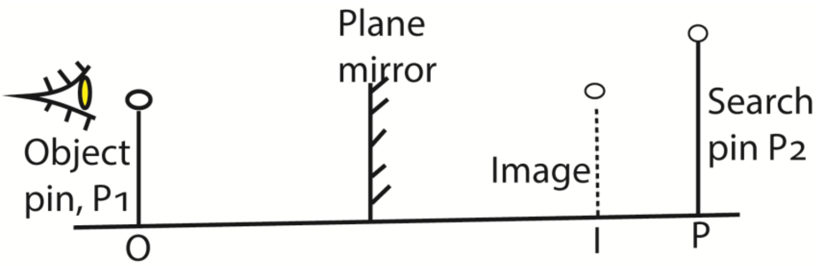
SECTION A

1. (a) (i) Distinguish between real and virtual images. (02marks)

A real image is one formed by actual intersession of rays and can be formed on the screen while a virtual image is formed by apparent intersession of rays and cannot be formed on a screen.

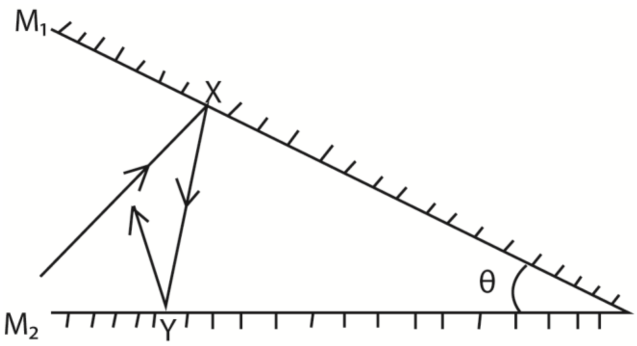
(ii) Describe how the position of an image in a plane mirror can be located (03marks)

Method 1: IMAGE LOCATION BY NO PARALLAX



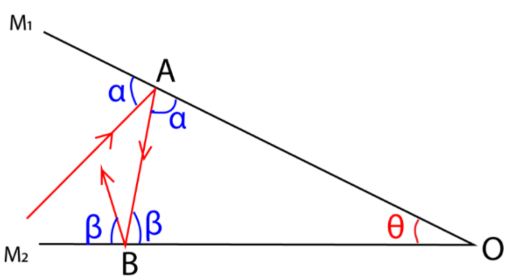
- An object pin **O** is placed in front of a plane mirror to form a virtual image **I**.
- A large search pin **P** is placed behind the mirror and moved to such a position that there is no parallax between pin **P2** and the image **I**.
- The image position has therefore been located.

(b) The diagram in the figure below shows a ray of light undergoing two successive reflections at points X and Y in two mirrors M_1 and M_2 inclined at an angle θ.



Show that the ray is deviated through an angle 2θ (03marks)

Consider an incident ray of light reflected successively from two mirrors M_1 and M_2 inclined at an angle θ to each other at O as shown



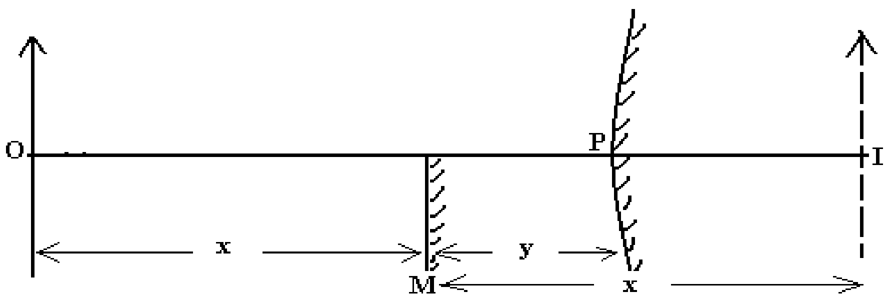
Let the glancing angles at A and B be α and β respectively.
Deviation by M_1 = 2α (clockwise direction)
Deviation by M_2 = 2β (clockwise direction)
Total deviation = 2α + 2β
= 2 (α + β) ---------------------- (i)
But, α + β + θ = 180^0 (Angle sum of a triangle)
⇨ α + β = (1800 - θ) ---------------------(ii)

Combining equation (i) and (ii) gives
Total deviation = 2 (180^0 - θ) (clockwise direction)
= 360^0 - 2θ (clockwise direction)
= 2θ (anti-clockwise direction)

(c) (i) What is a radius of curvature of a convex mirror? (01mark)

Radius of curvature of a convex mirror is the radius of a hollow sphere of which the mirror forms part

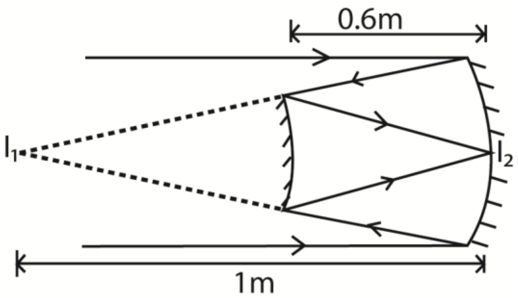
(ii) Describe the experiment to determine the focal length of a convex mirror using a plane mirror. (05marks)



(i) An object pin **O** is placed in front of a convex mirror as shown in the diagram above
(ii) A virtual diminished image is formed at **I**.
(iii) A plane mirror **M** is placed between **O** and **P** so as to intercept half the field of view of the convex mirror.
(iv) Mirror **M** is adjusted until its own image of **O** coincides with **I** by no parallax method.
(v) Measure the distances **x** and **y.**
(vi) The focal length of the mirror is calculated from $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

Where u = (x + y) and v = (v-x)(virtual)

(d) A small convex mirror is placed 0.60m from the pole and on the axis of a large concave mirror of radius of curvature 2.0m. The position of the convex mirror is such that a real image of a distant object is formed in the pane of a hole drilled through the concave mirror at its pole. Calculate the radius of curvature of the convex mirror. (04marks)



I1 is the virtual object of convex mirror that produces a real image, I2

Action of convex mirror;

u = -(1-0.6) = -0.4; v = 0.6

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{1}{-0.4} + \frac{1}{0.6}$

f = -1.2m

but radius of curvature = 2f = 2 x 1.2 = 2.4m

2. (a) (i) Define the terms linear magnification and angular magnification as applied to a lens. (02marks)

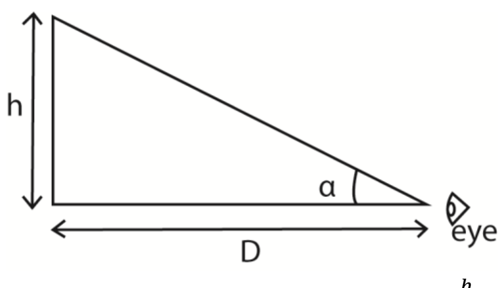
Linear magnification is the ratio of image height to the object height.

Angular magnification is the ration of the angle subtended by the final image at the eye using a lens to the angle subtended by the object to unaided eye

(ii) Derive the expression for magnifying power of a magnifying glass when the final image is formed at the near point. (04marks)

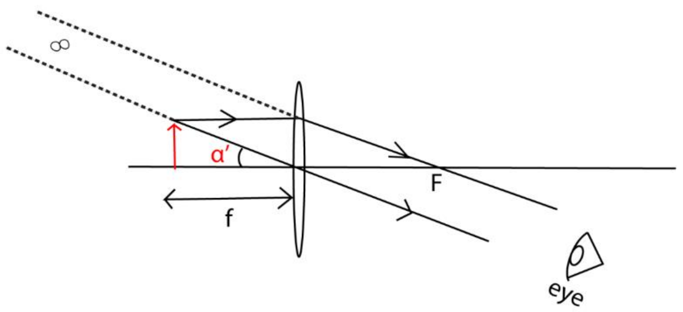
Solution

For the image to be formed at infinity, the object must be at, f.
Using unaided eye



The virtual angle, α, is given by tanα ≈ α = $\frac{h}{D}$ for small angle in radians .... (i)

If the final image at near point subtend an angle α' to the eye when a magnifying glass is used as given in the diagram below



For small angle tanα' ≈ α' $=\frac{h'}{f}$ for small angle in radians........................ (ii)

Linear magnification from (i) and (ii), m = $\frac{\alpha'}{\alpha} = \frac{h'}{D} \div \frac{h'}{f} = \frac{h'}{f}$

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ and multiplying through by v

$\frac{v}{f} = \frac{v}{u} + 1$

Since, v = f

$\frac{D}{f} = m + 1$ or m = $\frac{D}{f}$ -1 where f is the focal length

(b) An object is placed at a distance f + x from a converging lens of focal length, f. the lens produces an image at a distance, f + y from the lens. Show that f^2 =xy. (03marks)

u = f + x and v = f +y

From $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$\frac{1}{f} = \frac{1}{f+x} + \frac{1}{f+y}$

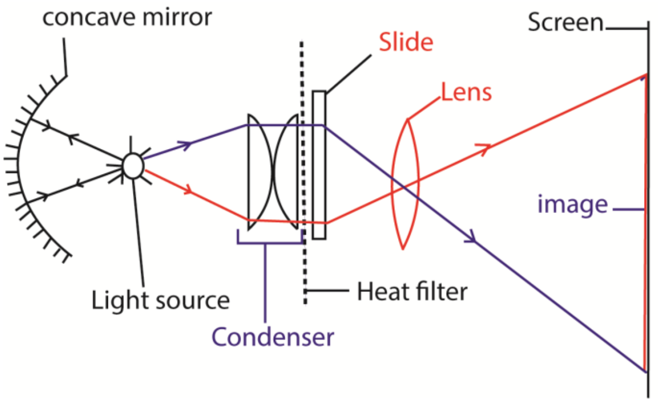
$f^2 = xy$

(c) (i) Describe with the aid of a labelled diagram the structure and operation of a simple projection lantern. (04marks)

Projection lantern

A **projector** is an instrument used to produce a large image of a small object.

- The slide, or film, is placed behind the **projector** lens outside its focal length and is illuminated buy a small but powerful source of light from concave reflector through condensing lenses.
- A magnified, real and inverted image on the screen



Area magnification = $\frac{Area\ of\ the\ image}{Area\ of\ the\ object}$

(ii) The slide of a projection lantern has dimension 36mm by 24mm. Find the focal length of the lens required to project an image 1.44m by 0.98m on a screen placed 4.0m from the lens. (04marks)

Area magnification = $\frac{1.44\ x\ 0.98}{36\ x\ 10^{-3}\ x\ 24\ x10^{-3}}$ = 1633.3

Linear magnification = $\sqrt{1633.3}$ = 40.4

From M = $\frac{v}{f} - 1$, v = 4.0m

40.4 = $\frac{4}{f} - 1$; f = 0.097m

(d) Distinguish between a chromatic and spherical aberration. (03marks)

Chromatic aberration is the formation of blurred images with colored edges when white light is incident on a lens due to the fact that the lens has different focal lengths for the different colors.

Spherical aberration is the formation of blurred but non colored images when a wide beam of light is incident on a lens because the lens has different foci for marginal and paraxial rays.

3. (a) (i) What is a wave? (01mark)

A wave is a periodic disturbance that travels with a definite velocity through the medium.

(ii) Explain why an open tube is preferable as a musical instrument. (03marks)

A closed pipe gives only odd numbered harmonics while an open pipe produced both odd and even numbered harmonics. Hence open pipe gives many different overtones and thus better quality musical notes than closed pipes.

(b) (i) State two factors that affect the speed of sound in air (01mark)

- Temperature of the air
- Humidity of the air
- Wind velocity

(ii) Explain the term reverberation. (02mark)

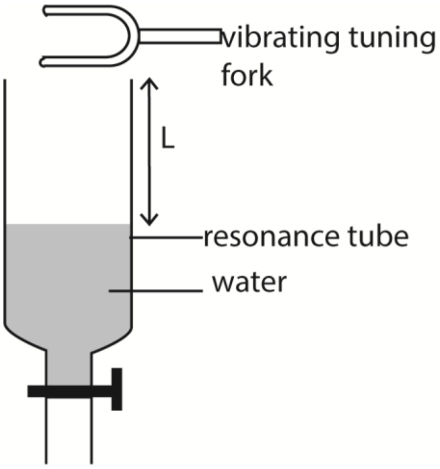
Reverberation occurs when sound produced at one instant by a source is closely followed by its echo. This is due to the reflecting surface being too close to the source. Therefore the observer fails to distinguish between the original sound and its echo; the observer gets the impression that the original sound is prolonged.

(iii) What is the implication of reverberation in a hall? (02marks)

The soft clothing of the audience absorb the sound instead of reflecting it. Consequently, the music and speed appear to be weaker. Reverberation of a small degree is necessary because it enhance audibility. However, if it is too long, it makes music and speech sound confused and indistinct.

(c) Describe an experiment to determine the velocity of sound in air using resonance method. (06mark)

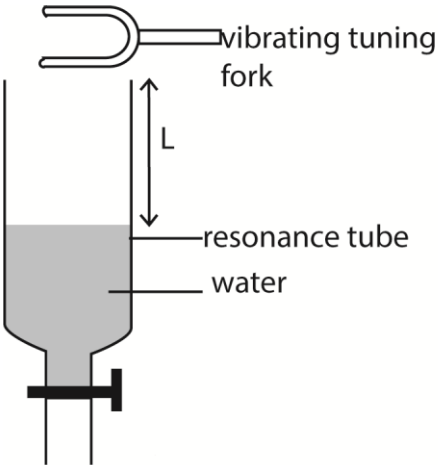
Solution



A resonance tube is place to stand in a tall jar full of water.
Starting with a short length air column, a vibrating tuning fork is held over the mouth of resonance tube. The tube is raised until a point where a loud sound is heard. The length L of the air column and frequency f of tuning fork are recorded.

The experiment is repeated with other five tuning forks of different frequencies
Values of L, f and $\frac{1}{f}$ are tabulated.
A graph of L against $\frac{1}{f}$ is plotted and slope S is determined
The velocity, v, of sound = 4S.

Or



- A glass tube which can be drained from bottom is filled with water.
- A sounding tuning fork of frequency f is brought to the mouth of the tube.
- The water is slowly drained until a loud sound is heard. The tap is closed and length L_1 is measured.
- The tuning fork is again sounded at the mouth of the tube and the water drained further until a loud sound is heard and distance L_2 is noted
- Velocity, v, of sound in air = $2f(L_2-L_1)$

(d) (i) What is harmonic in sound? (01mark)
Harmonic is one of the frequencies that cam be produced by a given instrument (both stringed and piped)

(ii) A string of length 0.5m and mass 50g is stretched between two fixed points. If the tension in the string is 100N, find the frequency of second harmonic. (04marks)

From $f = \frac{v}{\lambda}$ ………………………… (i)

But $v = \sqrt{\frac{T}{\mu}}$; where μ is the mass per unit length.

$\mu = \frac{5 \times 10^{-3}}{0.5} = 0.01 kgm^{-1}$

$v = \sqrt{\frac{100}{0.01}} = 100 ms^{-1}$

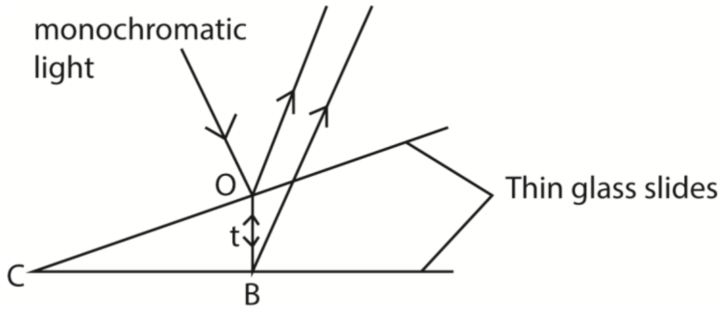
For second harmonic, first overtone, λ = L = 0.5m

Substituting in eqn. (i) $f = \frac{100}{0.5} = 200Hz$

4. (a) Distinguish between constructive and destructive interference. (03marks)

Constructive interference occurs when two waves superpose in phase whereas destructive interference occurs when two waves are superposed out of phase.

(b) (i) Explain how interference fringes formed in air-wedged film between to glass slides when monochromatic light is used. (06marks)



When light from monochromatic source is reflected down towards the wedge and is partially reflected upwards from the bottom of the top glass slide and partially transmitted through the air film at O to point B where it is reflected upwards.

The two wave trains are coherent and when they superpose above the upper side, they produce interference pattern in form of alternative dark and bright fringes parallel to the line of intersection of the slide.

The path difference is 2t where t is the small thickness of the film at O.

At C where the path different is apparently zero, a bright fringe is expected, however, a dark fringe is observed. This is due to phase change of π radians (equivalent to path difference of $\frac{\lambda}{2}$) that occurs when a wave is reflected at a denser medium. λ

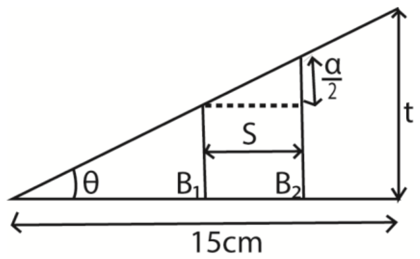
Hence for constructive interference (bright fringes) $\left(2t + \frac{\lambda}{2}\right) = n\lambda$, for n = 1, 2, 3…

Destructive interference (dark fringes) $2t = n\lambda$, for n = 1, 2, 3 …

(iv) Describe the appearance of fringes when white light is used. (02marks)

Colored fringes are observed.

(c) Two glass slides in contact at one end are separated by a sheet of paper 15cm from the line of contact to form an air-wedge. When the air wedge is illuminated normally by light of wavelength 6.0×10^{-7}m, interference fringes of separation 1.8mm are found in reflection. Find the thickness of the paper. (04marks).



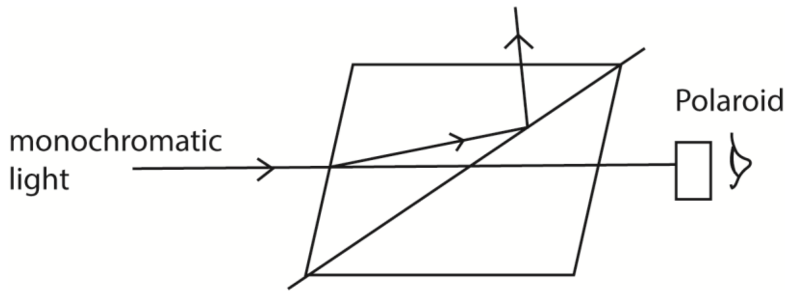
$S = 1.8 \times 18^{-3}$m

$\tan\theta = \frac{\lambda}{2S} = \frac{t}{L}$

$t = \frac{\lambda L}{2S} = \frac{6.0 \times 10^{-7} \times 15 \times 10^{-2}}{2 \times 1.8 \times 10^{-3}} = 2.5 \times 10^{-5}$m

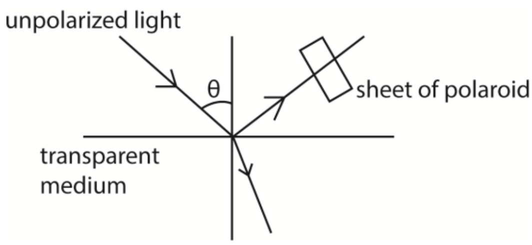
(d) (i) Describe, with aid of a labelled diagram, one method of producing plane polarized light. (04marks)

Solution



- A narrow beam of ordinary light is made incident on nicol prism and viewed through analyzer as shown above
- The angle of incidence is gradually increased or change and at each angle, the polaroid is rotated about an axis through its plane.
- At certain angle of incidence, light is completely extinguished
- At this point, the emergent light is plane polarized.

Or



- A narrow beam of unpolarized light is made incident on transparent medium.
- The reflected light is observed through a Polaroid.
- The angle of incidence is varied
- At each angle of incidence, the polaroid is rotated about the axis along the light incident on it
- At one angle of incidence, the light gets cut off the observer as the Polaroid is rotated.
- The reflected ray is now completely polarized.

(v) State two uses of polarized light. (01mark)

- Determination of sugar concentration
- Stress analysis in some materials like glass

SECTION B

5. (a) Define:

(i) The tesla (01mark)

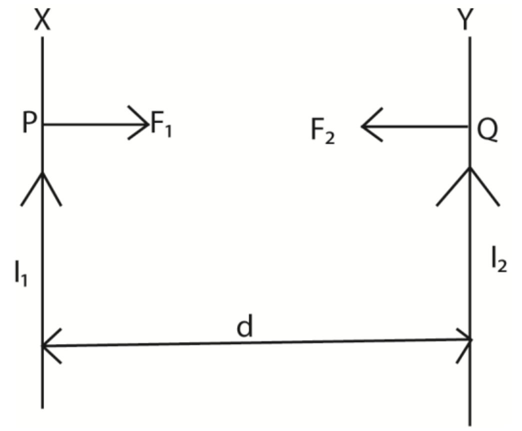
A tesla (1 T) is defined as the magnetic field intensity generating one newton (N) of force per ampere (A) of current per meter of conductor:

(ii) Magnetic flux (01mark)

Magnetic flux is the product of the magnitude of the magnetic flux density and the area perpendicular to the magnetic field.

(b) Two infinitely long straight wire currying currents, I_1 and I_2 respectively are placed parallel to each other in a vacuum at a distance, d, meters apart. Derive an expression for the force per meter between the wires. (05marks)

Consider two infinitely long parallel wires X and Y carrying currents I_1 and I_2 respectively. The conductors are separated by a distance, d.



Magnitude of magnetic flux density, B_1 at any point, Say Q on Y due to the current in Q is given by $B_1 = \frac{\mu_0 I_1}{2\pi d}$

Force acting per meter length of Y $= B_1 I_2$

$$= \frac{\mu_0 I_1 I_2}{2\pi d}$$

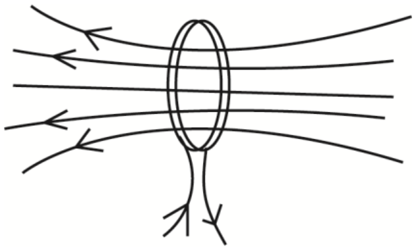
Magnitude of magnetic flux density, B_1 at any point, Say Q on Y due to the current in Q is given by $B_2 = \frac{\mu_0 I_2}{2\pi d}$

Force acting per meter length of X = $B_2 I_1$

$$= \frac{\mu_0 I_1 I_2}{2\pi d}$$

Hence $F_1 = F_2 = \frac{\mu_0 I_1 I_2}{2\pi d}$

(c)(i) Sketch the magnetic field pattern due to a current flowing in a circular coil. (02mark)



(ii) Write an expression for magnetic field flux density, B, at the center of circular coil of N turns of radius, r, and carrying a current I (01 mark)

$B = \frac{\mu_0 NI}{2r}$

(iii) A wire of length 7.85m is wound into a circular coil, find the magnetic flux density at the center of the coil of radius 0.05m. If the current of 2A passes through the coil, find the magnetic flux density at the center of the coil. (04marks)

Solution

Number of turns, $N = \frac{lenght\ of\ wire}{circumfrence\ of\ each\ turn}$

$= \frac{L}{2\pi r} = \frac{7.85}{2\pi \ x\ 0.05} = 25$ turns

But $B = \frac{\mu_0 NI}{2r} = \frac{4\pi \ x\ 10^{-7}\ x\ 25\ x\ 2}{2\ x\ 0.05} = 6.28 \times 10^{-4}$T

(d) (i) Explain the term back e.m.f in a d.c motor. (02mark)

As the motor rotates the magnetic field, the flux linking changes. This induces an e.mf in the coil. The e.m.f acts in opposition to applied voltage, hence back e.m.f

(ii) Show how the back e.m.f in a motor is related to efficiency of motor (04marks)

Suppose E_b, V, and r are the magnitudes of back e.m.f, applied p.d and total resistance respectively.

If I is the current flowing, the power supplied = $VI = I^2R + IE_b$

IE_b is the rate at which the motor does mechanical work, I^2r is the power dissipated in the coil and VI is the power supplied by the motor.

Efficiency of the motor, $\eta = \frac{Mechanical\ power\ got}{Power\ supplied}\ x\ 100\%$

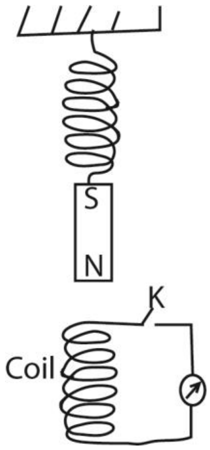
$= \frac{IE_b}{VI}\ x\ 100\%$

$= \frac{E_b}{V}\ x\ 100\%$

6. (a)(i) Define the terms amplitude and root mean square (r.m.s) value of an alternating current. (02amrks)

Amplitude of an alternating current is the maximum value of alternating current.
Root mean square value of an alternating current is the value of steady current that dissipates heat at the same rate as alternating current.

(b)



A small magnet is attached to a spring as shown above. Switch, K is closed and the magnet is displaced downwards slightly and released to oscillate vertically. Explain

(i) The observation made (03marks)

The galvanometer deflects in one direction when the magnet approaches the coil and deflects in opposite direction when it recedes.

This is because as the magnet moves toward the coil, the flux linking it changes and e.m.f is induced in the coil. Since the circuit is complete, current flows in the direction of the induced e.m.f.

As the magnet moves away from the coil, an e.m.f is induced in the opposite direction.

(ii) Why the magnet takes long to come to rest when K is opened (03marks)

When the switch is open, there will be no flow of induced current that would cause an opposing magnetic field that produce electromagnetic damping. Consequently, the oscillation take long to stop.

(c) A sinusoidal voltage of r.m.s value 10V is supplied across a 50μF capacitor.

(i) Find the peak value of the charge on the capacitor. (02marks)

From Q = CV

⇨ $Q = CV_0 \sin \omega t = Q_0 sin\omega t$

Where Q0 = CV_0

So the peak value of charge, $Q_0 = CV_0$

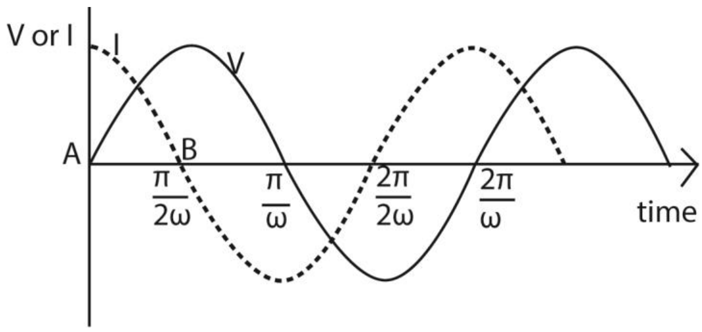
$= CV_{r.m.s}\sqrt{2}$

= 50 x 10-6 x 10 x $\sqrt{2}$

= 7.07×10^{-4}C

(ii) Draw a sketch graph of charge Q on the capacitor against time. (01mark)

(iii) Draw on the same sketch in (c)(i) a graph of voltage against time. (01mark)



Explanation

The current I through (not across) a capacitor is C $\frac{dV}{dt}$. This is the slope of the voltage.

When a capacitor is connected to an AC voltage (at the zero crossing) the maximum current flow will occur immediately, i.e. t = 0,$\frac{dV}{dt}$ will approach infinity instantly and then repeat as a sinusoidal waveform.

There will be a peak current at every zero crossing of the voltage waveform. The current waveform will lead the voltage waveform 90 degrees.

(iv) If the a.c supply has a frequency of 50Hz, calculate the r.m.s value of the current through the capacitor. (04marks)

Solution

Capacitive resistance = $\frac{V_{r.m.s}}{I_{r.m.s}}$

$I_{r.m.s} = \frac{V_{r.m.s}}{X_C}$ ………………………………… (i)

Also, $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \, x 50 \, x \, (50 \, x \, 10^{-6})}$ =63.66Ω

Thus, $I_{r.m.s} = \frac{10}{63.66}$ = 0.15A

7. (a) (i) Distinguish between self-induction and mutual induction (02marks)

Self-induction is a type of electromagnetic induction where by an e.m.f is induced in a coil due to change in the current flowing in the same coil.
Mutual induction is a type of electromagnetic induction where by change in current in one coil or induces e.m.f in the neighboring coil or circuit.

(ii) An aired cored inductor is connected in series with a switch and d.c. source. The switch is closed and left for some time. Explain why a spark is observed across the switch contacts when the switch is reopened. (03marks)

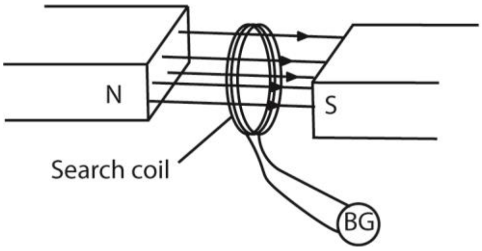
When the switch is opened, the falling current causes a change in the magnetic flux linking the inductor coil.

A change in the magnetic flux linking the coil, induce a large e.m.f in the circuit and leads to high the electric field intensity between the contact points causing ionization of gases.

When the oppositely charged ions collide, a spark is produced.

(b) Describe, with the aid of a diagram, how the magnetic flux density between the poles of a strong magnet can be measured. (06marks)

Solution



A search coil is connected in series with a ballistic galvanometer, B.G and a resistor.
The search coil is placed between the poles pieces of the magnet with its plane normal to the magnetic field.
When the ballistic galvanometer pointer settles, the coil is completely withdrawn from the field and the first deflection θ of the B.G is noted.
A capacitor of known capacitance C is charged to a p.d V and then discharged through the ballistic galvanometer and the corresponding θ' is noted.
The magnetic flux density B is now calculated from B = $\frac{CVR\theta}{NA\theta'}$ where A is the area of the coil, N is the number of turns in the coil and R is the resistance of the coil circuit.

(c)(i) Explain how eddy currents can be produced. (02marks)

Eddy currents are currents induced in a conductor moving across magnetic field; these currents oppose the motion of a solid conductor.

When a piece of metal moves in a magnetic field, a force acts on delocalized electrons in accordance with Fleming's left hand rule. The electrons deficient atoms also attract electrons from other atoms. This movement of electrons cause current loops that are called Eddy currents.

(iii) Explain the application of eddy currents. (03marks)

- Damping a 'galvanometer. In the galvanometer the coil is wound on a metal former. Eddy currents in the metal slow down the turning of the coil towards its eventual position, and also suppress its swings about that position; in the end the coil comes to rest sooner than if it were not damped.
- Cause overheating in dynamos and motors damaging the insulation of windings.
- Speedometer
- Electric brakes

(d) A coil of 500 turns and mean area 4.0 x $10^{-2}m^2$ is rotated at a uniform rate of 600 revolution per minute about an axis perpendicular to a uniform magnetic field of flux density 0.2T. Calculate the maximum value of the e.m.f induced in the coil. (04marks).

E = BANωsinωt

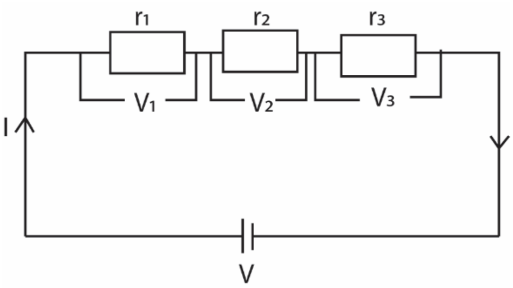
E_{max} = BANω

But ω = $\frac{2\pi \; x \; 600}{60}$ = 20π $rads^{-1}$

∴ E = 0.2 x 4.0 x 10^{-2} x 500 x 20π = 251.3V

SECTION C

8. (a) (i) Derive the formula for combined resistance of three resistors in series. (04marks)



For series arrangement, the same current I flows through the resistors but each resistor has its own P.d. across

For r_1, $V_1 = r_1I$ .... (i)

For r_2, $V_2 = r_2I$ .... (ii)

For r_3, $V_3 = r_3I$ .... (iii)

$V = V_1 + V_2 + V_3$

$= r_1I + r_2I + r_3I$

$= I(r_1 + r_2 + r_3)$

Resultant resistance, R = $\frac{V}{I}$ = $(r_1 + r_2 + r_3)$

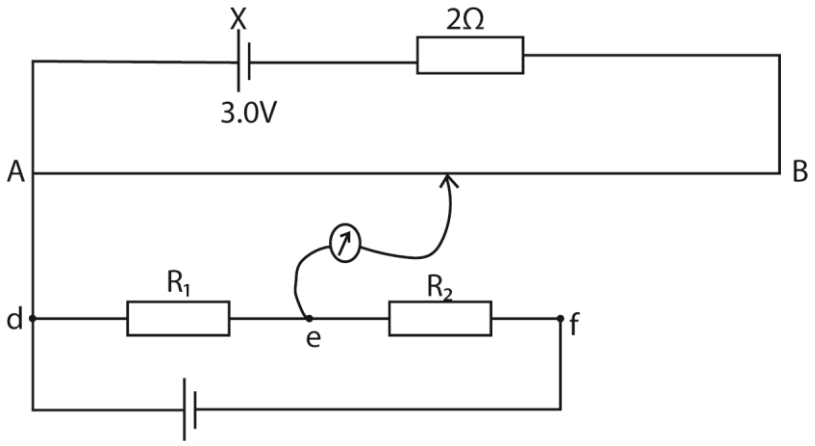
(ii) Explain why a metal wire becomes hot when an electric current flows through it. (04marks)

Electrons are accelerated by the electric field in the conductor. As they drive, the collide with ions in the conductor losing some of their kinetic energy to the ions, this energy increases vibrational energy of the ions, hence temperature increases

(i) What advantage does the potentiometer have over Wheatstone bridge when used to compare two low resistances? (02marks)

The potentiometer gives accurate balance lengths for low resistance because resistances of conducting wires do not affect the results. For the Wheatstone bridge, the resistance of its end connection become significant when used to compare low resistances, which makes it less accurate.

(b)



In the figure above, AB is a slide wire of length 1.0m and resistance 10Ω. X is a driver cell of e.m.f 3.0V and negligible internal resistance. When the center –zero galvanometer is connected in turns to points e and f, the balance lengths obtained are 45.0cm and 80.0cm respectively.

Calculate the

(i) The current flowing through R_1. (04marks)

If the current through the driver circuit and R_1 is I_d and I_1 respectively, it follows that

$IR_1 = I_dR$

At e, R = $\frac{45}{100}\ x\ 10 = 4.5\Omega$

$I_d = \frac{3}{10+2} = 0.25A$

$I_1R_1 = 0.25 \times 4.5 = 1.125$

$I_1 = \frac{1.125}{R_1}$

(ii) Resistances of R_1 and R_2. (02marks)

When at f

$I_1(R_1 + R_2) = I_d\left(\frac{80}{100}\ x\ 10\right) = 0.25 \times 8\ = 2$

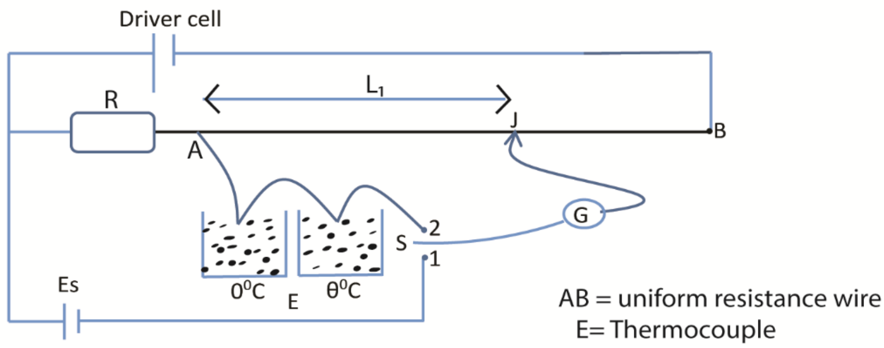
$\therefore\ I_1(R_1 + R_2) = 2$………………. (i)

Also $I_1R_1 = 1.125$ ……………. (ii)

From Eqn. (i) and (ii)

$\frac{R_1}{R_1 + R_2} = \frac{1.125}{2} = \frac{9}{16}$

(c) Describe with aid of a diagram, how a calibrated slide wire potentiometer may be used to measure thermoelectric e.m.f. (04marks)



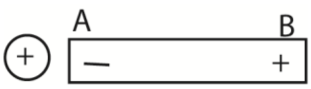
- With switch S in position 1, J is moved along AB until the galvanometer G shows no deflection. The balancing length L_1 is noted
- With switch S in position 2, J is moved along AB until the galvanometer G shows no deflection. The balancing length L_2 is noted
- The e.m.f of the thermocouple is $E = IkL_2$

  While $E_S = I(kL_1 + R)$

  $\therefore E = \frac{E_S k L_2}{R + kL_1}$ where k is the resistance per cm of the uniform resistance wire

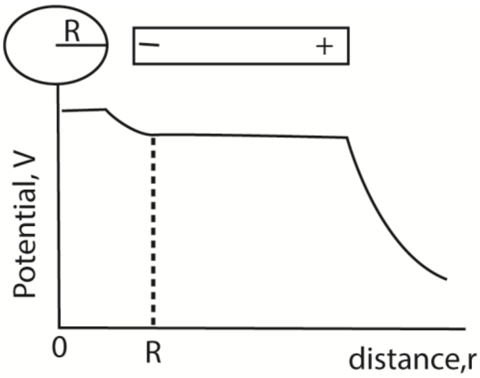
9. (a) Explain why a redistribution of charge occurs on uncharged metal rod when a positively charged metal sphere is brought near one end (03marks)

When a positively charged metal sphere is brought close to an uncharged rod, say AB as shown below; delocalized electrons in metallic lattice of the rod are electrostatically attracted by the sphere and move towards A

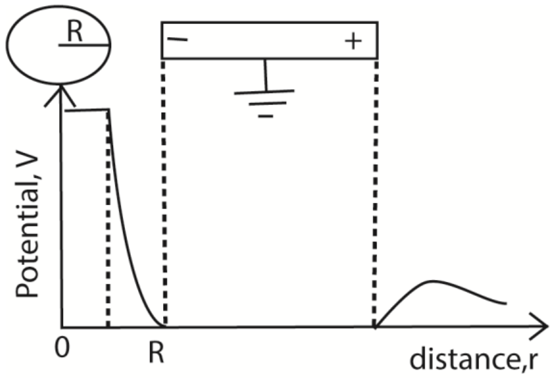


(b) Sketch a graph showing the variation of potential

(i) Relative to the earth along the axis of metal rod in (a) from the center of the charged sphere to the furthest end of the rod. (02marks)



(ii) along the axis of the rod in (a) from the center of the sphere if the rod is earthed. (02marks)



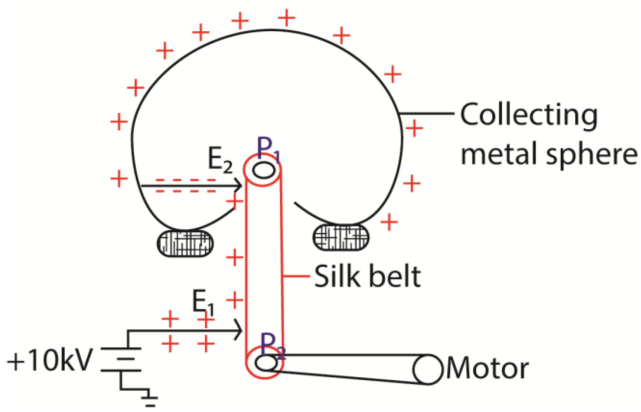
When the rod is earthed, t gets zero potential (potential of the earth)

(c) Explain why the electric field intensity close to the surface of a charged conductor is always at right angles to the surface of the conductor. (03marks)

The surface of a charged body is an equipotential surface. Therefore when the charge moves on the surface of the conductor, no energy change occurs hence no work is done. This implies that the component of the force due to the electric field along the surface of the conductor is zero. Hence the electric field lines are perpendicular to the surface of the conductor.

(d) Describe with the aid of a diagram the mode of operation of Van de Graff generator. (006marks)

Van der Graff generator



Main features

a. It consists of a large hollow metal sphere (collecting sphere) supported on insulating stand.

b. A silk belt inside the tube driven by an electric motor possesses the sharply pointed electrode metal E_1, held at electric potential of about 10kV relative to the earth.

c. As the belt moves up, it passes another sharply pointed metal electrode E_2 connected inside the hollow sphere.

Mode of operation

(i) The metal rod E_1, is kept at a high positive potential of about 10kV with respect to the earth.

(ii) The high positive charge at the sharp ends ionizes the air around.

(iii) The positive ions are repelled to the silk belt carries then towards the collecting sphere.

(iv) At E_2, the silk belt induces negative charges on the sharp ends of E_1 and the positive charges on the outer of the sphere. The electric field at point ends E_2 ionizes the air around it.

(v) The negatively charged ions are repelled to the silk belt which is carrying positively charged ions

(vi) The positive ions are neutralized before passing over the upper pulley P_1.

(vii) The process of silk belt charging up and discharging is repeated many times per second and each time the belt passes, the sphere charges up positively until it has electric it has electric potential of about 10^6V relative to the earth.

(e) Explain how two insulating bodies rubbed together acquire charge.

When two dissimilar insulators are rubbed together, heat is generated due to friction. Heat cause a material of lower function to lose electron to the other. The material that loses electrons becomes positively charged while the one that accepts electron becomes negatively charge.

(e) A proton is fired from infinity with a speed of 3.7 x 10^6ms^{-1} towards a stationary charge of
+50e. Calculate the speed of the proton at a point 10^{12}m from stationary charge. (Assume mass of proton = 1.6 x 10^{-27}kg) (04marks)

Initial kinetic energy = Electric potential energy gained + Final K.E

$$\frac{1}{2}m_p u_p^2 = \frac{e\ x\ 50e}{4\pi\varepsilon_0 r} + \frac{1}{2}m_p v_p^2$$

$$\frac{1}{2}\ x\ 1.67\ x\ 10^{-27}\ x\ (3.7\ x\ 10^6)^2 = \frac{9\ x\ 10^9\ x\ (1.6\ x\ 10^{-19})^2 x\ 50}{10^{-12}} + \frac{1}{2}\ x\ 1.67\ x\ 10^{-27}\ x\ (v_p)^2$$

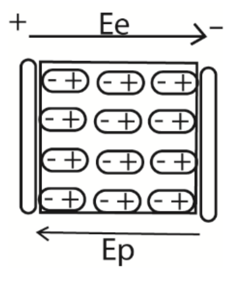
$$V_p^2 = -1.064\ x\ 10^{11}$$

v_p has no real roots.

10. (a)(i) What is meant by a dielectric material? (01marks)

A dielectric material is an electrical insulator that can be polarized by an applied electric field

(ii) Explain the effect of a dielectric on the capacitance of a capacitor. (05marks)



When a dielectric is placed between the plates of a charged capacitor, the nucleus of the molecules of the dielectric are urged in the direction of the field and the electrons in opposite direction.

The molecules get polarized and the surface of the dielectric near the capacitor develops charges opposite to those on adjacent plates while the charges inside the dielectric cancel out.

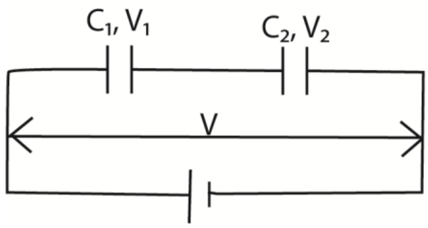
Since the charge on the dielectric are not conductible, electric field intensity develops between the surfaces of the dielectric in the direction opposite to the supplied field. The resultant electric field intensity is thus reduced.

But E = $\frac{V}{d}$ hence the p.d between the plates V is reduced.

From C = $\frac{Q}{V}$; a reduction in A leads to increase in C

(b) Two capacitors of capacitances, C_1 and C_2, are connected in series with a battery of e.m.f, V. Show that the p.d, V_1 across the capacitor of capacitance, C_1 is given by

$V_1 = \left(\frac{C_2}{C_1 + C_2}\right)V$ (04marks)



If the charge on each capacitor is Q, then the total p.d across the network,

$V = V_1 + V_2$

$= \frac{Q}{C_1} + \frac{Q}{C_2}$

$= Q\left(\frac{1}{C_1} + \frac{1}{C_2}\right)$

$= Q\frac{C_2 + C_1}{C_1 C_2}$

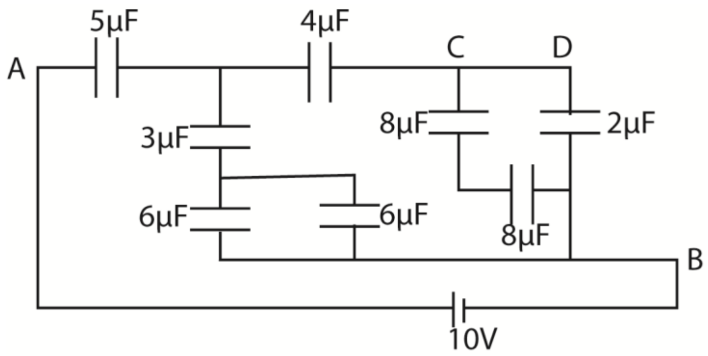
$Q = \frac{C_1 C_2}{C_1 + C_2}V$

Also, $Q = C_1 V_1$

Then $C_1 V_1 = \frac{C_1 C_2}{C_1 + C_2}V$

$V_1 = \left(\frac{C_2}{C_1 + C_2}\right)V$

(c) The figure below shows a network of capacitors connected to a 10V battery. Calculate the total energy stored in the network. (06marks)



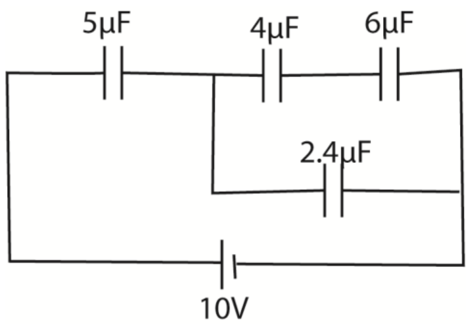
The two 8μF capacitor are in series, therefore their effective capacitance, $C_1 = \frac{8 \, x \, 8}{8+8} = 4\mu F$

The two 6μF capacitors are in parallel and their effective capacitance, C_2 = 6 + 6 = 12μF

C_2 and 3μF capacitors are in series and their effective capacitance $C_3 = \frac{12 \, x \, 3}{12+3} = 2.4\mu F$

C1 and 2μF capacitors are in parallel, their effective capacitance C_4 =2 +6 =6μF

The diagram can be summarized as follows

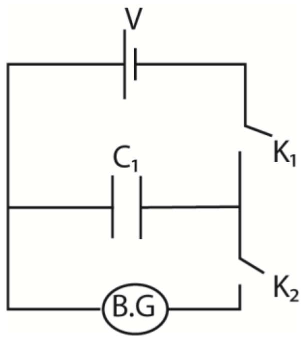


The effective capacitance of 2μF, 4μF and 6μF = $\left(\frac{4 \, x \, 6}{4+6} + 2.4\right) \mu F = 4.8\mu F$

Effective capacitance between 5μF and 4.8μF = $\frac{5 \, x \, 4.8}{5+4.8} = 2.45\mu F$

Energy stored in the network, E = $\frac{1}{2}CV^2 = \frac{1}{2} \, x \, 2.45 \, x \, 10^{-6} x \, 10^2$ = 1.225 x 10^{-4}J

(d) Describe how the unknown capacitance of a capacitor can be determined using a ballistic galvanometer



- The circuit is connected as shown with a capacitor of known capacitance C_1.
- Switch K_1 is closed and K_2 is opened. The capacitor of capacitance C_1 is charged by the battery of e.m.f V.
- K_1 is opened and K_2 is closed to discharge the capacitor through the ballistic galvanometer, B.G. the first deflectionof the B.G θ_1 is noted
- The capacitor is then is then replaced with the capacitor of unknown capacitance C_2.the experiement is repeated and deflection θ_2 is noted
- Hence $\frac{c_2}{c_1} = \frac{\theta_2}{\theta_1}; c_2 = c_1\frac{\theta_2}{\theta_1}$