SP015 NOTES

Chapter 1: Physical Quantities & Measurement

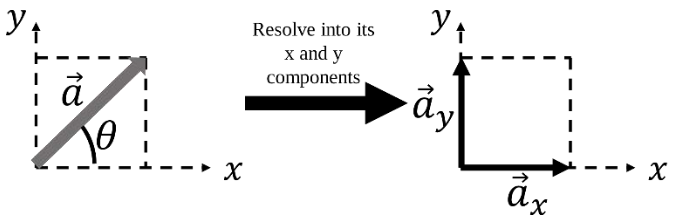
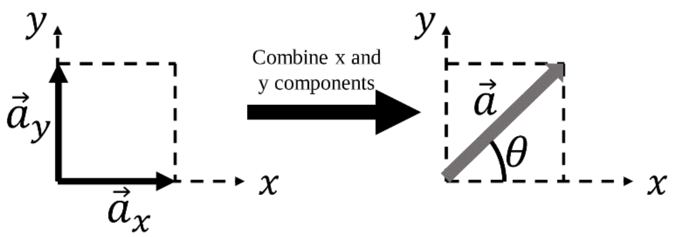
Dimensions = physical nature of a quantity
The statement "Dimension of quantity x is length" can be written as $[x] = L$

Homogeneity ⇒ "same kind"
Consider

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

On the LHS, s has dimension of length and SI unit of metres.
On the RHS, ut and $\frac{1}{2}at^2$ also has a dimension of length and SI unit of metres.
Since both sides has the same dimensions, we call this equation to be **homogeneous**.

Term	**Definition**
Scalar Quantity	A quantity of only magnitude
Vector Quantity	A quantity of both magnitude **and** direction

<table>
<tr><th colspan="2">Vector Resolution & Combination of Vectors</th></tr>
<tr><td>
</td><td>$|\vec{a}_x| = |\vec{a}| \cos\theta$
$|\vec{a}_y| = |\vec{a}| \sin\theta$</td></tr>
<tr><td>
</td><td>$\vec{a} = \sqrt{|\vec{a}_x|^2 + |\vec{a}_y|^2}$
$tan^{-1} = \frac{|\vec{a}_y|}{|\vec{a}_x|}$</td></tr>
</table>

Significant figures

Rules	Number	No of significant figure
1) All non-zero digits are significant.	5	1
	12	2
	132	3
2) All zeros that occur between any two non-zero digits are significant.	505	3
	500.5	4
3) All zeros that are on the right of a decimal point and also to the left of a non- zero digit is never significant.	0.00871	3
	250	2
4) All zeros that are on the right of a decimal point are significant, only if, a non-zero digit does not follow them.	20.00	4
	500.60	5
5) All the zeros that are on the right of the last non-zero digit, after the decimal point, are significant.	0.05	1
	0.0500	3
6) All the zeros that are on the right of the last non-zero digit are significant if they come from a measurement.	500	1
	500.	3

Rules	Operation	No of significant figure
7) Addition/Subtraction - The result has the same number of decimal places as the least precise measurement used in the calculation.	$82.2 + 12 - 12.585 = 82$	2
8) Multiplication/Division - Number of significant figures in the result is the same as the least precise measurement in the least precise measurement used in the calculation.	$\frac{2.5(3.15)}{2.315} = 3.4$	2
9) Logarithms - Keep as many significant figures to the right of the decimal point as they are significant in the original number.	$ln(4.00) = 1.39$	3
	$e^{0.0245} = 1.03$	2

From Lab Manual
https://www.geol.lsu.edu/jlorenzo/geophysics/uncertainties/Uncertaintiespart2.html
In considering combination of uncertainties, one may consider maximum uncertainty, the rules of which are:

a) For addition and subtraction,
$$x = a \pm b \Rightarrow \Delta x = \Delta a + \Delta b$$
b) For multiplication with a constant *k*,
$$x = ka \Rightarrow \Delta x = k\,\Delta a$$
c) For multiplication or divisions between variables,
$$x = \frac{ab}{c} \Rightarrow \frac{\Delta x}{x} = \left(\frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}\right)$$
d) For exponentials where *n* is a constant,
$$x = a^n \Rightarrow \frac{\Delta x}{x} = n\left(\frac{\Delta a}{a}\right)$$

Uncertainties for Linear Graphs ($y = mx + c$)

Gradient	$$\Delta m = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{(n-2)\sum_{i=1}^{n}(x_i - \bar{x})^2}}$$
y-intercept	$$\Delta c = \sqrt{\frac{1}{n-2}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2\left(\frac{1}{n} + \frac{\bar{x}^2}{\sum_{i=1}^{n}(x_i - \bar{x})^2}\right)}$$

Plotting a linear graph

5.4.2 Procedure to draw a straight line graph and to determine its gradient with its uncertainty

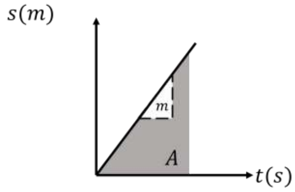
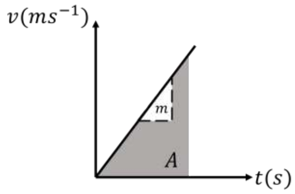
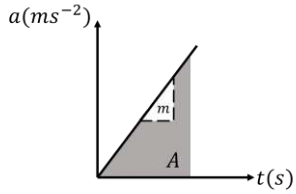
(a) Choose appropriate scales to use at least 80% of the sectional paper. Draw, label, mark the two axes, and give the units. Avoid using scales of 3, 7, 9, and the likes or any multiple of them. Doing so will cause difficulty in plotting the points later on.

(b) Plot all points clearly with ×. At this stage you can see the pattern of the distribution of the graph points. If there is a point which is clearly too far-off from the rest, it is necessary to repeat the measurement or omit it.

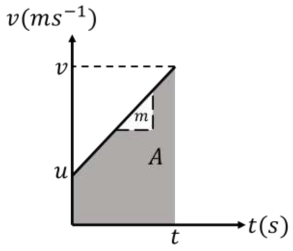
(c) Calculate the centroid and plot it on the graph.

Chapter 2: Kinematics of Motion

Terms	Definitions
Instantaneous velocity (or acceleration)	Velocity (or acceleration) at a specific instant of time
Average velocity (or acceleration)	Velocity (or acceleration) over 2 points in time.
Uniform velocity (or acceleration)	Constant velocity (or acceleration)

Type of Graph	Displacement-time graph	Velocity-time graph	Acceleration-time graph
			
Gradient represents	Velocity	Acceleration	Nothing
Area under graph represents	Nothing	Displacement	Velocity

Equations of Motion with Constant Acceleration

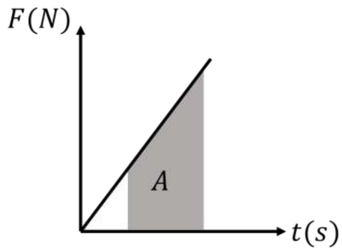
By definition, $$a = \frac{v-u}{t}$$	$v = u + at - - - [1]$
Consider area under velocity time graph, 	$s = \frac{(u+v)t}{2} - - - [2]$
Substitute [1] into [2]	$s = ut + \frac{1}{2}at^2 - - - [3]$
Rearranging for t for [1], $$t = \frac{v-u}{a}$$ Substitute into [2]	$v^2 = u^2 + 2as - - - [4]$

Projectile Motion

x-direction	y-direction
$a_x = 0$	$a_y = -g$
$v_x = u_x$	$v_y = u_y - gt$
$s_x = u_x t$	$s_y = u_y t - \frac{1}{2} g t^2$
$v_x^2 = u_x^2$	$v_y^2 = u_y^2 - 2g s_y$
$v^2 = v_x^2 + v_y^2$	
$tan(\theta) = \frac{v_y}{v_x}$	
Max height ⇒ $v_y = 0$	
Range ⇒ $s_y = 0$	

Chapter 3: Dynamics of Motion

Momentum & Impulse

<table>
<tr><td>Variable</td><td>Definition/ Note</td><td rowspan="4">
</td></tr>
<tr><td>Momentum</td><td>Product of mass and velocity, $p = mv$
SI Unit: $kg\, ms^{-1}$</td></tr>
<tr><td>Impulse</td><td>Change in momentum, $J = \Delta p \;=\; mv - mu$
Newton's 2nd Law, $F = \frac{\Delta p}{\Delta t} \Rightarrow \Delta p \;= F\Delta t \;= J$
SI Unit: $kg\, ms^{-1}$</td></tr>
<tr><td>Area under $F - t$ graph</td><td>Impulse</td></tr>
</table>

Conservation of Momentum

<table>
<tr><td>Statement of Conservation Law</td><td>$\Delta(\Sigma p) = 0$
$\Sigma p_f \;= \Sigma p_i$</td></tr>
<tr><td>In 1 dimension</td><td>$\Sigma p_f \;= \Sigma p_i$
$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$</td></tr>
<tr><td>In 2 dimensions</td><td>
<table>
<tr><td>x-component</td><td>y-component</td></tr>
<tr><td>$\Sigma p_{f-x} = \Sigma p_{i-x}$
$m_1u_{1-x} + m_2u_{2-x} = m_1v_{1-x} + m_2v_{2-x}$</td><td>$\Sigma p_{f-y} = \Sigma p_{i-y}$
$m_1u_{1-y} + m_2u_{2-y} = m_1v_{1-y} + m_2v_{2-y}$</td></tr>
<tr><td colspan="2">Pythagoras's Theorem reminder
$p^2 \;= p_x^2 + p_y^2$
Trig Functions
$tan\,(\theta) = \frac{p_y}{p_x};\, sin\,(\theta) = \frac{p_y}{p};\, cos\,(\theta) = \frac{p_x}{p}$</td></tr>
</table>
</td></tr>
<tr><td>Types of Collision</td><td>
<table>
<tr><td>Elastic Collisions</td><td>Inelastic Collisions</td></tr>
<tr><td>$\Delta(\Sigma K) = 0$</td><td>$\Delta(\Sigma K) \neq 0$</td></tr>
</table>
</td></tr>
</table>

Forces & Free Body Diagrams

Forces	Equation, Sources & Direction
Weight (a.k.a gravitational force), W	$W = mg$ **Source:** Gravitational pull **Direction:** Toward gravitational source
Tension, T	**Source:** Force acting along string/rope/cable **Direction:** Away from the point mass along the string/cable/rope
Normal Force, N	**Source:** A support force through surface contact **Direction:** Perpendicular to the surface in contact
Frictional Force, f	$f = \mu N$ **Source:** Rough surfaces **Direction:** Opposing the direction of motion of the point mass

Types of frictional force:

a. Static friction – friction keeping the body at rest/stationary, $f_s = \mu_s N$
b. Kinetic friction – friction experienced by the body when it has relative motion to the surface in contact, $f_k = \mu_k N$

Relationship:

$$f_s > f_k$$

Newton's Laws of Motion

Law	Description
First Law of Motion	$\Sigma F = 0$, $\Sigma F_x = 0$, $\Sigma F_y = 0$ if $F_{external} = 0$
Second Law of Motion	$F_{net} \propto \frac{dp}{dt}$ Reminder that for 2 dimensions, $F_{net}^2 = F_x^2 + F_y^2$ where $F_x = ma_x;\ F_y = ma_y$
Third Law of Motion	$\vec{F}_{12} = -\vec{F}_{21}$

Chapter 4: Work, Energy and Power

Variables	Definition/ Equations	Units
Work	Scalar product between force and displacement due to said force. $$W = \vec{F} \cdot \vec{s} = \lvert\vec{F}\rvert\lvert\vec{s}\rvert \cos\theta_{\vec{F}\,\vec{s}}$$	$kg\,m^2 s^{-2}$ Nm $Joule$
Gravitational Potential Energy	Energy stored in a body to due its position in a gravitational field $$U_{gp} = mgh$$	
Elastic Potential Energy	Energy stored in a deformed elastic body $$U_{ep} = \frac{1}{2}kx^2 = \frac{1}{2}Fx$$ Represented by the area under the $F - x$ graph.	
Kinetic Energy	Energy of a moving body $$K = \frac{1}{2}mv^2$$	
Power	Rate of work done. $$P_{ave} = \frac{dW}{dt} = \frac{\Delta E}{\Delta t}$$ $$P_{inst} = \vec{F} \cdot \vec{v}$$	Js^{-1} $Watt$

Theorem/Conservation Law

Law	Statement
Mechanical Energy Conservation	$\Delta(\Sigma E) = 0 \Rightarrow \Sigma E_{final} = \Sigma E_{initial}$
Work-Energy Theorem	$W = \Delta \mathrm{E}$

Chapter 5: Circular Motion

Variables	Definitions	Equations/ Units
Angular Displacements, θ	the angle through which a rigid object rotates about a fixed axis	Radians $[rad]$
Period, T	Time taken for 1 complete rotation	$T = f^{-1}$ Seconds $[s]$
Frequency, f	Number of complete rotation per unit time	Hertz [Hz] = $\left[\frac{1}{s}\right]$
Angular frequency, ω	Rate of change of angular displacement	$\omega = \frac{v}{r} = 2\pi f$ Radians per second $[rad\ s^{-1}]$
Centripetal Acceleration	Centre pointing acceleration vector in a body following a circular path.	$a_c = \frac{v^2}{r} = r\omega^2 = v\omega$ $[ms^{-2}]$
Centripetal Force	Centre pointing acceleration vector in a body following a circular path.	$F_c = ma_c$ [N]

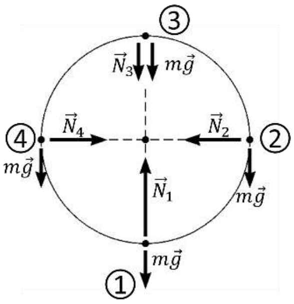
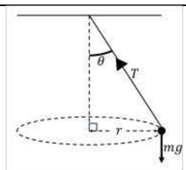
Units

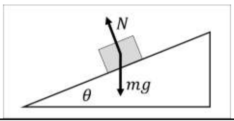
$$360^o = 2\pi\, rad = 1 \text{ revolution/rotation}$$

Uniform Circular Motion

Circular motion in which the body moves in **constant** speed.

3 cases to consider

<table>
<tr><td>Case</td><td>Considerations</td></tr>
<tr><td>All</td><td>$$\Sigma F_{\text{center pointing}} = \frac{mv^2}{r} = ma_c$$</td></tr>
<tr><td>Horizontal</td><td>String
$F_T = \frac{mv^2}{r}$
Road
$F_f = \frac{mv^2}{r} = \mu mg = \frac{mv^2}{r} \Rightarrow v = \sqrt{\mu gr}$</td></tr>
<tr><td>Vertical</td><td>Roller Coaster/String
<table>
<tr><td rowspan="4">
</td><td colspan="2">Roller Coaster/String</td></tr>
<tr><td>$N_1 - mg = \frac{mv_1^2}{r}$</td><td>$N_3 + mg = \frac{mv_3^2}{r}$</td></tr>
<tr><td>$N_2 = \frac{mv_2^2}{r}$</td><td>$N_4 = \frac{mv_4^2}{r}$</td></tr>
<tr><td colspan="2">For strings, simply replace N_i with T_i.</td></tr>
</table></td></tr>
<tr><td>Conical pendulum/ Banked Curve</td><td>
<table>
<tr><td rowspan="3">


</td><td>$T \sin\theta = \frac{mv^2}{r}$</td></tr>
<tr><td>$T \cos\theta = mg$</td></tr>
<tr><td>For banked curve, simply replace T with N.</td></tr>
</table></td></tr>
</table>

Chapter 7: Part 1 – Simple Harmonic Motion (SHM)

SHM is when $a \propto -y$, where a is the acceleration of the body and y is its displacement.

→ $a \propto -y \Rightarrow a = -\omega^2 y$, $y(t) = y_{max}\sin(\omega t)$, $a(t) = -\omega^2 y_{max}\sin(\omega t)$
→ Amplitude, $A = y_{max}$
→ angular frequency = ω
→ time = t

Velocities

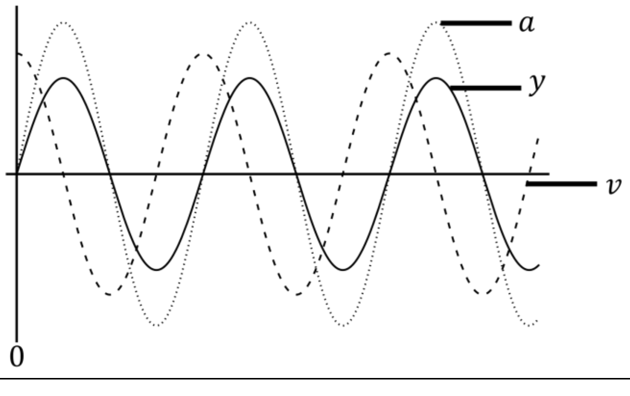
As function of time	As function of displacement
$v(t) = \frac{d}{dt}\,y(t) = \frac{d}{dt}\left(y_{max}\sin(\omega t)\right)$ $v(t) = \omega y_{max}\cos(\omega t)$	$y(t) = y_{max}\sin(\omega t)$ $sin^2 x + cos^2 x = 1$ $\cos(\omega t) = \frac{v}{\omega y_{max}} = \sqrt{1 - \left(\frac{y}{y_{max}}\right)^2}$ $\Rightarrow v(t) = \pm\omega\sqrt{y_{max}^2 - y^2}$

Energies

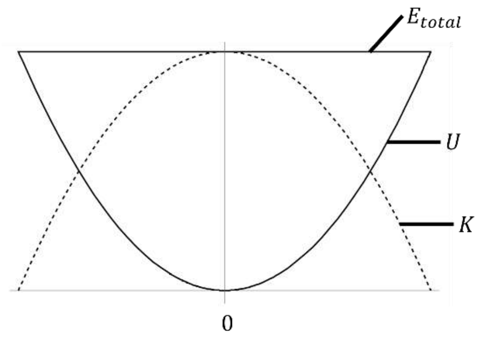
Potential	Kinetic
$ma = -m\omega^2 y = -ky \Rightarrow \mathrm{k} = m\omega^2$ $U = \frac{1}{2}ky^2$ $U = \frac{1}{2}m\omega y^2 = \frac{1}{2}m\omega\left(y_{max}\sin(\omega t)\right)^2$ $\Rightarrow U = \frac{1}{2}m\omega y^2 = \frac{1}{2}m\omega y_{max}^2\sin^2(\omega t)$	$K = \frac{1}{2}mv^2$ $K(t) = \frac{1}{2}m\left(\omega y_{max}\cos(\omega t)\right)^2$ $K(y) = \frac{1}{2}m\left(\omega\sqrt{y_{max}^2 - y^2}\right)^2$ $\Rightarrow K = \frac{1}{2}m\omega^2 y_{max}^2\cos^2(\omega t) = \frac{1}{2}m\omega^2(y_{max}^2 - y^2)$
Total Energies $E_T = U + K$ $E_T = \frac{1}{2}m\omega y^2 + \frac{1}{2}m\omega^2(y_{max}^2 - y^2)$ $\Rightarrow E_T = \frac{1}{2}m\omega^2 y_{max}^2$	

Graphs

Kinematics

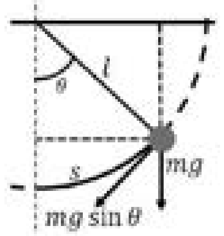


Energies



Cases

Simple Pendulum



Small angle approximation,

$$-mg\sin\theta \approx -mg\left(\frac{s}{l}\right) = ma$$

$$a = -\frac{g}{l}s$$

$$\omega = \frac{2\pi}{T} = \sqrt{\frac{g}{l}}$$

$$\Rightarrow T = 2\pi\sqrt{\frac{l}{g}}$$

Spring System

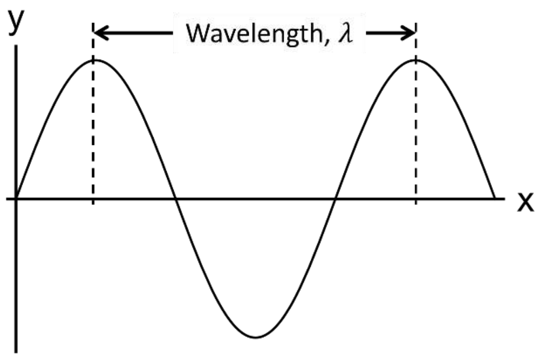
$$F = -kx = ma \Rightarrow a = -\frac{k}{m}x$$

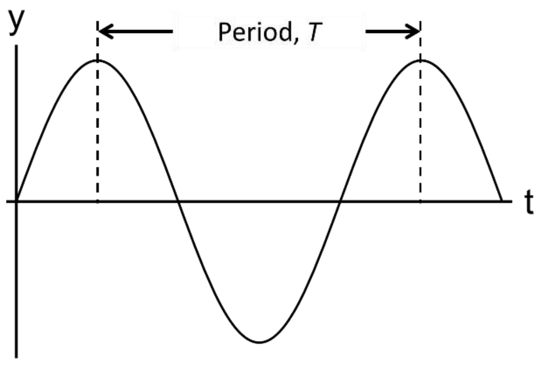
$$\omega = \frac{2\pi}{T} = \sqrt{\frac{k}{m}}$$

$$\Rightarrow T = 2\pi\sqrt{\frac{m}{k}}$$

Chapter 7: Part 2 – Progressive Waves

Wavelength vs Period

<table>
<tr>
<td>


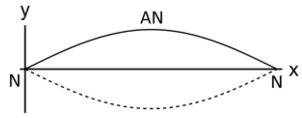
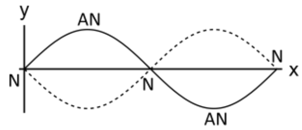
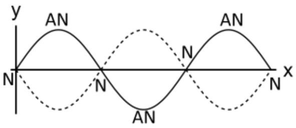
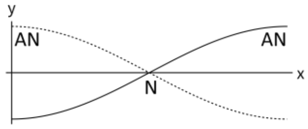
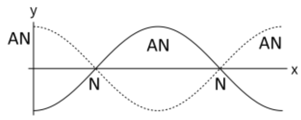
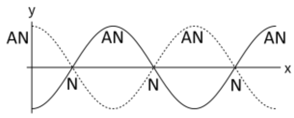
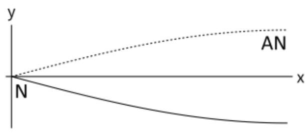
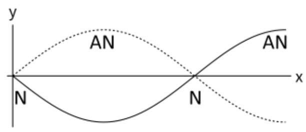
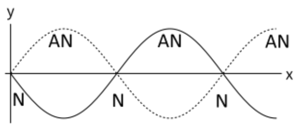
</td>
<td>


</td>
</tr>
<tr>
<td>Wavenumber, $k = \frac{2\pi}{\lambda}$</td>
<td>Frequency, $f = \frac{\omega}{2\pi}$</td>
</tr>
<tr>
<td colspan="2">Wave propagation velocity, $v = f\lambda = \frac{\omega}{k}$</td>
</tr>
</table>

Equations

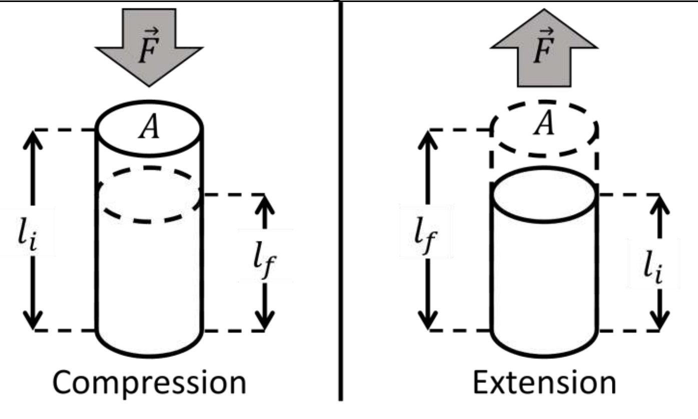
<table>
<tr>
<td>Progressive wave equation</td>
<td>$y(x,t) = A\,sin\,(\omega t \pm kx)$
$+$ if wave travels in $-x$ direction.
$-$ if wave travels in $+x$ direction.</td>
</tr>
<tr>
<td>Particle vibrational velocity</td>
<td>$v = \frac{d}{dt}\big(y(t)\big) = \omega A\,cos\,(\omega t \pm kx)$</td>
</tr>
<tr>
<td>Standing Wave Equation</td>
<td>$y_{total} = y_1 + y_2 = A\,sin\,(\omega t + kx) + A\,sin\,(\omega t - kx)$
$y_{total} = 2A\,cos\,(kx)\,sin\,(\omega t)$</td>
</tr>
</table>

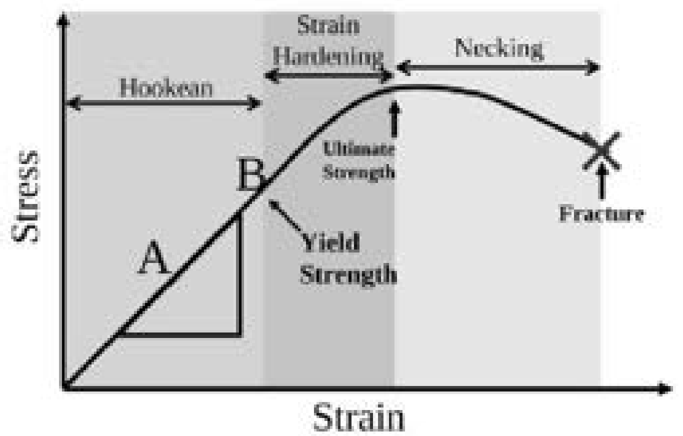
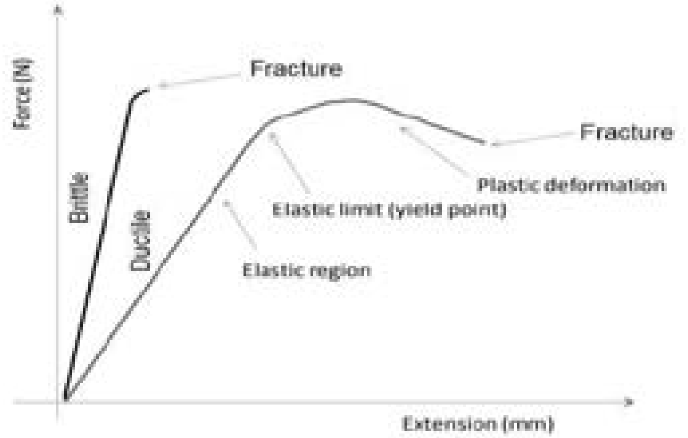
Cases

<table>
<tr><td>Case</td><td>Fundamental Tone</td><td>1st overtone</td><td>2nd overtone</td></tr>
<tr><td rowspan="2">Stretched String
$(v = \sqrt{\frac{T}{\mu}})$</td><td>First Harmonic

Length, L
$\mathrm{v} = \mathrm{f}\lambda = f(2L)$
$f_o = \frac{1}{2L}\left(\sqrt{\frac{T}{\mu}}\right)$</td><td>Second Harmonic

$\mathrm{v} = \mathrm{f}\lambda = f(L)$
$f_1 = \frac{1}{L}\left(\sqrt{\frac{T}{\mu}}\right)$</td><td>Third Harmonic

$f_2 = \frac{3}{2L}\left(\sqrt{\frac{T}{\mu}}\right)$</td></tr>
<tr><td colspan="3">General Equation
$$f_n = \frac{n}{2L}\left(\sqrt{\frac{T}{\mu}}\right), n = \{1, 2,3, \dots\}$$</td></tr>
<tr><td rowspan="2">Open Tube</td><td>First Harmonic

$\mathrm{v}_{\mathrm{sound}} = \mathrm{f}\lambda = f(2L)$
$f_o = \frac{\mathrm{v}_{\mathrm{sound}}}{2L}$</td><td>Second Harmonic

$\mathrm{v}_{\mathrm{sound}} = \mathrm{f}\lambda = f(L)$
$f_1 = \frac{\mathrm{v}_{\mathrm{sound}}}{L}$</td><td>Third Harmonic

$f_2 = \frac{3\mathrm{v}_{\mathrm{sound}}}{2L}$</td></tr>
<tr><td colspan="3">General Equation
$$f_n = \frac{n\mathrm{v}_{\mathrm{sound}}}{2L}, n = \{1, 2,3, \dots\}$$</td></tr>
<tr><td rowspan="2">Closed Tube</td><td>First Harmonic

$\mathrm{v}_{\mathrm{sound}} = \mathrm{f}\lambda = f(4L)$
$f_o = \frac{\mathrm{v}_{\mathrm{sound}}}{4L}$</td><td>Third Harmonic

$\mathrm{v}_{\mathrm{sound}} = \mathrm{f}\lambda = f\left(\frac{4}{3}L\right)$
$f_1 = \frac{3\mathrm{v}_{\mathrm{sound}}}{4L}$</td><td>Fifth Harmonic

$\mathrm{v}_{\mathrm{sound}} = \mathrm{f}\lambda = f\left(\frac{4}{5}L\right)$
$f_1 = \frac{5\mathrm{v}_{\mathrm{sound}}}{4L}$</td></tr>
<tr><td colspan="3">General Equation
$$f_n = \frac{n\mathrm{v}_{\mathrm{sound}}}{4L}, n = \{1, 2,3, \dots\}$$</td></tr>
</table>

Chapter 8: Physics of Matter

Force-Induced Deformation

Definition	Diagram
Stress, $$\delta = \frac{F}{A}$$ Unit: Nm^{-2}	
Strain, $$\varepsilon = \frac{\Delta l}{l_i} = \frac{l_f - l_i}{l_i}$$	
Young's Modulus, $$Y = \frac{\delta}{\varepsilon} = \frac{F}{A}\left(\frac{\Delta l}{l_i}\right)$$ Unit: Nm^{-2}	

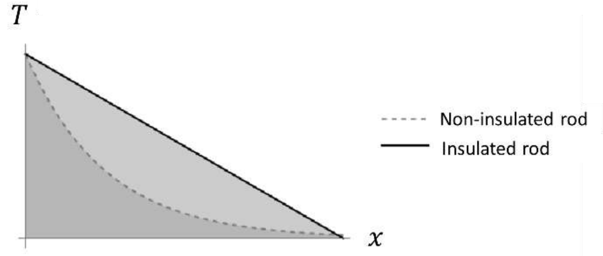
Graph	Description
	Hookean Limit = Yield Strength, The point at which the material will no longer obey Hooke's Law. Between 0 and the Hookean Limit, the type of deformation is known as **elastic deformation**. Beyond Hookean limit, the type of deformation is **plastic deformation.** Peak of stress-strain graph = Ultimate Tensile Strength Necking = dislocation of movements in the crystal structure of the material. Non-existent plastic deformation ⇒ **Brittle** Large plastic deformation region ⇒ **Ductile** Strain Energy ⇒ $U = \frac{1}{2}F\Delta L$ Strain Energy per unit volume ⇒ $\frac{U}{V} = \frac{1}{2}\delta\varepsilon$
	

Heat Transfer

Fourier's Law in 1 Dimension

$$\frac{dQ}{dt} = -A\kappa_x \frac{dT}{dx}$$ $\frac{dQ}{dt}$ = heat energy flow rate, A = cross sectional area, κ_x = coefficient of thermal conductivity in x-axis, $\frac{dT}{dx}$ = temperature gradient along x-axis.

Graphs

	Non-insulated rod does not have a linear drop in temperature because heat energy is able to escape from the sides of rod to the environment. In insulated rods, heat loss through the rod sides are negligible.

Heat-Induced Deformation

Thermal Expansion Equations

Linear	$\Delta L = \alpha L_o \Delta T \Rightarrow L_f = L_o(1 + \alpha\Delta T)$	α = coefficient of linear expansion β = coefficient of linear expansion γ = coefficient of linear expansion **Note:** $\Delta T = 1^oC = 1K$ But $T = 1^oC \neq 1K$
Area	$A_f = L_f^2 = L_o^2(1 + \alpha\Delta T)^2$ $A_f = L_o^2 + 2\alpha L_o^2 \Delta T + \alpha^2 L_o^2 \Delta T^2$ For small ΔT, $\Delta T^2 \approx 0$, $A_f = A_o + 2\alpha A_o \Delta T$ $\Rightarrow \Delta A = \beta A_o \Delta T$ Where $\beta = 2\alpha$	
Volume	$\Delta V = \gamma V_o \Delta T$ Where $\gamma = 3\alpha$	

Chapter 9: Kinetic Theory of Gases & Thermodynamics

Kinetic Theory of Gases

Foundational Assumption:
Gas is composed of large numbers of **non-null mass point-like particles** that obeys **Newton's laws of motion** and interact **elastically** with each other where the average kinetic energy of the gas particles depends solely on the absolute temperature of the gas particle system.

Conversions & Constants

$1u = 1a.m.u. = 1.660539 \times 10^{-27} kg$
$N_A = 6.022 \times 10^{23}$ particles per mole
$k_B = 1.38 \times 10^{-23} JK^{-1}$ per particle

Macroscopic Equations

$pV = nRT$	$pV = Nk_BT$

Variables	**Unit**	**Variables**	**Unit**	**Variables**	**Unit**
p	Pa	N	particles	R	$Jmol^{-1}K^{-1}$
V	m^3	n	Mol	T	K

Microscopic Equations

$$v_{rms} = \sqrt{\overline{v^2}} = \sqrt{\frac{3k_BT}{m}} = \sqrt{\frac{3RT}{m_{molar}}}$$

$pV = \frac{1}{3}Nmv_{rms}^2$	$p = \frac{1}{3}\rho v_{rms}^2$

For single particle of *f* degrees of freedom,

$$K_{tr} = \frac{3}{2}\left(\frac{R}{N_A}\right)T = \frac{3}{2}k_BT$$

$$U = \frac{f}{2}k_BT$$

Equipartition Theorem

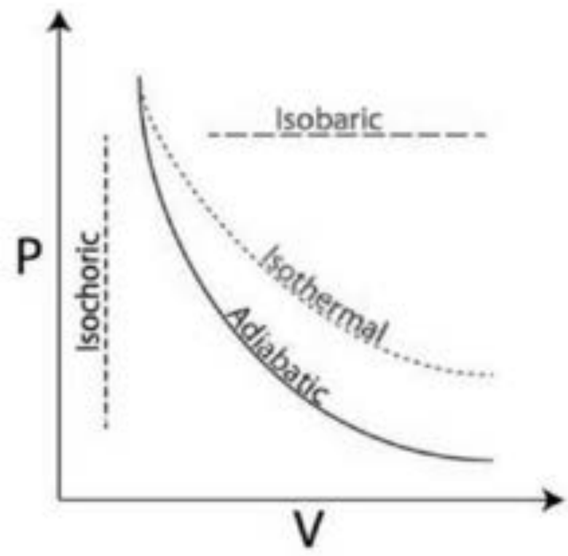
At equilibrium, each degree of freedom contributes $\frac{1}{2}k_BT$ of energy per molecule.

Thermodynamics

First Law of Thermodynamics

$\Delta U = Q - W$ where ΔU = change in internal energy, Q =heat added to the system and W = work done by the system.		
$\Delta U = \frac{f}{2} N k_B \Delta T = \frac{f}{2} nR\Delta T$	$\Delta Q = mc\Delta T$	$\Delta W = -p\,\Delta V$

Thermodynamical Work

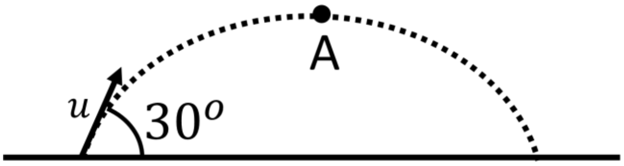
Isothermal	$\Delta T = 0 \Rightarrow \Delta U = 0$ $Q = W$ $p = \frac{nRT}{V}$, $\Delta W = -p\Delta V$ $W = -\int_{V_i}^{V_f} p\,dV = -\int_{V_i}^{V_f} \frac{nRT}{V} dV$ $= -nRT \int_{V_i}^{V_f} \frac{1}{V} dV$ $W = -nRT\,ln\left(\frac{V_f}{V_i}\right)$	
Isobaric	$\Delta p = 0$ $W = -\int_{V_i}^{V_f} p\,dV = -p(V_f - V_i)$	
Isochoric	$\Delta V = 0$ $\Delta U = \Delta Q$	
Adiabatic	$\Delta W = -\Delta U = -\frac{f}{2} nR\Delta T$ $\Delta W = \int_{T_i}^{T_f} \frac{f}{2} nRdT$ $\Delta W = \frac{f}{2} nR(T_f - T_i)$	

===End of Notes===

SP015

PAST YEAR QUESTIONS

Worksheet 4: PYQ Kinematics

<table>
<tr><td>21/22</td><td>
a. A bus is moving with an initial speed u begins to slow down at a uniform rate of $3ms^{-2}$. Calculate u if it takes 6.67s to travel at a distance of 67m.
b. A ball is thrown horizontally from the top of a building with a speed of $20ms^{-1}$. After 7s, the ball hits the ground. What is the height of the building?
c. The figure below shows the path taken by an object projected with an initial speed, u at an angle 30^o to the horizontal.


What is the speed of the object at point A in terms of u?
d. A motorcycle accelerates from rest to $5ms^{-1}$ in 4.5s and then continues at this speed for another 4.5s. Calculate the total distance travelled by the motorcycle.
</td></tr>
<tr><td></td><td>
a. Method 1

$$v^2 = u^2 + 2as \Rightarrow v^2 = u^2 + 2(-3)(67)$$
$$v = u + at \Rightarrow v = u + (-3)(6.67)$$
$$v = 0.04ms^{-1};\ u = 20.05ms^{-1}$$

Method 2

$$s = ut + \frac{1}{2}at^2$$
$$\Rightarrow 67 = 6.67(u) + \frac{1}{2}(-3)(6.67)^2$$
$$u = 20.05ms^{-1}$$

b.

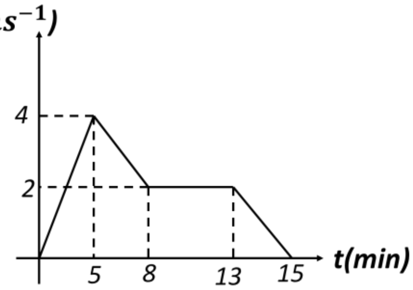
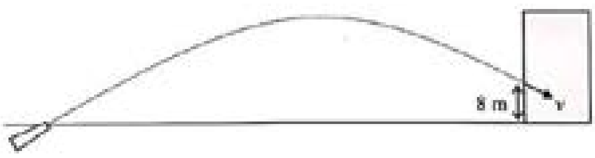
$$s_y = u_y t + \frac{1}{2}a_y t^2 \Rightarrow s_y = 0 + \frac{1}{2}(-9.81)7^2 \Rightarrow$$
$$s_y = -240.345m$$

c.

$$v_y = u_y + a_y t = u\sin\theta - gt;\ v_x = u_x = u\cos\theta \Rightarrow v = \sqrt{v_x^2 + v_y^2}$$
$$v = \sqrt{u^2 - 2gt\sin\theta + g^2t^2}$$

d.

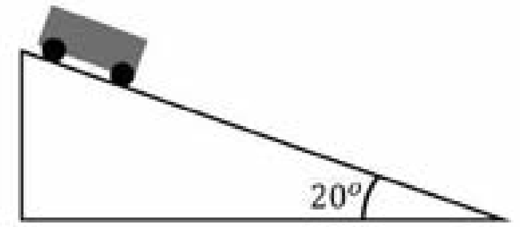
$$s_1 = \frac{1}{2}(u+v)t = \frac{1}{2}(0+5)4.5 = 11.25m$$
$$s_2 = vt = 5(4.5) = 22.5m$$
$$s_{total} = s_1 + s_2 = 11.25 + 22.5$$
$$s_{total} = 33.75m$$
</td></tr>
<tr><td>20/21</td><td>
A student took 15minutes to cycle from his house to school. He starts from rest and reaches a maximum speed of $4ms^{-1}$ in 5 minutes at constant acceleration. After reaching the maximum speed, he decelerates uniformly to $2.0ms^{-1}$ in 3 minutes and continues cycling with this speed for 5 minutes. He then took 2 minutes to decelerate uniformly to stop.
A. Sketch a labelled graph of speed versus time for the whole journey.
B. Calculate the acceleration of the bicycle for the time segments of 0-5 minutes and 13-15 minutes.
C. Determine the total distance from his house to school.
</td></tr>
<tr><td></td><td>A.</td></tr>
</table>

	 B. $$a_{0-5min} = \frac{v-u}{t} = \frac{4-0}{5 \times 60} = 0.013ms^{-2}$$ $$a_{13-15min} = \frac{v-u}{t} = \frac{0-2}{2 \times 60} = -0.017ms^{-2}$$ C. $$s_{total} = s_{0-5mins} + s_{5-8mins} + s_{8-13mins} + s_{13-15mins}$$ $$s_{total} = \left(\frac{1}{2}(v+u)t\right) + \left(\frac{1}{2}(v+u)t\right) + vt + \frac{1}{2}(v+u)t$$ $$s_{total} = \left(\frac{1}{2}(4+0)(5 \times 60)\right) + \left(\frac{1}{2}(2+4)(3 \times 60)\right) + 2(5 \times 60) + \frac{1}{2}(0+2)(2 \times 60)$$ $$s_{total} = 1860m$$
19/20	A. A boat with an initial speed of $30ms^{-1}$, decelerates at $3.5ms^{-2}$ for 4.5s before reaching a buoy. Calculate the speed of the boat at the buoy. B. The figure below shows a stream of water hitting a wall at a height of 8m with a velocity of $40ms^{-1}$ at an angle of 35^o below the horizontal.  Determine the initial velocity of the water as it leaves the nozzle.
	A. $v = u + at \Rightarrow v = 30 + (-3.5)(4.5) = 14.25ms^{-1}$ B. $v_y^2 = u_y^2 - 2gs_y$ $$\Rightarrow \left(40\sin(-35^o)\right)^2 = (u\sin\theta_i)^2 - 2(9.81)(8)$$ $$\Rightarrow u\sin\theta_i = 26.141ms^{-1} --- [1]$$ $$u_x = v_x = v\cos\theta_f = 40\cos(-35^o)$$ $$\Rightarrow u\cos\theta_i = 32.766ms^{-1} --- [2]$$ Solving equations 1 and 2 simultaneously yields, $$u = 41.9161ms^{-1};\ \theta_i = 38.5832^o$$

Worksheet 9: PYQ Momentum, Newton's Law, and Energy

21/22	A. A 500g soccer ball is kicked horizontally at the speed of $12ms^{-1}$ towards a wall. It rebounds off the wall at the speed of $2ms^{-1}$. Calculate the magnitude of the impulse on the ball. B. Two rugby players with mass 75kg and 100kg run directly towards each other with velocities of $6ms^{-1}$ to the right and $8ms^{-1}$ to the left respectively. If they grab each other as the collide, calculate the combined velocity of the two players just after the collision. C. A man of mass 75kg and a woman of mass 55kg stand facing each other on a smooth horizontal surface, both wearing roller blades. The woman pushes the man to the right with a horizontal force of 85N. Determine the acceleration of the woman. D. How large of a net force required to accelerate a 600N at a rate $0.7ms^{-2}$ on a smooth horizontal surface?

<table>
<tr>
<td></td>
<td>
E. A shopping trolley with a total mass of 40kg is released from rest and rolls down a 2m long surface which is inclined at 20^o as shown in the figure below.



Calculate the work done to stop the trolley at the bottom of the surface if it experiences a constant frictional force of 16N.

F. A man is lifting three boxes each weighing $80N$ to a 1.2m high shelf in 2s. Calculate the power required by the man to lift the boxes.

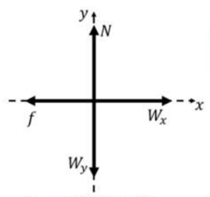
G. Calculate the release height of a the falling of a 2kg sphere if its kinetic energy is 300J just before striking the ground. The air resistance can be ignored.
</td>
</tr>
<tr>
<td></td>
<td>
A. $\vec{J} = m(\vec{v} - \vec{u}) = 0.5((-2) - (12)) \Rightarrow J = -7Ns$

B. $m_1u_1 + m_2u_2 = (m_1 + m_2)v \Rightarrow (75)(6) + (100)(-8) = (100 + 75)v \Rightarrow v = -2ms^{-1}$

C. $F_{12} = -F_{21} \Rightarrow m_{woman}a_{woman} = -85 = (55)a_{woman} \Rightarrow a_{woman} \approx 1.54ms^{-2}$

D. $mg = m(9.81) = 600N \Rightarrow m = 61.2kg$

E.



$$\Sigma F_x = W\cos 70^o - f = mg\cos 70^o - f$$
$$\Sigma F_x = (40)(9.81)\cos 70^o - 16 = 118.2N$$
$$W = (\Sigma F_x)\cdot s = (118.2)(2) = 236.4Nm$$

F. Total Weight, $W_{total} = 3(80) = 240N$

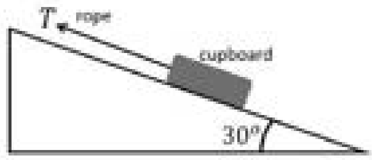
Work Done, $W = \Delta K = (mg)h = (240)(1.2)$

Power required, $P = \frac{W}{t} = \frac{240(1.2)}{2}$

$P = 144W$

G. $E_k = E_{gp} \Rightarrow 300 = mgh = (2)(9.81)(h) \Rightarrow h = 15.3m$
</td>
</tr>
<tr>
<td>20/21</td>
<td>
A. A 20g bullet is fired and travels with speed of $800ms^{-1}$. It hits 5kg wooden block initially at rest and is stuck inside, causing the block to move. Determine the final velocity of the bullet and the block immediately after the block is hit and show that the collision is inelastic.

B. The figure shows a 40kg cupboard being pulled along a rough inclined plane 30^o to the horizontal by a light rope.

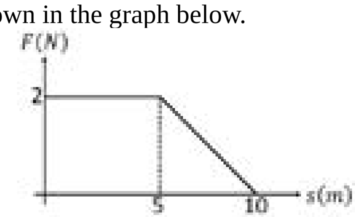


The cupboard moves at a constant velocity. The coefficient of kinetic friction between the cupboard and inclined plane is 0.5.

i. Draw a free body diagram of the cupboard.

ii. Determine the magnitude of the frictional force and tension acting on the cupboard.

C. A 2kg object moving with an initial velocity of $5ms^{-1}$ is acted on by a force of 2N. The force-displacement of the motion is shown in the graph below.



Determine the velocity of the object at 10m displacement.

D. A car with mass 1500kg is moving with a constant force, F acting on it along its direction of motion. Upon achieving a speed of $20ms^{-1}$, it delivers a maximum power of $100kW$. Later the car enters a 50m rough road and decelerates to a speed of $10ms^{-1}$. Determine the constant force F and the work done to overcome the frictional force on the rough road.
</td>
</tr>
</table>

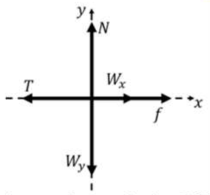
A. $m_1u_1 + m_2u_2 = (m_1 + m_2)v \Rightarrow (0.02)(800) + (5)(0) = (5 + 0.02)v \Rightarrow v = 3.19ms^{-1}$

$$\Sigma K_{initial} = \frac{1}{2}m_1u_1^2 = \frac{1}{2}(0.02)(800)^2 = 6.4kJ --- [1]$$

$$\Sigma K_{final} = \frac{1}{2}m_2v^2 = \frac{1}{2}(m_1 + m_2)v^2 = \frac{1}{2}(5 + 0.02)(3.19)^2 = 25.542J --- [2]$$

Since $\Sigma K_{initial} \neq \Sigma K_{final} \Rightarrow$ inelastic collision

B.



$$\Sigma F_x = \Sigma F_y = 0$$

$$\Sigma F_x = 0 \Rightarrow T = W_x + f = W \sin 30^o + f$$

$$\Sigma F_y = 0 \Rightarrow N = W_y = W \cos 30^o$$

$$f = \mu N = \mu W \cos 30^o = 0.5(40)(9.81) \cos 30^o$$

$$f = 169.9N$$

$$T = mg \sin 30^o + f$$

$$T = (40)(9.81) \sin 30^o + 169.9$$

$$T = 562.3N$$

C. Area under graph, $A = 5(2) + \frac{1}{2}(2)(5) = 15J$

$W = \Delta K = \frac{1}{2}m(v^2 - u^2) \Rightarrow 15 = \frac{1}{2}(2)(v^2 - (5)^2) \Rightarrow v = 2\sqrt{10}ms^{-1}$

D. $P = 100(10^3) = Fv = F(20) \Rightarrow F_{engine} = 5kN$

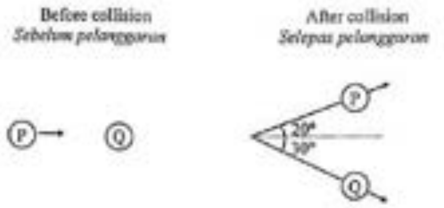
$$F_{net} = ma = m\frac{v^2 - u^2}{2s} = (1500)\frac{10^2 - 20^2}{2(50)} = -4.5kN$$

$$F_{engine} = F_{friction} + F_{net} \Rightarrow W_{engine} = W_{friction} + W_{net}$$

$$5kN(50) = W_{friction} + (4.5kN)(50) \Rightarrow W_{friction} = 25kN$$

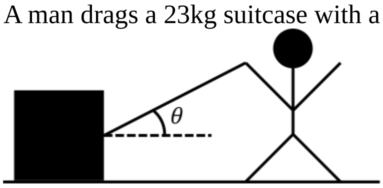
19/20

A. The figure below shows a 0.52kg ball P moving at $0.69ms^{-1}$ collides with a stationary ball Q.



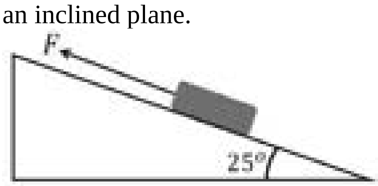
After the collision, the velocity of the balls P and Q are $0.3ms^{-1}$ and $0.45ms^{-1}$ respectively. Determine the mass of ball Q.

B. A man drags a 23kg suitcase with a 45N force at constant speed as shown in the figure below.



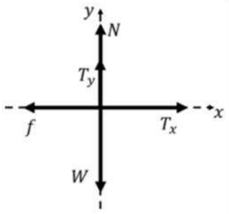
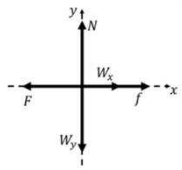
The frictional force on the suitcase is 18N. With the help of a free body diagram, calculate the coefficient of kinetic friction between the suitcase and the floor.

C. The figure below shows a 15kg blocks being pulled by a 100N force at an initial speed of $2ms^{-1}$ up an inclined plane.



The block travels a distance of 6.2m parallel to the inclined plan. The coefficient of kinetic friction is 0.14. By using the work-energy theorem, calculate the change in the kinetic energy of the block.

D. A 120kg motorcycle accelerates uniformly from rest to $25ms^{-1}$ in 5s. Calculate the instantaneous power of the motorcycle at time $t = 3s$.

	A. 2 possible solutions: x: $m_P u_P = m_P v_p cos\, 20^o + m_Q v_Q cos\, 30^o$ $0.52(0.69) = (0.52)(0.3) cos\, 20^o + m_Q (0.45) cos\, 30^o$ $m_Q = 0.545kg$ y: $0 = m_P\, v_P\, sin(20^o) - m_Q\, v_Q\, sin(30^o)$ $(0.52)(0.3)\, sin(20^o) = m_Q\, (0.45)\, sin(30^o)$ $m_Q = 0.237kg$ B.  constant speed: $\Sigma F_x = \Sigma F_y = 0$ $\Sigma F_x = 0$ $\Rightarrow f = 18 = T_x = T \cos\theta = 45 \cos\theta$ $\theta = 66.42^o$ $\Sigma F_y = 0$ $\Rightarrow N = W - T_y = mg - T \sin\theta$ $f = 18 = \mu N = \mu(mg - T \sin\theta)$ $18 = \mu\big((23)(9.81) - (45) \sin(66.42)\big)$ $\mu = 0.098$ C.  $\Sigma F_y = 0$ $\Rightarrow N = W_y = W \cos 65^o = mg \cos 25^o = (15)(9.81) \cos 25^o$ $N = 133.4N$ $\Sigma F_x = F - f - W_x = F - \mu N - mg \sin 25^o$ $\Sigma F_x = 100 - (0.14)(133.4) - (15)(9.81) \sin 65^o = 19.1N$ $\Delta K = W = \Sigma F_x \cdot s = (19.1)6.2$ $\Delta K = 118.42J$ D. $v = u + at \to 25 = 0 + a(5) \to a = 5ms^{-2}$ $v(t = 3s) = u + at = 0 + 5(3) = 15ms^{-1}$ $P = Fv = ma(v) = (120)(5)(15)$ $P = 9kW$

Worksheet 11: PYQ Circular Motion

21/22	In a bike race, a racer and his bike of mass 230kg moves around a curve on a level track with a velocity of $80kmh^{-1}$. If the radius of the curve is 90m, what is the frictional force acting on the bike at the curve?
	$F_c = F_f = \frac{mv^2}{r} \Rightarrow F_f = \frac{(230)\left(\frac{80 \times 1000}{60 \times 60}\right)^2}{90}$ $F_f = 126.2N$
20/21	A 20g stone tied at the end of an inelastic string rotates in a horizontal circle. The length of the string is 1.0m and the stone rotates with a constant angular velocity of 2 revolutions per second. a. Draw a free body diagram of the stone. b. Calculate the centripetal acceleration of the stone.
	a. Refer to lecturer b. $a = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = r\omega^2 = (1)(2 \times 2\pi)^2$ $a = 16\pi^2 \approx 157.9\, rads^{-2}$
19/20	A 16g is swung vertically using a 0.5m string. Calculate the a. Minimum tension in the string if the speed of the ball is $1.5ms^{-1}$ b. Speed of the ball when the string breaks.
	a.

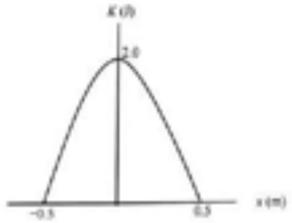
	Minimum tension $\rightarrow$ ball position at top $\Rightarrow F_c = \frac{mv^2}{r} = T + W$ $\frac{0.016(1.5^2)}{0.5} = T + (0.016)(9.81) \Rightarrow T = -0.085N$ b. $a = \frac{v^2}{r} = \frac{(r\omega)^2}{r} = r\omega^2 = (1)(2 \times 2\pi)^2$ $a = 16\pi^2 \approx 157.9\, rads^{-2}$

Worksheet 17: PYQ Waves

21/22

A. A mass of 200g is attached to a spring. When the mass displaced a certain distance from equilibrium and released, it oscillates at a period of 0.85s. What is the constant of the spring?

B. The figure shows a particle of mass 4.0kg moves in simple harmonic motion and its kinetic energy, K varies with position, x.



Determine the period.

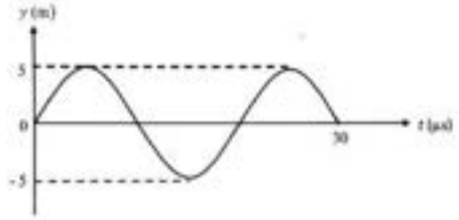
C. What is the speed of a transverse wave in a rope of length 5.00m and mass 55.00g under a tension of 600.00N?

D. A transverse wave is represented by the following equation:

$$y = 7\,sin\,(5t - 3x)$$

where y and x are measured in centimetres and t in seconds. What is the maximum vibrational velocity of a particle in the wave?

E. The figure shows how the displacement, y of a particle varies with time, t when a wave passes through the particle at speed $6kms^{-1}$. The wave is reflected and superimposed with an incident wave.



What is the equation of the standing wave formed?

F. The security alarm in a parking area produces a siren with frequency of 980Hz. As a car drives away, the driver observes the frequency changes to 850Hz. The speed of sound is in $345ms^{-1}$. What is the speed of the car?

A. $T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow 0.85 = 2\pi\sqrt{\frac{0.2}{k}} \Rightarrow k = 10.93\ Nm^{-1}$

B. When $x = A$,

$$K = E_{total} = \frac{1}{2}m\omega^2 A^2$$

$$K = \frac{1}{2}m\left(\frac{2}{T}\right)^2 A^2 \Rightarrow 2 = \frac{1}{2}(4)\left(\frac{2}{T}\right)^2 (0.5)^2 \Rightarrow T = 3.1416s$$

C.

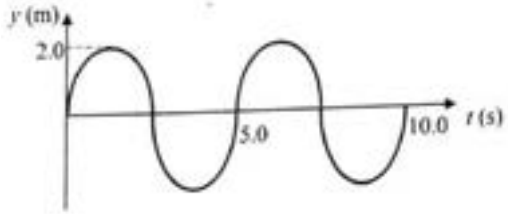
$$v = \sqrt{\frac{F_T}{\mu}} = \sqrt{\frac{F_T l}{m}} = \sqrt{\frac{600(5)}{0.055}} \Rightarrow v = 233.55ms^{-1}$$

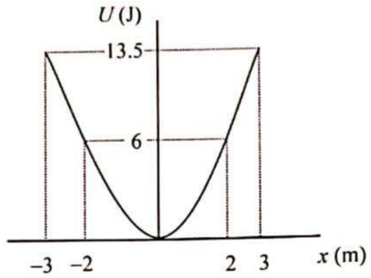
D.

$$v_{vibration} = \frac{dy}{dt} = \frac{d}{dt}(7\,sin\,(5t - 3x))$$

$$v_{vibration} = 35\,cos\,(5t - 3x)$$

$$v_{max-vibration} = 35cms^{-1}$$

	E. From diagram ⇒ $T = 20\,\mu s$; $A = 5m$; $v = 6kms^{-1} = 6000ms^{-1}$ General equation for standing wave: $y(x,t) = 2A\,cos(kx)\,sin(\omega t)$ $k = \frac{2\pi}{\lambda} = \frac{2\pi}{vT} = \frac{2\pi}{(6000)(20(10^{-6}))} = \frac{50}{3}\pi m^{-1}$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{20(10^{-6})} = \pi(10^{-5})\,rad\,s^{-1}$ $y(x,t) = 10\,cos\left(\frac{50}{3}\pi x\right)\,sin(\pi(10^{-5})t)$ Where x is in metres and t is in seconds. F. $\frac{f_{app}}{f_{source}} = \frac{v \pm v_{observer}}{v \mp v_{source}}$ $\frac{850}{980} = \frac{345 - v_{observer}}{345 \mp 0} \Rightarrow v_{observer} = 45.77ms^{-1}$
20/21	A. The figure shows the displacement-time graph of a body performing simple harmonic motion.  a. Determine the amplitude, angular frequency and maximum speed of the motion. b. Deduce the expression for the motion. c. Sketch the velocity-time graph for the motion. B. A stretched wire of length 1.0m is fixed at both ends. The speed of the transverse wave in the wire is $10ms^{-1}$. If the mode of vibration is third overtone, calculate the a. Wavelength b. Frequency of the third overtone c. Lowest resonant frequency of the wire. C. A train with a velocity of $40ms^{-1}$ is approaching an observer standing on a platform. The frequency of the siren from the train is 1600Hz. Assuming the speed of sound in air is $330ms^{-1}$, determine the a. Frequency of the sound heard by the observer. b. Frequency of the sound heard by the observe when the train is leaving the platform.
	A. $A = 2m$; $T = 5s$ $\omega = \frac{2\pi}{T} = \frac{2\pi}{5} \Rightarrow \omega = 0.4\pi\,rads^{-1}$ $v = \frac{dy}{dt} = \frac{d}{dt}(2\,sin\,0.4\pi t)$ $v_{max} = 0.8\pi \approx 2.51ms^{-1}$ $y(t) = 2\,sin\,0.4\pi t$ B. $2\lambda = L \Rightarrow \lambda = 0.5L = 0.5(1) \Rightarrow \lambda = 0.5m$ $v = f\lambda \Rightarrow f = \frac{v}{\lambda} = \frac{10}{0.5} \Rightarrow f = 20Hz$ Lowest resonant ⇒ fundamental frequency $\lambda = 2L = 2m \Rightarrow f = \frac{v}{\lambda} = \frac{10}{2} \Rightarrow f = 5Hz$ C. $\frac{f_{observed}}{f_{source}} = \frac{v \pm v_{observer}}{v \mp v_{source}}$ $\frac{f_{observed}}{1600} = \frac{330 \pm 0}{330 - 40}$ $f_{observed} = 1820.69Hz$ $\frac{f_{observed}}{f_{source}} = \frac{v \pm v_{observer}}{v \mp v_{source}}$ $\frac{f_{observed}}{1600} = \frac{330 \pm 0}{330 + 40}$ $f_{observed} = 1427.03Hz$
19/20	A. The figure shows the potential energy of 0.5kg object that undergoes a simple harmonic motion.



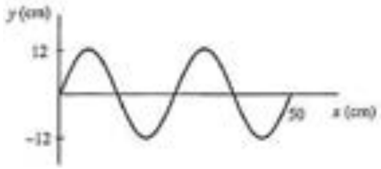
Determine the

i. Velocity when time $t = 2s$

ii. Kinetic energy of the object when displacement $x = 1.5m$

B. An oscillating pendulum has length 0.3m and 240g bob. If the total energy is 0.06J, calculate the amplitude of the oscillation.

C.



The figure shows a graph of displacement y against distance x for a progressive wave propagating to the right in a string with mass 920g, length 3m and tension 15N. Determine the wave equation.

D. A 1.53m closed pipe makes a humming sound at frequency 282Hz when the wind blows across the open end. The speed of sound is $343ms^{-1}$. With the help of a diagram, determine the number of nodes in the standing wave.

E. The frequency of whistle by a moving train and the frequency heard by a stationary observer are 520Hz and 460Hz respectively. If the speed of sound in the air is $343ms^{-1}$, calculate the speed of the train.

A.

$$A = 3$$

$$U(x) = \frac{1}{2}m\omega^2x^2 \Rightarrow 13.5 = \frac{1}{2}(0.5)\omega^2(3^2)$$

$$\omega = 2.45\,rads^{-1}$$

General equation $\Rightarrow y(t) = A\sin(\omega t) = 3\sin(2.45t)$

$$v = \frac{dy}{dt} = \frac{d}{dt}\big(3\sin(2.45t)\big) = 7.35\cos(2.45t)$$

$$v(t = 2s) = 7.35\cos\big(2.45(2)\big) \Rightarrow v(t = 2s) = 1.37ms^{-1}$$

$$K = \frac{1}{2}m\omega^2(A^2 - x^2)$$

$$K(x = 1.5m) = \frac{1}{2}(0.24)(2.45)^2(3^2 - 1.5^2)$$

$$K(x = 1.5m) = 10.129J$$

B.

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{2\pi\sqrt{\frac{l}{g}}} \Rightarrow \omega = \sqrt{\frac{g}{l}} = \sqrt{\frac{9.81}{0.3}} = 5.718rads^{-1}$$

$$E_{total} = \frac{1}{2}m\omega^2A^2 \Rightarrow 0.06 = \frac{1}{2}(0.24)(5.718)^2A^2 \Rightarrow A = 0.124m$$

C. General Equation $\Rightarrow y(x,t) = A\sin(\omega t \pm kx)$

$$A = 12cm;\ k = \frac{2\pi}{\lambda} = \frac{2}{25}\pi cm^{-1}$$

$$\omega = 2\pi f = 2\pi\left(\frac{v}{\lambda}\right) = 2\pi\left(\frac{\left(\sqrt{\frac{F_T}{\mu}}\right)}{\lambda}\right) = 2\pi\left(\frac{\left(\sqrt{\frac{15}{\left(\frac{0.92}{3}\right)}}\right)}{0.25}\right) = 55.95\pi\,rads^{-1}$$

$y(x,t) = 12\sin\left(55.95\pi t - \frac{2}{25}\pi x\right)$, where x and y are in centimetres and t is in seconds.

D. $L = 1.53m;\ f_n = 282Hz;\ v_{sound} = 343ms^{-1}$

For fundamental frequency $\Rightarrow L = \frac{\lambda}{4} \Rightarrow \lambda = 4L \Rightarrow v = f_o\lambda_o \Rightarrow f_o = \frac{v}{\lambda_o} = \frac{v}{4L} = \frac{343}{4(1.53)} = 56Hz$

$n = \frac{f_n}{f_o} = \frac{282}{56} \approx 5 \Rightarrow$ 5th Harmonic $\Rightarrow$ 3 nodes

Worksheet 20: PYQ Physics of Matter

21/22

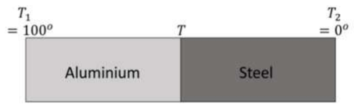
A. A 5.0m long wire a cross sectional area of $4.0 \times 10^{-4} m^2$. The wire extended by 0.5cm. Calculate the Young's modulus of the wire when a 200kg is suspended at its one end.

B. An aluminium rod of radius 0.5cm and length 20cm is welded end-to-end with a steel rod of the same dimensions. The free end of the aluminium rod is held at 100^oC while the steel free end is placed in a ice bath. When the system is at steady state, calculate the temperature at the aluminium-steel interface. [Given the thermal conductivity of aluminium is $250Wm^{-1o}C^{-1}$ and the thermal conductivity of steel is $14Wm^{-1o}C^{-1}$]

C. An aluminium tube of external diameter 3.00cm at 25^oC is heated to 80^oC. Calculate the external area of the tube at 80^oC if the coefficient of linear expansion for aluminium is $2.4 \times 10^{-5} K^{-1}$.

A. $Y = \frac{Fl}{A\Delta l} = \frac{(200)(9.81)(5)}{(4\times10^{-4})0.5(10^{-2})} = 4.905 \times 10^9 Nm^{-2}$

B.



$$\frac{dQ_{Al}}{dt} = \frac{dQ_{steel}}{dt} \Rightarrow k_{Al}A_{Al}\frac{(T_1 - T)}{l_{Al}} = k_{steel}A_{steel}\frac{(T - T_2)}{l_{steel}}$$

$$k_{Al}(T_1 - T) = k_{steel}(T - T_2) \Rightarrow 250((100 + 273.15) - T) = 14(T - (0 + 273.15))$$

$$T = 367.85K$$

C. $A_o = \pi\left(\frac{0.03}{2}\right)^2 = 0.000225\pi;\ \frac{\Delta A}{A_o} = \frac{A_f - A_o}{A_o} = 2\alpha\Delta T$

$$\frac{A_f - 0.000225\pi}{0.000225\pi} = 2(2.4 \times 10^{-5})(80 - 25) \Rightarrow A_f = 0.00708724m^2$$

20/21

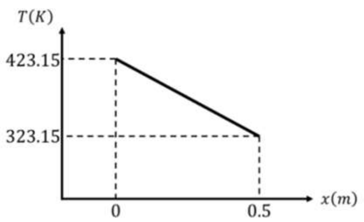
A. A 1.5m steel wire is stretched 2.0mm by force F. The diameter of the steel wire is 4.0mm. The Young's modulus of steel is $2.0 \times 10^{11}\ Nm^{-2}$. Determine the force F applied on the wire.

B. A perfectly insulated aluminium rod has length $50cm$ and cross-sectional area $3.0cm^2$. At the steady state, the temperatures at 0cm and 50cm ends are 150^oC and 50^oC.
(Thermal conductivity of aluminium is $210W\ m^{-1}\ K^{-1}$)
  a. Sketch a labelled graph of temperature against distance.
  b. Calculate the temperature gradient along the rod.
  c. Calculate the rate of heat flow in the rod.

A. $Y = \frac{Fl}{A\Delta l} = \frac{Fl}{\left(\frac{d^2}{4}\right)\pi\Delta l} \Rightarrow 2(10^{11}) = \frac{F(1.5)}{\left(\frac{(4\times10^{-3})^2}{4}\right)\pi(0.002)} \Rightarrow F = 3351N$

B.

a.



b. $\frac{dT}{dx} = \frac{323.15 - 423.15}{0.5 - 0} = -200\ Km^{-1}$

c. $\frac{dQ}{dt} = -k_{Al}A_{Al}\frac{dT}{dx} = -(210)(3(10^{-2})^2)(-200)$

$\Rightarrow \frac{dQ}{dt} = 63.5Js^{-1}$ (towards the cold end)

19/20

A. The diameter of a circular shoe heel is 13mm. If both heels support 70% of the weight of a 54kg woman, calculate the stress on both heels.

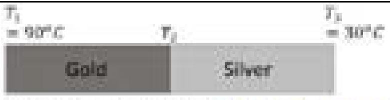
B. A gold rod is in contact with a silver rod. The gold end and the silver end of the compound is at 90^oC and 30^oC respectively. The silver rod has thermal conductivity $427\ Wm^{-1}K^{-1}$, length 2.5cm and cross-sectional area $7.85 \times 10^{-5}m^2$. If 341.3J heat flows through the gold rod in 10s, calculate the temperature at the contact surface.

C. The are of a metal plate changes from $120m^2$ to $120.059m^2$ when the temperature increases by 30^oC. Calculate the coefficient of linear expansion of the metal.

A.

$$\delta = \frac{F}{A} = \frac{0.7(54)(9.81)}{2\left(\frac{13(10^{-3})}{2}\right)^2} = 1.397 \times 10^6 Nm^{-2}$$

B.



$\frac{dQ_{gold}}{dt} = \frac{dQ_{silver}}{dt} = \frac{341.3J}{10s} = 34.13Js^{-1} = -k_{silver}A_{silver}\frac{dT}{dx} = -(427)(7.85\times10^{-5})\frac{30-T_j}{0.035}$

$\Rightarrow$ $T_j = 55.46^oC$

C. $\frac{\Delta A}{A_0} = \frac{A_f - A_0}{A_0} = 2\alpha\Delta T \Rightarrow \frac{120.059-120}{120} = 2\alpha(30) \Rightarrow$ $\alpha = 8.19444(10^{-6})K^{-1}$

Worksheet 23: PYQ Molecular Energies & Thermodynamics

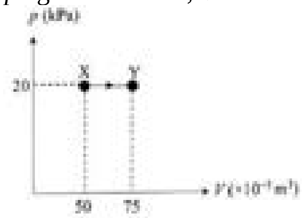
21/22

A. What is the pressure of one mole ideal gas in the container of volume $4\times10^{-4}m^3$ at temperature $363.15K$?

B. Given the molar mass of oxygen is $32\,gmol^{-1}$. What is the root mean square speed of the oxygen molecules at a temperature of 333K.

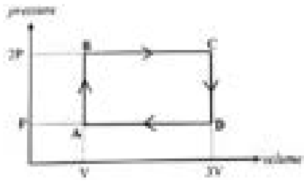
C. A balloon contains helium gas at 30^oC and $2\times10^{-5}\,Pa$. Calculate the number of helium gas molecules per unit volume.

D. The figure shows a graph of pressure, p against volume, V of an ideal gas.



When the gas changes from state X to state Y, the amount of heat transfer into the gas is 1.0kJ. What is the internal energy of the gas?

E. The figure shows a graph of pressure versus volume of an ideal gas undergoing a cyclic thermodynamic process **ABCDA.**



Calculate the work done by the gas.

A. $pV = nRT \Rightarrow p = \frac{nRT}{V} = \frac{(1)(8.31)(363.15)}{4(10^{-4})}$

$\Rightarrow$ $p = 75.4(10^5)\,Pa \approx 75.4atm$

B. $1mol = 32g = 6.02\times10^{23}$oxygen gas molecules

$1\text{molecule} = \frac{32}{6.02(10^{23})}(10^{-3})kg$

$\frac{1}{2}mv_{rms}^2 = \frac{3}{2}k_BT$

$\Rightarrow \frac{1}{2}\left(\frac{32}{6.02(10^{23})}(10^{-3})\right)v_{rms}^2 = \frac{3}{2}(1.38\times10^{-23})(333)$

$v_{rms} \approx 509.27ms^{-1}$

C. $pV = Nk_BT \Rightarrow \frac{N}{V} = \frac{p}{k_BT} = \frac{2(10^{-5})}{(1.38\times10^{-23})(30+273.15)}$

$\frac{N}{V} = 4.78(10^{15})\text{molecules }m^{-3}$

D. $\Delta U = \Delta Q + \Delta W = \Delta Q - \int_{V_i}^{V_f} p\,dV$

$\Delta U = \Delta Q - p(V_f - V_i)$

$\Delta U = (+10^3) - (20)(10^3)(75-50)(10^{-3})$

$\Delta U = 500J$

E. $W_{total} = W_{A\to B} + W_{B\to C} + W_{C\to D} + W_{D\to A}$

$W_{total} = 0 + 2P(3V - V) + 0 + P(V - 3V)$

$W_{total} = 2PV$

20/21

1. A container contains $3.0mol$ of nitrogen gas at 30^oC. If nitrogen gas behaves like an ideal gas, calculate the

	a. Total translational kinetic energy of the gas molecules. b. Internal energy of the gas. c. Root mean square speed of the nitrogen molecules if the mass is 28 g per mole. 2. The pressure of a tyre rises from 200kPa to 400kPa at constant temperature 30^oC. Assuming the air in the tyre acts as an ideal gas, calculate the a. Work done per mole of the air. b. Heat transferred in this process.
	1. a. $\Sigma K = \frac{3}{2}nRT = 3\left(\frac{3}{2}\right)(8.31)(30+273.15)$ $\Rightarrow \Sigma K = 11.336kJ$ b. $U = \frac{5}{2}nRT = \frac{5}{2}(8.31)(30+273.15)$ $\Rightarrow U = 18.893kJ$ c. $\frac{1}{2}\left(\frac{28\times10^{-3}}{6.02(10^{23})}\right)v_{rms}^2 = \frac{3}{2}(1.38\times10^{-23})(30+273.15)$ $\Rightarrow v_{rms} \approx 519.455ms^{-1}$ 2. a. Work done by the gas, $W = \int_{V_i}^{V_f} p\,dV = \int_{V_i}^{V_f}\frac{nRT}{V}dV = nRT\,ln[\frac{V_f}{V_i}]$ Constant temperature $\Rightarrow p_iV_i = p_fV_f$ $W = nRT\,ln[\frac{p_i}{p_f}] = (1)(8.31)(30+273.15)\,ln[\frac{200000}{400000}]$ $\Rightarrow$ Work done by the gas, $W = -1746J$ b. Constant temperature $\Rightarrow \Delta U = 0$ $\Delta U = \Delta Q - \Delta W \Rightarrow \Delta Q = \Delta W = -1746J$
19/20	A. A sealed cylinder contains 1.2×10^{24} helium atoms at initial pressure $1.04\times10^5 Pa$. The cylinder is heated until the final temperature and the change in the internal energy of the helium gas are 315K and $1.6\times10^3 J$. The molas mass of helium is 4 $gmol^{-1}$. Calculate the i. Density of the helium gas. ii. Final pressure of the helium gas. B. A $0.8m^3$ container at 60^oC is filled with 0.6 mol ideal gas. The gas is isothermally compressed to a volume of $0.2m^3$. Then the gas expands isobarically to its initial volume. Calculate the total work done in the processes.
	A. i. $N = 1.2(10^{24})$ atoms; $p_i = 1.05(10^5)Pa$; $\Delta V = 0$; $T_f = 315K$; $\Delta U = 1.6(10^3)J$ $\rho = \frac{m_{gas}}{V}; n = \frac{N}{N_A} = \frac{12\times10^{23}}{6.02\times10^{23}} = 1.993mol;$ $n = \frac{m_{gas}}{m_{molar}} = \frac{\rho V}{m_{molar}}$ $pV = nRT = \left(\frac{\rho V}{m_{molar}}\right)RT \Rightarrow p_i = \left(\frac{\rho}{m_{molar}}\right)RT_i$ $\Delta U = \frac{3}{2}nR(T_f - T_i) \Rightarrow T_i = T_f - \frac{2\Delta U}{3nR}$ $p_i = \left(\frac{\rho}{m_{molar}}\right)R\left(T_f - \frac{2\Delta U}{3nR}\right)$ $\Rightarrow 1.05(10^5) = \left(\frac{\rho}{0.004}\right)(8.31)\left(315 - \frac{2(1.6)(10^3)}{3(1.993)(8.31)}\right)$ $\rho = 0.202\,kgm^{-3}$ iii. $\Delta V = 0 \Rightarrow \frac{p}{T} = \frac{nR}{V} =$ constant $\frac{p_i}{T_i} = \frac{p_f}{T_f} \Rightarrow \frac{1.05(10^5)}{\left(315-\frac{2(1.6)(10^3)}{3(1.993)(8.31)}\right)} = \frac{p_f}{315}$ $p_f = 131986\,Pa$ B.

$$W_{total} = W_1 + W_2$$

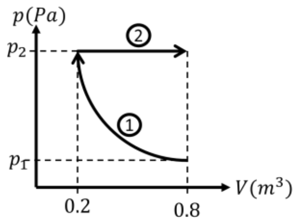
$$W_{total} = \left(\int_{0.8}^{0.2} p\, dV\right) + \left(\int_{0.2}^{0.8} p\, dV\right)$$

$$W_{total} = \left(\int_{0.8}^{0.2} \frac{nRT}{V} dV\right) + \left(p_2 \int_{0.2}^{0.8} dV\right) \frac{p_1}{p_2} = \frac{\left(\frac{nRT_1}{0.8}\right)}{p_2} = \frac{0.8}{0.2} = 4$$

$$W_{total} = \left(nRT\, ln\, \left(\frac{0.2}{0.8}\right)\right) + \left(\frac{nRT_1}{4(0.8)}(0.8 - 0.2)\right)$$

$$W_{total} = \left((0.6)(8.31)(60 + 273.15)\, ln\, \left(\frac{0.2}{0.8}\right)\right) +$$
$$\frac{(0.6)(8.31)(60+273.15)}{4(0.8)}\left(p(0.8 - 0.2)\right)$$

Work done by the gas, $W_{total} = -1991.3J$



The Physics Workbook

SHAFIQ RASULAN
MARY GWADOLINE YUSUS
JOHN LIEW KENG HONG

Foreword by
Misinah Mahamad Fadzil
Head of Science Dept

CONTENT

LIST OF SELECTED CONSTANTS

Speed of light in vacuum	c	$= 3.00 \times 10^{8}\, ms^{-1}$
Permeability of free space	μ_o	$= 4\pi \times 10^{-7}\, H\, m^{-1}$
Permittivity of free space	ε_o	$= 8.85 \times 10^{-12}\, F\, m^{-1}$
Electron charge magnitude	e	$= 1.6 \times 10^{-19}\, C$
Planck constant	h	$= 6.63 \times 10^{-34}\, Js$
Electron mass	m_e	$= 9.11 \times 10^{-31} kg$ $= 5.49 \times 10^{-4}\, u$
Neutron mass	m_n	$= 1.674 \times 10^{-27} kg$ $= 1.008665u$
Proton mass	m_p	$= 1.672 \times 10^{-27} kg$ $= 1.007277u$
Hydrogen mass	m_H	$= 1.673 \times 10^{-27} kg$ $= 1.007825u$
Deuteron mass	m_d	$= 3.34 \times 10^{-27} kg$ $= 2.014102u$
Molas gas constant	R	$= 8.31\, J\, K^{-1}\, mol^{-1}$
Avogadro constant	N_A	$= 6.02 \times 10^{23}\, mol^{-1}$
Boltzmann constant	k	$= 1.38 \times 10^{-23} JK^{-1}$
Free-fall acceleration	g	$= 9.81 ms^{-2}$
Atomic mass unit	$1u$	$= 1.66 \times 10^{-27} kg$ $= 931.5 \frac{MeV}{c^2}$
Electron volt	$1eV$	$= 1.6 \times 10^{-19}\, J$
Constant of proportionality for Coulomb's Law	$k = \frac{1}{4\pi\varepsilon_o}$	$9.0 \times 10^{9}\, N\, m^{2}\, C^{-2}$
Atmospheric pressure	$1atm$	$= 1.013 \times 10^{5} Pa$
Density of water	ρ_w	$= 100 kgm^{-3}$

LIST OF SELECTED FORMULAE

1	$v = u + at$	23	$\theta = \frac{1}{2}(\omega_o + \omega)t$
2	$s = ut + \frac{1}{2}at^2$	24	$\omega^2 = \omega_o^2 + 2\alpha\theta$
3	$v^2 = u^2 + 2as$	25	$\tau = rF\, sin\,\theta$
4	$s = \frac{1}{2}(u + v)t$	26	$I = \Sigma mr^2$
5	$p = mv$	27	$I_{\text{solid sphere}} = \frac{2}{5}MR^2$
6	$J = F\Delta t$	28	$I_{\text{solid cylinder/disc}} = \frac{1}{2}MR^2$
7	$J = \Delta p\ = mv - mu$	29	$I_{ring} = MR^2$
8	$f = \mu N$	30	$I_{\text{rod}} = \frac{1}{12}ML^2$
9	$W = \vec{F} \cdot \vec{s} = Fs\, cos\,\theta$	31	$\Sigma\tau = I\alpha$
10	$K = \frac{1}{2}mv^2$	32	$L = I\omega$
11	$U = mgh$	33	$y = A\, sin\,\omega t$
12	$U_s = \frac{1}{2}kx^2 = \frac{1}{2}Fx$	34	$v = \omega A\, cos\,\omega t = \pm\omega\sqrt{A^2 - y^2}$
13	$W = \Delta K$	35	$a = -\omega^2 A\, sin\,\omega t = -\omega^2 y$
14	$P_{av} = \frac{\Delta W}{\Delta t}$	36	$K = \frac{1}{2}m\omega^2(A^2 - y^2)$
15	$P = \vec{F} \cdot \vec{v} = Fv\, cos\,\theta$	37	$U = \frac{1}{2}m\omega^2 y^2$
16	$a_c = \frac{v^2}{r} = r\omega^2 = v\omega$	38	$E = \frac{1}{2}m\omega^2 A^2$
17	$F_c = \frac{mv^2}{r} = mr\omega^2 = mv\omega$	39	$\omega = \frac{2\pi}{T} = 2\pi f$
18	$s = r\theta$	40	$T = 2\pi\sqrt{\frac{l}{g}}$
19	$v = r\omega$	41	$T = 2\pi\sqrt{\frac{m}{k}}$
20	$a_t = r\alpha$	42	$k = \frac{2\pi}{\lambda}$
21	$\omega = \omega_o + \alpha t$		
22	$\theta = \omega_o t + \frac{1}{2}\alpha t^2$		

LIST OF SELECTED FORMULAE – PAGE 2

43	$v = f\lambda$	63	$\gamma = 3\alpha$
44	$y(x,t) = A\, sin\, (\omega t \pm kx)$	64	$n = \frac{m}{M} = \frac{N}{N_A}$
45	$v_y = A\omega\, cos\, (\omega t \pm kx)$	65	$v_{rms} = \sqrt{< v^2 >}$
46	$y = 2A\, cos\, kx\ \ sin\, \omega t$	66	$v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$
47	$f_n = \frac{nv}{2L}$	67	$PV = \frac{1}{3} Nmv_{rms}^2$
48	$f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$	68	$P = \frac{1}{3}\rho v_{rms}^2$
49	$f_n = \frac{nv}{4L}$	69	$K_{tr} = \frac{3}{2}\left(\frac{R}{N_A}\right)T = \frac{3}{2}kT$
50	$v = \sqrt{\frac{T}{\mu}}$	70	$U = \frac{1}{2}fNkT = \frac{1}{2}fnRT$
51	$\mu = \frac{m}{L}$	71	$\Delta U = Q - W$
52	$f_a = \left(\frac{v \pm v_o}{v \mp v_s}\right)f$	72	$W = nRT\, ln\left(\frac{V_f}{V_i}\right) = nRT ln\left(\frac{P_i}{P - f}\right)$
53	$\sigma = \frac{F}{A}$	73	$W = \int P\, dV = P\left(V_f - V_i\right)$
54	$\varepsilon = \frac{\Delta L}{L_o}$	74	$W = \int P\, dV = 0$
55	$Y = \frac{\sigma}{\varepsilon}$		
56	$U = \frac{1}{2}F\Delta L$		
57	$\frac{U}{V} = \frac{1}{2}\sigma\varepsilon$		
58	$\frac{Q}{t} = -kA\left(\frac{\Delta T}{L}\right)$		
59	$\Delta L = \alpha L_o \Delta T$		
60	$\Delta A = \beta A_o \Delta T$		
61	$\Delta V = \gamma V_o \Delta T$		
62	$\beta = 2\,\alpha$		

QUANTITIES & SI UNITS

Quantities	Symbols used	SI Units	Quantities	Symbols used	SI Units
Displacement	s, x	m	Angular acceleration	α	$rad\, s^{-2}$
Velocities	u, v	ms^{-1}	Torque	τ	Nm
Accelerations	a	ms^{-2}	Moment of Inertia	I	$kg\, m^2$
Time	t	s	Angular Momentum	L	$kg\, m^2\, rad\, s^{-1}$
Momentum	p	$kg\, ms^{-1}$ or Ns	Period	T	s
Force	F	N or $kg\, ms^{-2}$	Wavenumber	k	$rad\, m^{-1}$
Work	W	J or Nm	Coefficient of thermal conductivity	k	$Wm^{-1}K^{-1}$
Energy	E		Coefficient of thermal expansion	α (linear) β (area) γ (volume)	K^{-1}
Power	P	W or $N\, ms^{-1}$	Molar mass	M	$kg\, mol^{-1}$
Angular displacement	θ	rad	Density	ρ	$kg\, m^{-3}$
Angular velocities	ω	$rad\, s^{-1}$			

Formal Assessments

Chapter	1	2	3	4	5	6	7	8	9
Assessment									
UPS 1									
UPS 2									
UPS 3									
Assignment	CHAPTER 6: ROTATION OF RIGID BODY								
Practical Test	SIMPLE HARMONIC MOTION EXPERIMENT								
PSPM Weightage (%)	3	12	17	10	5		29	10	14

Chapter 1: Physical Quantities & Measurements (mgy)

Question 1
Determine the S.I unit of impulse using dimensional analysis.

Question 2
Show that the expression $v = at$ is dimensionally correct, where v, a and t represent the speed, acceleration, and time interval of an object respectively.

Question 3
Verify the homogeneity of equation $a = \frac{1}{2}(u + v)t^2$ where a is acceleration, u and v are velocities, and t is time.

Question 4
Shown that the expression $A = \pi r^2$ is homogenous.

Question 5
A force F is given by $F = at + bt^2$, where t is the time. Find the dimension of 'a'.

Question 6
The pressure P of a liquid with density ρ and moving with velocity v is given by $P = a - bpv^2$? What is the dimension of b?

Question 7
Shafiq have a ladder that has a length of 5.5 m leaning against a building at an angle 65° to the horizontal. You climb from the bottom of the ladder to the top. How far do you move

i. horizontally?
[2.32m]

ii. vertically?
[4.98m]

Question 8
Two forces F_1 and F_2 acted upon a box resting on a floor. $F_1 = 50\ N$ acted horizontally to the left while $F_1 = 35\ N$ acted upwards. Determine the magnitude of the net force experienced by the box.
[$\mathbf{61.03\ N}$]

Question 9
Mr John walks 5 m at 50° north of east and then 15 m to the south. Calculate the resultant of vertical displacement.
[$\mathbf{11.17\ m}$; **downward**]

Chapter 2: Kinematics (sr)

Question 1

a. A ball is thrown horizontally from the top of a building of height 80m. The ball strikes the ground at a horizontal distance of 15m from the building. Calculate the

   i. the time of flight.
   [4.0386s]

   ii. initial speed of the ball.
   [3.7142ms^{-1}]

   iii. angle at which the trajectory of the ball makes with the ground just before the impact.
   [84.64^o]

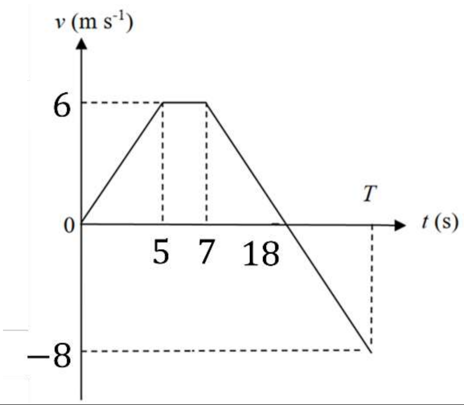
b. The speed of a car travelling along a straight road decrease uniformly from $26ms^{-1}$ to $12ms^{-1}$ over 75m. Calculate

   i. the deceleration of the car.
   [$-3.55ms^{-2}$]

   ii. the time taken for the speed to decrease from $26ms^{-1}$ to $12ms^{-1}$.
   [3.944s]

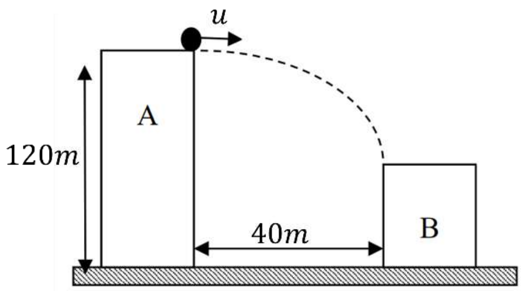
Question 2

The figure shows a graph of velocity against time for a remote-control car travelling along a straight smooth horizontal track. Sketch the displacement-time graph from 5s to 7s. Determine the value of T.
[32.67s]



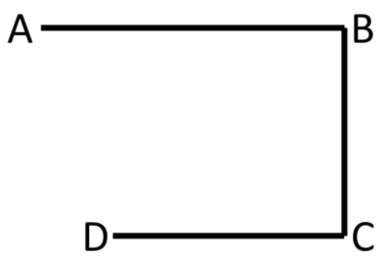
Question 3

The figure shows a ball is thrown from the top of the building A with an initial horizontal speed of u. The ball reaches the top of another building B after 2.4s. The height of building A is 120m. Calculate the initial speed, u of the ball and the height of building B.
[16.67ms^{-1}; 91.75m]



Question 4

The figure shows a pathway of a car. The car moves from A to B at $7ms^{-1}$ for 15s, then from B to C at $6ms^{-1}$ for 12s and finally from C to D at $8ms^{-1}$ 10s.



Calculate

a. the distance of each pathway passed by the car.
   [$\{105, 72, 80\}m$]

b. the displacement of the car
   [76.22m at -70.852^o]

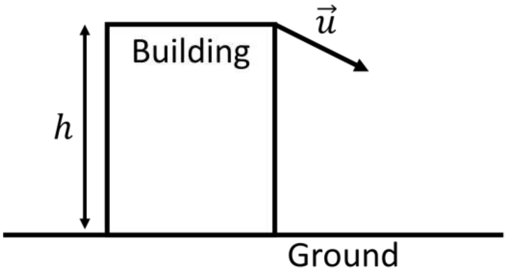
c. the average speed of the car
   [6.946ms^{-1}]

d. the average velocity of the car.
   [$2.06ms^{-1}$ at -70.852^o]

Question 5

In the figure shown, a ball is thrown from the edge of the roof at height h above the ground. The ball hits the ground $1.85s$ later at a distance $d = 30m$ from the building and at an angle 55^o with the horizontal. Calculate h and the initial velocity of the ball upon being thrown.

[26.074m; 16.98ms^{-1} at 17.20^o]



Question 6

a) A car moving from rest on a straight road and accelerates $2.5ms^{-2}$ until it reaches a velocity of $30ms^{-1}$. Then the car travels 300m at constant velocity before the brakes are applied. The car was stopped after 6.5s.

   i. How long did the car travel before it stopped?
   [28.5s]

   ii. Determine the average velocity of the car from rest until before the brakes are applied.
   [18.56ms^{-1}]

b) A cheetah running with a constant acceleration covers the distance between two points 90m apart in 6.7s. Its speed as it passes the second point is $15ms^{-1}$. Calculate the cheetah's speed at the first point.
   [11.866ms^{-1}]

Question 7

a) An athlete throws a shot at 40^o with the horizontal and the shot lands at a distance of 15.8m. Calculate the initial speed of the shot and the maximum height of the shot.
   [12.546ms^{-1}, 3.315m]

b) An object is thrown horizontally from the edge of a table with an initial velocity of $2.8ms^{-1}$. If the height of the table is 1.2m, calculate

   i. the final velocity of object before it reaches the floor.
   [5.6ms^{-1}]

   ii. the horizontal displacement of the object.
   [1.384m]

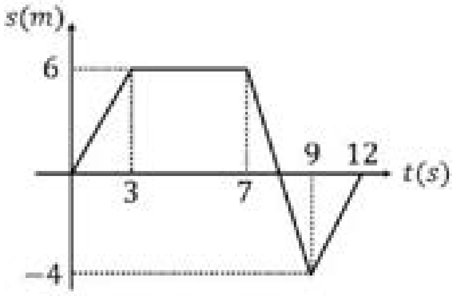
Question 8

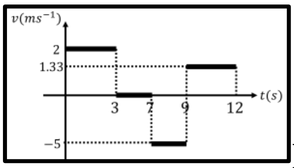
A package of supplies is dropped from a plane that is flying horizontally with a velocity of $55ms^{-1}$ at an altitude 200m. Calculate the time taken by the package to reach the ground and the speed of the package when it strikes the ground.

[6.383s; 83.3643ms^{-1}]

Question 9

The figure shows a displacement-time graph of a tricycle moving along x-axis. Calculate the instantaneous velocity at $t = 1.0s$ and sketch the velocity-time graph for the tricycle motion.

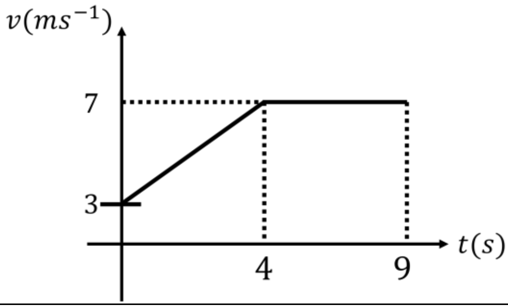


[2ms^{-1}; 

]

Question 10

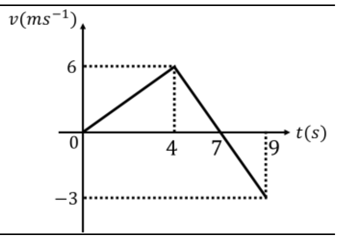
A bus moves linearly in the direction of positive x-axis. The graph in figure shows the bus's velocity as a function of time. Calculate the car's average velocity during the first 5 seconds? **[5.4ms^{-1}]**



Question 11

The figure shows velocity-time graph of the motion for a ball moving in a straight line. Determine the average acceleration of the particle for the whole journey.

[$-0.333ms^{-2}$]



Question 12

An arrow is launched with a velocity $23ms^{-1}$ at an angle of 45° to the horizontal from the roof of a building of height 40m. Determine

i. the maximum height reached by an arrow from the ground
[62.936m]

ii. the time taken for it to hit the ground.
[5.74s]

iii. the horizontal distance travelled.
[121.85m]

Question 13

A water rocket is launched upward from ground at speed $\boldsymbol{u}$. The rocket returns to the Ground 9.2seconds later. Determine

i. the value of $\boldsymbol{u}$?
[45.13ms^{-1}]

ii. maximum height can be achieved by the rocket.
[103.81m]

iii. velocity of the rocket just before it hits the ground.
[$-45.13ms^{-1}$]

Question 14

A person throws a ball with velocity $20ms^{-1}$ at angle of 30° above the horizontal. The distance between the initial velocity to the wall is 50m. What is the vertical velocity of the ball just before it hits the wall?

[$-18.322ms^{-1}$]

Question 15

A jet lands on an aircraft carrier at a speed of $68ms^{-1}$.

i. What is its acceleration if it stops in 1.8s due to an arresting cable that snags the airplane and brings it to a stop?
[$-37.78ms^{-2}$]

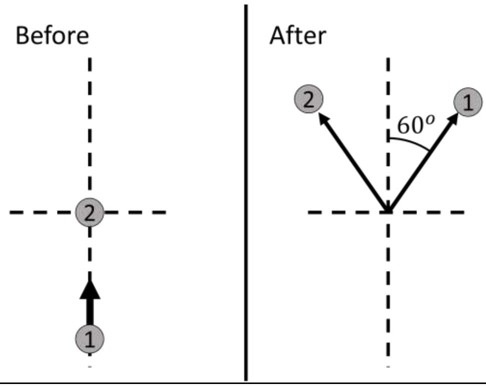
ii. If the plane touches down at front of the aircraft carrier (assume initial position when landing s = 0 m), what is the final position of the plane?
[61.196m]

Chapter 3: Dynamics of Linear Motion (sr)

Question 1

The figure shows ball 1 of mass 250g and velocity $5ms^{-1}$ collides obliquely with a stationary ball 2 of mass 450g. After the collision, ball 1 moves with velocity of 12 ms^{-1} at an angle 75° from its initial direction. Calculate the velocity of ball 2 after collision.

[6.53ms^{-1} at 9.26^o]

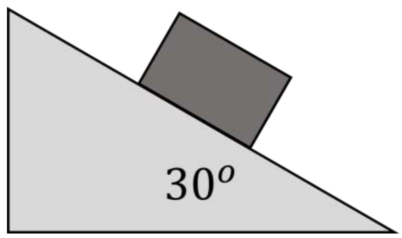


Question 2

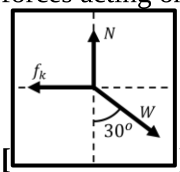
a. A bullet of mass 4g is fired horizontally with a velocity of 800 ms^{-1}. It hits a wooden block initially at rest and embedded inside it. Both of them move with a common velocity of $4.20ms^{-1}$. Determine the mass of the wooden block and the type of collision.

[$0.758kg$; $K_i \neq K_f \Rightarrow$ Inelastic]

b. A box of mass 4kg is placed on an inclined rough surface as shown in the figure shown. It is released from rest and accelerates at a constant rate of $3.2ms^{-2}$.



i. Sketch a free body diagram showing all forces acting on the box.

[**]**

ii. Determine the coefficient of kinetic friction.

[0.2]

Question 3

A 5kg body moves towards the west with a momentum of $45ms^{-1}$. A 30N force to the east acts on the body for a period of 12s. Determine the magnitude of

i. the impulse of the force

[360Ns]

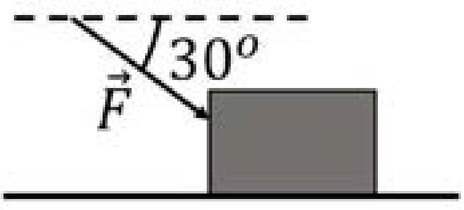
ii. the final velocity of the body.

[63ms^{-1}]

Question 4

A 30kg box is pushed at constant speed across a horizontal floor with a 20N force angled at 30^o below the horizontal, as shown in the diagram below. Sketch the free-body diagram of the box and calculate the reaction force on the box.

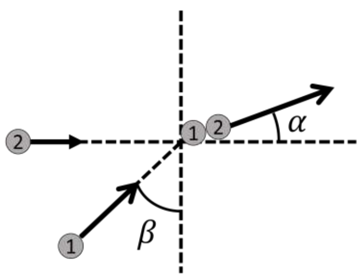
[304.3N]



Question 5

Suppose two identical balls collide obliquely as shown in the diagram and sticks together after the collision. Determine the velocities after the impact. Assume $u_1 = u_2 = 45ms^{-1}$ and $\beta = 35^o$.

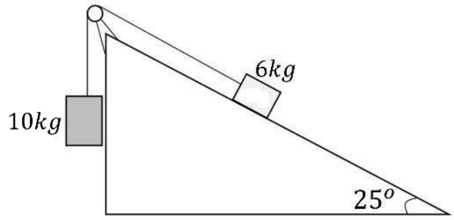
[$39.92ms^{-1}$ with $\alpha = 27.503^o$]



Question 6

Two boxes of mass 6kg and 10kg are connected by a light string that passes over a frictionless pulley as shown in the figure. The 6kg box is on a rough inclined plane of angle 25^o. If the coefficient of kinetic friction is 0.22, determine the acceleration and tension of the system.

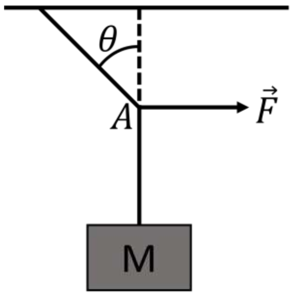
[59.667ms^{-2}; $T = 3.84N$]



Question 7

A 10kg mass is suspended by a 2m rope from the ceiling and 50N force is applied midpoint (point A) of the rope, as shown in the diagram. What is the angle the rope makes with the vertical in equilibrium?

[$\theta = 21^o$]



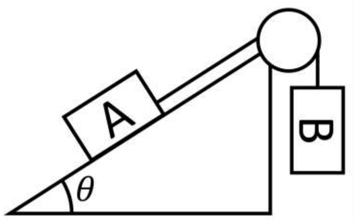
Question 8

a) A 6.2kg object moves towards the north with a momentum of $30kgms^{-1}$. A 4.1N force acts on the object in the south direction for a period of 30s. Determine the final speed of the object.
[$15ms^{-1}$]

b) A 25g bullet moving $275ms^{-1}$ to the right strikes a piece of wood. Assume that the bullet undergoes uniform deceleration and stops in 8s. Find the average force experienced by the bullet.
[0.86N]

Question 9

a) The figure shows a 18kg box A placed on a frictionless inclined plane at 30^o. The box is connected to a 12kg box B by a string through a pulley. Determine the acceleration of the system.
[0.981ms^{-2}]

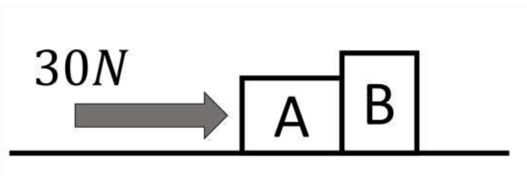


b) A 2.5kg ball is released from rest and falls under gravity through a height *h* from the ground. Just before it hits the ground, it is found that the ball has a velocity of 12.53ms^{-1}. Determine height of release, *h*.
[8m]

Question 10

The figure shows two wooden blocks A and B placed side by side on a smooth horizontal table. Blocks A and B weigh 350g and 700g respectively. A horizontal force of 30 N is applied on block A so that both blocks accelerate together. Determine the acceleration of the blocks. Find the force exerted on block B due to block A.

[31.58ms^{-2}; 22.11N]



Question 11

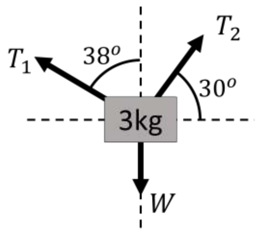
a. A 75N force is applied horizontally to a 15kg block resting on a table. After traveling 8.2m, the speed of the block is 6.1ms^{-1}. Calculate the coefficient of kinetic friction.
[0.28]

b. An object A of mass 2.1kg moves in a straight line and eventually collides with a stationary object B of mass 1.8kg. After the collision, the objects stick together and continue to move in the same direction. The system loses energy of 0.45J after the collision. Determine the velocity of A before the collision.
[0.671ms^{-1} or 1.186ms^{-1}]

Question 12

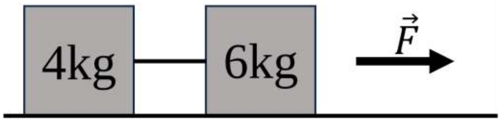
The figure shows a system is in equilibrium. Sketch free-body diagram and calculate the magnitude of T_1 and T_2.

[{25.74, 18.30}N]



Question 13

The figure shows two blocks of masses 4kg and 6kg are connected with each other via a string and moves with the same acceleration on a frictionless horizontal surface. A constant horizontal force 30N is applied to the block of mass 5 kg.



i. Find the acceleration of the blocks
[$3ms^{-2}$]

ii. Calculate the tension in the cord connecting them.
[$T = 12N$]

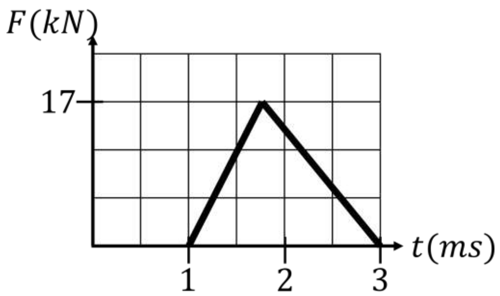
Question 14

An object of mass 420kg moves at a speed of $30ms^{-1}$ to the right. It breaks up into two parts, one having a mass of 55kg moving at a speed of $15ms^{-1}$ in the opposite direction. Determine the magnitude and direction of the velocity for the second part.

[to the right, 36.78ms^{-1}]

Question 15

A force-time curve for a ball struck by a bat is shown in the figure.



From this curve, determine

i. the impulse delivered to the ball,
[$17Ns$]

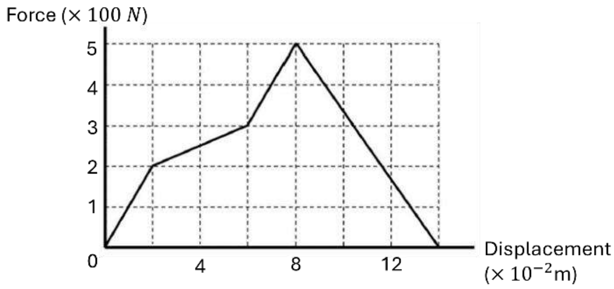
ii. the average force exerted on the ball.
[8500N]

Chapter 4: Work, Energy & Power (jl)

Question 1

The figure shows a force-displacement graph for an object is being pushed along a certain distance. Determine the work done from the graph.

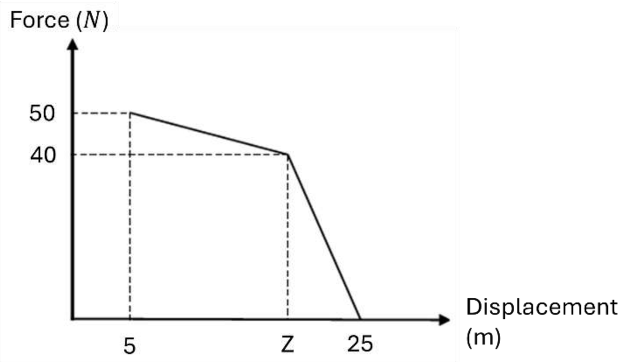
[35 J]



Question 2

The force applied to a body versus its displacement is shown in the graph. Determine the value of Z if the work done by the force applied is 700J.

[Y=17 m]

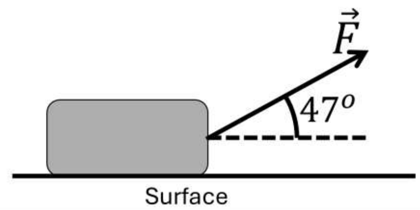


Question 3

The figure shows a block of mass 60kg pulled by a constant force, $F = 200N$ on rough surface at an angle of 47° to the horizontal.

Calculate the net work done on the block is the block moves 20m and the frictional force between the block and the surface is 70N.

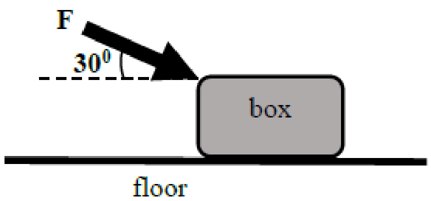
[1327.99 J]



Question 4

The figure shows a box being pushed by a constant force, F of 35N, at an angle of 30° with the horizontal. The kinetic frictional force between the box and the floor is 10N. How much total work is done if the box is pushed through 6m?

[121.87 J]



Question 5

A block of mass 2kg is pushed 2.5m along a frictionless horizontal table by a constant 20N force directed 30° above the horizontal. Calculate the work done by

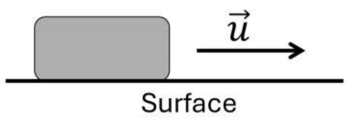
i) the applied force. **[43.30 J]**

ii) the force of gravity. **[0 J]**

Question 6

A 500g block is shot on the surface in the figure shown with an initial speed of $2ms^{-1}$. How far will it go if the coefficient of friction between it and the surface is 0.250?

[0.8155 m]



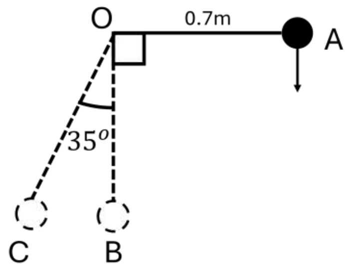
Question 7

The figure shows a pendulum of length 0.7m with a bob of mass 0.14kg is released from rest at A.

Calculate the

(i) speed of the bob at B.
[3.71 m s^{-1}]

(ii) potential energy of the bob at C.
[0.179 J]

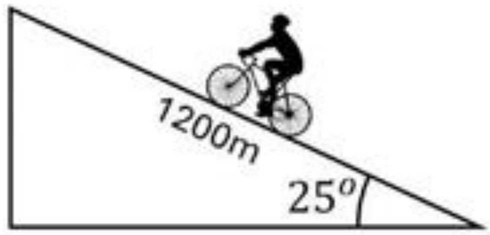


Question 8

The figure shows cyclist travels 1.2km along the steep road of angle 25° at an average speed of $4.5ms^{-1}$ during the mountain stage of the Tour de Langkawi. The mass of the cyclist and bicycle is 70kg.

Calculate the total mechanical energy of the cyclist and bicycle at the end of the finishing line.

[5.81$\times 10^5 J$]



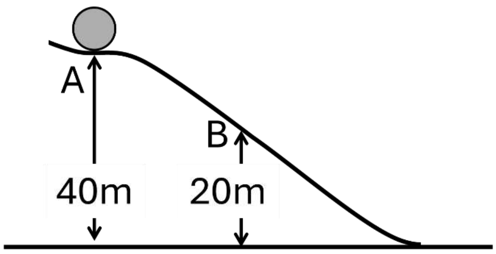
Question 9

A ball of mass 4kg initially at rest slides along a smooth and curvy surface as shown in figure.

Calculate

(i) the potential energy of the sphere at point A
[1569.6 J]

(ii) The speed of the sphere as it passes point B
[19.81 ms^{-1}]



Question 10

A horizontal spring attached to a wall has a force constant of $850Nm^{-1}$. A block of mass 1.5kg is attached to the opposite end of that spring and rests on a frictionless horizontal spring. The block is pulled to a position of 6.0cm from equilibrium and released. Calculate the speed of the block as it passes through the equilibrium point.

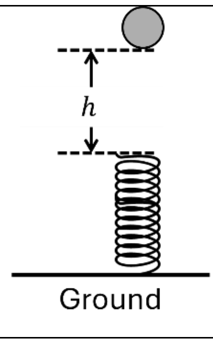
[1.43 m s^{-1}]

Question 11

An object of mass 2.0kg is placed 30cm directly above the top end of a vertical spring as shown in the figure. It is then released from that height. The spring constant $k = 20Nm^{-1}$.

i) Calculate the speed of the object just before it strikes the spring.
[2.43 m s^{-1}]

ii) Determine the maximum compression, *x*.
[0.768 m]



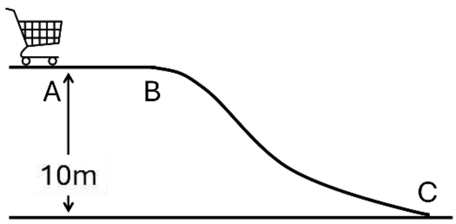
Question 12

In the figure shown, a small shopping cart of 8 kg moves on the frictionless track with a speed of 20 m s^{-1} along **AB** and down to **C**. Calculate the

i) kinetic energy of the cart as it moves along **AB.**
[1600 J]

ii) potential energy of the cart at point **B**.
[784.8 J]

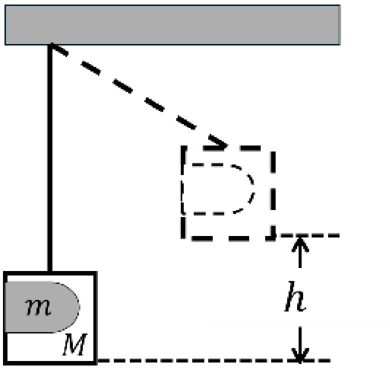
iii) speed of the cart at point **C**.
[24.42 m s^{-1}]



Question 13

In a block-bullet experiment, h = 5.0cm, m = 5.0g and M = 1kg. Find the common velocity after the bullet embedded into the block, v.

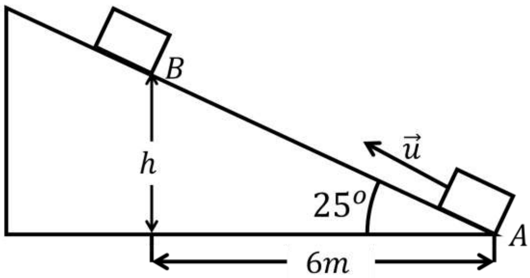
[0.981 m s^{-1}]



Question 14

An object of mass 2kg moves up a rough inclined plane with an initial velocity of $14.14ms^{-1}$, which makes an angle 30° with the horizontal. The coefficient of kinetic friction between the object and the plane is 0.20. Using the work-energy theorem, calculate the kinetic energy of the object at point B if the height $h = 1.5m$.

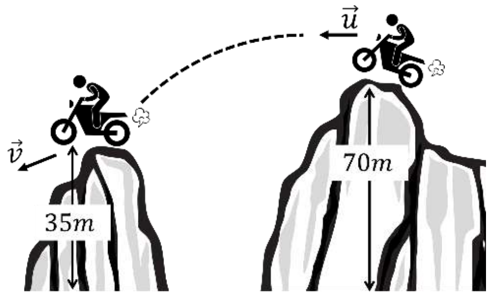
[160.32 J]



Question 15

A daredevil on his bike is trying to leap across the canyon shown in the figure by driving horizontally off the cliff at a speed of $38ms^{-1}$. By ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.

[48.39 J]



Question 16

A 65 kg man climbs up a staircase of total height 342m in 30 minutes. Calculate the average power exerted by the man. **[121.15 W]**

Question 17

An electric powered machine pulls a rope tied to a wooden crate fully loaded with fruits upward at a constant speed of $0.25ms^{-1}$. The electric power used is 68W. What is the tension in the rope?

[272 *N*]

Question 18

A 5kg block is placed on a horizontal rough surface. If the coefficient of friction is 0.30, calculate the power required to pull the block at a constant speed of $1.25ms^{-1}$.

[18.39 W]

Question 19

A 10kg box is lifted through a vertical distance of 15m in 5s with constant velocity. Calculate the applied power to lift the box.

[294.3 W]

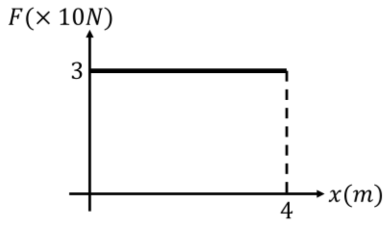
Question 20

A 0.25hp motor is used to lift a load at the rate of $5.0cms^{-2}$. Determine the mass of the load at this constant speed? [1 hp = 746 W]

[380.22 kg]

Question 21

A person applies a horizontal force to a stationary 40kg box and pushes it from point A to point B. The figure shows variations of horizontal force exerted by the man versus the displacement of the box during the process.

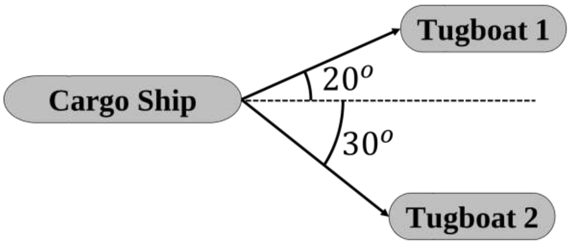


i) Determine the work done by the applied force to displace the box from point A to point B.
[120 J]

ii) Calculate the velocity at point B using work-energy theorem.
[2.45 m s^{-1}]

Question 22

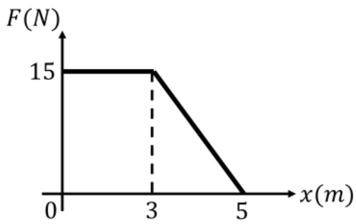
a. Two tugboats tow a cargo ship. Each tug exerts a constant force of $7.5 \times 10^6 N$ in the direction of 30^o and 20^o as shown in the figure. They pulled the tanker 1.25 km along the horizontal line. What is the total work they do on the oil tanker?
[$1.693 \times 10^{10} Ns$]



b. An electric powered machine pulls a rope tied to a wooden crate fully loaded with bricks upward at a constant speed of $0.34ms^{-1}$. The electric power used is 68W. What is the tension in the rope?
[200N]

Question 23

The graph in the figure shows how the force *F* on a body of mass 8 kg varies with displacement from the origin.

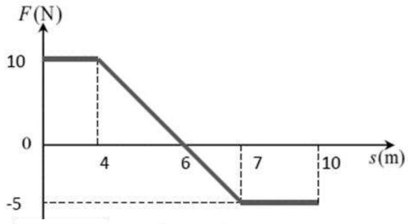


i. What is the work done by the force when the body is displaced 5.0 m from the origin?
[60 J]

ii. The velocity of the body at the origin is 6.0 m s-1. What its velocity when it is 5.0 m from the origin?
[7.14 m s^{-1}]

Question 24

An object of mass 2.0 kg travels along horizontal floor under the action of force, F. The figure shows the graph of force, *F* against displacement, *s*. The speed of the object at *s* = 0 is $10ms^{-1}$. Determine the kinetic energy of an object at *s* = 10 m. **[132.5 J]**



Question 25

An object with a mass of 5 kg is lifted vertically upwards by 10m in 2s. Calculate the

(i) work done by gravity on the object.
[$-490.5J$]

(ii) potential energy gained by the object.
[$490.5J$]

(iii) average power exerted to lift the object.
[$245.25W$]

Question 27

a) A winch accelerates a 250kg crate at $0.5ms^{-2}$ upwards. If the crate travels a total of 4m,

i. Calculate work done by the winch. **[10310Ns]**

ii. Determine work done by gravity. **[-9810Ns]**

iii. Find total work done on the lift. **[500Ns]**

b) A 9000W engine propels a boat at $15kmh^{-1}$. How much force is water resistance exerting on the speedboat? **[2160W]**

Chapter 5: Circular Motion (sr)

Question 1

The diameter of curvature of a bend along a level road is 25m. The coefficient of friction between the road and tyres of vehicle is 0.45.

i. Calculate the maximum speed such that the vehicle can go around the bend safely. **[7.43ms^{-1}]**

ii. Discuss how the maximum speed is affected in a wet road condition.
[small μ, small v_{max}]

Question 2

a. A High-Volume Low Speed fan with diameter of 480cm is used in order to circulate air. If this fan is spinning with angular velocity 240rpm, calculate the

i. frequency of the motion
[4Hz]

ii. centripetal acceleration of the tips of fan blade.
[$1515.97 ms^{-2}$]

b. A car is making a turn at a 45m radius roundabout. The coefficient of friction between the tyres of the truck and the road is 0.5. Calculate the maximum speed so the car can make a turn without skidding.
[14.86ms^{-1}]

Question 3

An elder sibling places his 30kg younger sister on a 8kg cart to which a 1.8m long rope is attached. He then holds the end of the rope and spins the cart and child around in a horizontal circle, keeping the rope parallel to the ground. If the tension in the rope is 150 N and rolling friction between the cart's wheels and the ground is negligible, determine the speed of the cart during the motion and the revolutions per minute that the cart makes.
[2.67ms^{-1}; 14.165rpm]

Question 4

A conical pendulum bob has a constant speed of $3ms^{-1}$. If the pendulum bob traces a circular path of 40cm diameter, determine the angle the string makes with the vertical.
[77.7^{o}]

Question 5

A 0.5kg ball attached to the end of a string is rotated in a horizontal circle of diameter 2m on a frictionless table surface. Calculate the maximum speed of the ball if the string snaps when the tension exceeds 50N.
[10ms^{-1}]

Question 6

A swing ball game moving in a circular motion at a radius of 0.8m. If the ball completes one full circle in 2.1s.

i. Calculate the centripetal acceleration of the ball.
[$7.162ms^{-2}$]

ii. If a new 900 g swing ball is used and completes the same circle in 3 minutes, calculate the centripetal force of the circular motion.
[0.88mN]

Question 7

A toy train moving at a constant speed completes one lap around a 210cm circular track in 7s.

i. Calculate the speed of the car.
[0.3ms^{-1}]

ii. Determine the magnitude of the centripetal force that keeps the car in a circle if its mass is 1.5 kg.
[0.404N]

Question 8

Car A and Car B travels in a uniform circular motion around a circular racetrack with a centripetal acceleration of α_A and α_B respectively.

a. Determine the ratio $\frac{\alpha_B}{\alpha_A}$ is velocity of car A is one-third of car B. **[$\frac{1}{9}$]**

b. If the mass of car B is 1200kg and the radius of the racetrack is 200m, calculate the static friction between car B tyres and the track such that the car achieves a speed of $60ms^{-1}$. **[21.6kN]**

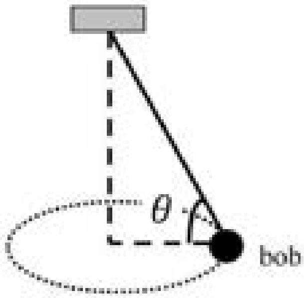
Question 9

a. A 0.8kg object is swung in a vertical circular motion on a string 0.75m long. If its speed is $4ms^{-1}$ at the top of the circle, what is the tension of the string there? **[9.22N]**

b. A conical pendulum with a bob of mass 0.35kg and a 0.7m string swings in a horizontal circle of diameter of 0.5m as shown in the diagram.

   i. Find the angle θ which the string makes with the horizontal axis. **[69.075^o]**

   ii. Find the tension in the string. **[5.25N]**



Question 10

A 0.25kg mass is tied at the end of a 2m light inextensible string. What is the tension T of the string at the top and bottom of the circle if the mass makes one revolution in one second?

[17.2867N; $22.1917N$]

Chapter 7: Oscillations and Waves (mgy)

Question 1

An object undergoes a simple harmonic motion according to the following equation:

$$y = 10\sin(2.2t)$$

where y is in centimetre and t is in seconds. At $t = 3\ s$, determine the object's

i. displacement
[3.11cm]

ii. velocity
[$20.91ms^{-1}$]

iii. acceleration
[$15.08cms^{-1}$]

Question 2

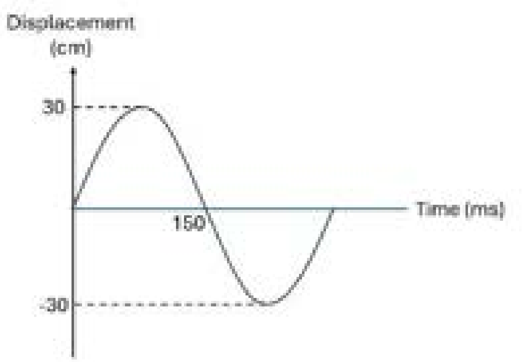
An object is executing a simple harmonic motion with an amplitude of $20cm$ and a maximum acceleration of 10.5 ms^{-2}. Calculate

i. the period of the motion
[0.79s]

ii. the speed of the object when it is at 5cm from the amplitude
[$1.53ms^{-1}$]

Question 3

The figure shows the displacement of a particle undergoing a simple harmonic motion.



i) Determine the angular frequency of the motion.
[$20.94\ rad\ s^{-1}$]

ii) Sketch velocity against time graph for the particle.

Question 4

A spring is mounted horizontally, with its right end held stationary and a 0.43 kg body is attached to the left end. The body is freely oscillating with a period of 0.75s and maximum displacement is 3cm.

i) Calculate the spring constant.
[$30.17\ Nm^{-1}$]

ii) Calculate the angular frequency of the oscillation.
[$8.38\ rad\ s^{-1}$]

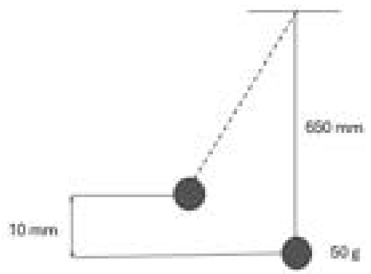
iii) Write the equation of the motion of the body.

iv) Calculate the velocity and acceleration of the body at displacement 0.015 m.
[$0.22\ ms^{-1}$; $-1.05\ ms^{-2}$]

v) Calculate the kinetic and potential energies at maximum displacement.
[$0\ J$; $0.014\ J$]

Question 5

A simple pendulum consists of a 50g mass tied to the end of a light string 650mm long. The mass is drawn to one side until it is 10mm above its rest position, as shown in the figure. When released, it swings with simple harmonic motion.



i. Calculate the frequency of the pendulum
[$0.62Hz$]

ii. Calculate the maximum speed of the mass during the first oscillation.
[$0.44\ ms^{-1}$]

iii. Sketch a graph of kinetic energy against displacement.

Question 6

Two progressive waves in a long string are given by,

$$y_1 = 0.01\sin\left(25t - \frac{x}{3}\right)$$
$$y_2 = 0.01\sin\left(25t + \frac{x}{3}\right)$$

Where y_1, y_2 and x are in meters and t in seconds.

i) Determine the expressions for the new wave when both waves are superimposed.

ii) Calculate the wavelength of the progressive waves.
[$4\pi m$]

Question 7

Two identical sinusoidal progressive waves travelling in opposite directions undergoes superposition to produce a standing wave with the wave function.

$$y = 5\cos(0.5x)\sin(50t)$$

Where y and x are in meters and t in seconds. Determine

i) the amplitude of the standing wave
[5m]

ii) the amplitude of the progressive wave
[2.5m]

iii) the maximum velocity of the wave
[$250ms^{-1}$]

iv) the distance between two consecutive antinodes
[6.28m]

Question 8

The water waves in Tasik Biru is represented by the equation.

$$y = 0.70\sin(40t - 3.5x)$$

Where x and y are in meters and t is in seconds.

i) Calculate the velocity of the water waves.
[$\mathbf{11.43\ ms^{-1}}$]

ii) A surfer is surfing on the water waves in Tasik Biru. When the surfer is at the position x = 1.6 m at the instant t = 60 s, determine the displacement of the surfer and the speed of the surfer.
[$\mathbf{0.34m; 23.19ms^{-1}}$]

iii) Write an equation which represents the water waves in Tasik Danu which have the same frequency as the water waves in Tasik Biru but the amplitude is half of that in Tasik Biru and propagates at a speed twice of that in Tasik Biru in the opposite direction.

Question 9

A 1.36m long horizontal tube with both ends open produces a loud sound of frequency 750Hz when a vibrating tuning fork is placed at one end of the tube. The loud sound occurs at the fifth overtone.

i) Sketch and label the standing waveform in the tube.

ii) Calculate

a. the speed of sound in the tube.
[$340ms^{-1}$]

b. the new fundamental frequency of the sound if one end of the tube is closed.
[$62.5\ Hz$]

Question 10

When a guitarist plucked a guitar, the string vibrates with a velocity of $450\ ms^{-1}$ to a tension of $850\ N$, it produces a fundamental frequency of $500\ Hz$. Calculate the mass and the length of the string. [$\mathbf{0.45\ m\ ;1.89\ \times 10^{-3}\ kg}$]

Question 11

A guitar string is tied down at both ends and placed under a tension of 200 N. A guitarist plucks the string of length 50cm and mass of 0.5g to produce its fundamental frequency.

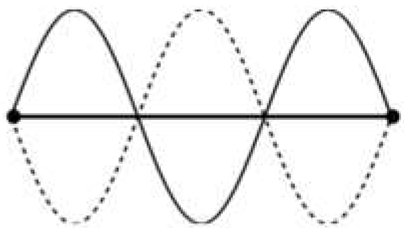
i) Sketch the stationary wave pattern formed in the guitar string at its fundamental frequency. Label all the nodes and antinodes at their respective positions.

ii) Calculate the fundamental frequency.
$\mathbf{[447.21N]}$

iii) The same length of string with different mass 4.0g is replaced into the guitar under the same tension. Explain quantitatively, what will happen to the fundamental frequency formed?
$\mathbf{[158.11N]}$

Question 12

Two sinusoidal waves with the same amplitude and wavelength travel in opposite direction along a string that is stretched along an axis. Their resultant wave is shown in the figure. The node-antinode distance is $4cm$. The mass of the string is $40g$ and the tension force applied is $55N$. Determine



i) the speed of waves travelling along the string.
$\mathbf{[17.99ms^{-1}]}$

ii) the wavelength and frequency of the standing waves formed.
$\mathbf{[0.16\,m\,;\ 112.44\,Hz]}$

Question 13

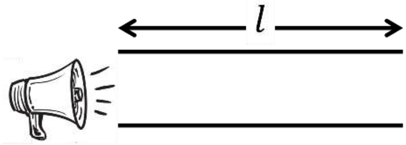
A copper wire of mass 400g and length 5.0m has one of its ends fixed to a wall and the other end is forced to vibrate transversely with a frequency of 250 Hz. If the tension of the wire is 140N, calculate

i) the speed and wavelength of the progressive wave produced.
$\mathbf{[41.83ms^{-1}; 0.17m]}$

ii) the number of harmonics for stationary wave produced.
[59]

Question 14

The figure shows a loudspeaker emitting sound wave of 550Hz in front of an open pipe of length, l. The air column resonates at its fifth harmonics. Given the speed of the sound in air is 340 ms^{-1}. Calculate



i) the length of the pipe, l
[1.55m]

ii) the wavelength of the sound wave in the air column.
[0.62m]

iii) the first overtone frequency.
[219.35Hz]

Question 15

A lorry producing 1.50kHz waves moves towards a stationary listener at one-half the speed of sound. Determine the apparent frequency of the sound wave heard by the listener when the lorry moves toward him? Given the speed of the sound in air is 340 ms^{-1}.
[3000Hz]

Question 16

An ambulance emits siren frequency 1050Hz. The speed of sound is 340 ms^{-1}. The ambulance travel at 45 ms^{-1} towards a stationary listener and rides away. Determine the change in the apparent frequency detected by the listener.
[282.9Hz]

Question 17

Misinah standing at a bus stop when the police motorcycle with velocity 47 ms^{-1} emitting siren with frequency 650 Hz pass through her. If the speed of sound in air is 340 ms^{-1}, calculate the frequency heard by Misinah when it is

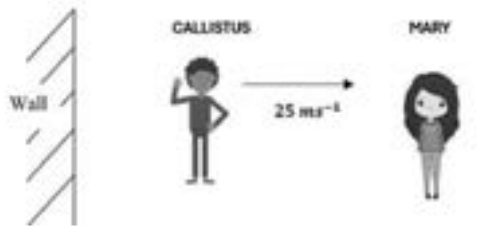
i) Approaching her
$\mathbf{[754.27Hz]}$

ii) Moving away from her

[$571.06Hz$]

Question 18

The figure shows that Mary is standing still. Callistus is walking towards Mary away from the wall with speed $25\ ms^{-1}$ while talking to her. Callistus emits a frequency of 600 Hz. The speed of sound in air is $340\ ms^{-1}$. Determine



i) The apparent frequency heard by Mary directly from Callistus.
[$647.62Hz$]

ii) The apparent frequency heard by Mary due to reflection of the wall
[$\mathbf{558.9\ Hz}$]

Question 19

A train that has a 200 Hz horn is moving at $45\ ms^{-1}$ in still air on a day when the speed of sound is $340\ ms^{-1}$. Calculate the

i) Frequencies observed by a stationary person at the side of the tracks as the train approaches and after it passes.
[$\mathbf{230.51Hz; 176.62Hz}$]

ii) Frequency observed by the train's engineer traveling on the train.
[200Hz]

Chapter 8: Physics of matter (jl)

Question 1

A copper wire (of Young Modulus, Y=1.30 × 10^{11} Pa) with initial length of 0.766m and cross-sectional area 3.85 × 10^{-7} m^2 is stretched until it reaches 0.777 m. Calculate the force applied to the wire.

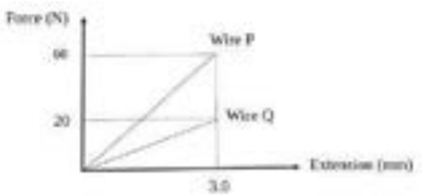
[560.05 *N*]

Question 2

A 10kg load is attached to a vertical 2.0m steel wire causes the wire to extend by 0.60mm. If the Young's modulus of steel is 200 GPa, calculate the extension of the wire causes by another 4 kg load added to the system.

[2.4 x 10^{-4} m]

Question 3



The figure shows the force-extension graphs of two wires P and Q of the same material. Both wires have the same length of 2m but different diameters. If the diameter of wire P is 0.60mm, determine the diameter of wire Q.

[3.46 x 10^{-4} m]

Question 4

A load of 10kg hangs from a steel wire with a length of 4.50m and cross-sectional area of 1.50mm^2. The Young's modulus of steel is 190GPa. Calculate

(i) the stress.
[6.54 x 10^7 N m^{-2}]

(ii) the strain energy per volume in the wire.
[1.13 x10^4 J m^{-3}]

Question 5

A load of 3kg hangs from a steel wire with a length of 1.50m and experiences a strain of 2.15 × 10^{-5}. The Young's modulus of steel is 200GPa. Calculate the diameter of the wire when subjected to this load.

[2.95 x 10^{-3} m]

Question 6

A copper wire with initial length of 0.75m and cross-sectional area of 2.75 × 10^{-7} m^2 is stretched until the strain in the wire is 0.015. If the Young's Modulus for copper is 1.30 × 10^{11} Pa, calculate

(i) the force applied
[536.25 Pa]

(ii) the strain energy in the wire
[3.02 J]

Question 7

A 2.5 m length of copper wire with a diameter of 0.4 mm is suspended from the ceiling. When a 5.0 N load is suspended from the bottom of the wire, it extends by 0.9 mm. Calculate the

(i) stress on the wire.
[5.09 x 10^7 Pa]

(ii) strain energy stored in the wire.
[2.50 x 10^{-3}]

Question 8

In steady state, a well-insulated copper rod of length 30.0cm and diameter of 1.8cm. One end held at 100 °C while the opposite end remains at 0 °C. Calculate the rate of heat flow through the rod.
[Thermal conductivity copper is 380 $W\ m^{-1}\ K^{-1}$]

[32.23 *W*]

Question 9

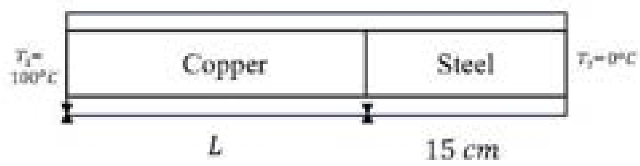
A 55 m^2 composite wall of a building consists of brick and concrete with the thickness of 20.0 cm and 40.0 cm respectively. The temperature of the outside surface of the brick and concrete is 50 °C and

25 °C respectively. Given coefficient of the thermal conductivity of brick and concrete are 0.6 W m^{-1} $^oC^{-1}$ and 0.8 W m^{-1} $^oC^{-1}$ respectively.

(i) Determine the temperature of the interface between the brick and the concrete.
[40^{o}C]

(ii) How much heat flows through the concrete in 2 hour?
[11.88 x 10^6 J]

Question 10

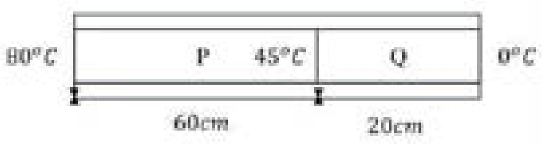


The figure shows two insulated plates, one made of copper and the other of steel, each with an area of 50.0 cm² and joined together at their ends. The steel rod has a length of 15 cm, while the copper rod has a length of L. At the steady state, the temperatures at the ends of copper and steel are T_1 = 100 ^{o}C and T_2 = 0 ^{o}C and temperature at the joint is 60 ^{o}C. Given the thermal conductivity for both plates are k_{copper} = 380 W m^{-1} $^oC^{-1}$ and k_{steel} = 46 W m^{-1} $^oC^{-1}$.

(i) Calculate the temperature gradient of the steel rod.
[-400 ^{o}Cm^{-1}]

(ii) Determine L.
[82.6 cm]

Question 11



Metal rods **P** and **Q** are well insulated as in the figure shown. The thermal conductivity of metal rods **P** and **Q** are k_P and k_Q respectively. Calculate the value of $\frac{k_P}{k_Q}$? **[2.0]**

Question 12

A metal coin having a coefficient of linear expansion 4.0 × 10^{-5} °C^{-1} with diameter of 3.00 cm at a temperature of 30 ℃, determine the coin's diameter when the temperature is raised to 80 ℃.
[3.006×10^{-2} m]

Question 13

A sheet of aluminium has an initial area of 555cm² when the temperature is 10°C. If the linear expansion coefficient for aluminium is 2.5 × 10^{-5} °C^{-1}, what is the final temperature when the area of the sheet becomes 666cm^2?
[8010 ^{o}C]

Question 14

A glass container is initially filled with 400 cm³ of a liquid at a temperature of 30°C. The coefficient of volume expansion for the liquid is 6.0 × 10^{-4} °C^{-1} and the coefficient of volume expansion for the glass is 5.0 × 10^{-6} °C^{-1}. Calculate the volume of overflow when the temperature of both glass and liquid reaches 90°C.
[14.28 m^3]

Question 15

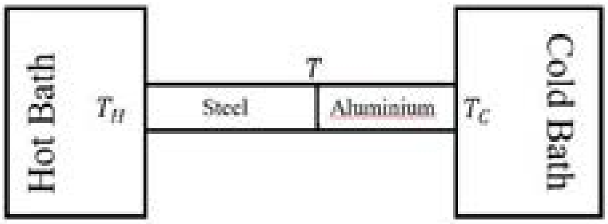
A steel rod has a length of 0.8 m and a cross-sectional radius of 2.0 cm when the temperature is 25 °C. Take α = 12 × 10^{-6} K^{-1} and Young's modulus of the rod to be Y = 250 × 10^9 Nm^{-2}.

(i) What is its change in length on a hot day when the temperature is 50 °C?
[1.92 x 10^{-4} m]

(ii) If the rod's ends were originally fixed, then determine the compression force on the rod.
[1.21 x 10^5 N]

Question 16

(i) A steel bar is welded to an aluminium bar of the same dimension. The other end of the steel bar is placed in a hot bath of temperature T_H while the end of the aluminium bar is placed in a cold bath of temperature T_c as shown in the figure. The system is in steady state and is properly insulated. Determine the temperature T at the interface of the steel- aluminium bar in terms of T_H, Tc, k_A (thermal conductivity of aluminium) and k_S (thermal conductivity of steel).



[$\boldsymbol{T = \frac{k_A T_H + k_S T_C}{k_A + k_S}}$]

(ii) At 30°C, the length of the steel bed of a suspension bridge is 150 m. The coefficient of linear expansion of steel is 12×10^{-6} °C^{-1}. If the extreme temperatures to which it is exposed are −10°C and 50°C, determine the maximum linear contraction and maximum linear expansion.

[0.072 m, 0.036 m]

Chapter 9: Kinetic Theory of Gases and Thermodynamics (jl)

Question 1

The root mean square speed of helium gas is 1140 m s^{-1}. The pressure of the gas is tripled, while the volume and the number of moles of the gas are kept constant. Calculate the

i new root mean square speed of the gas.

[1.97 x 10^3 m s^{-1}]

ii new temperature of the gas if the molar mass of helium gas is 4 g mol^{-1}.

[625.56 K]

Question 2

An ideal gas has a molar mass of 46 g mol^{-1}. Calculate the root mean square speed of the molecules at -20°C.

[377.29 m s^{-1}]

Question 3

The RMS speed of helium at STP is 2.5 km s^{-1}. Determine the density of helium at STP if the pressure at STP is 1.01 x 10^5 Pa.

[0.076 kg m^{-3}]

Question 4

A gas of mass 345g is held in a square container with a volume of 0.60m^3 at a pressure of 1.8 x 10^5 Pa. Determine the root mean square speed of the gas molecules.

[969.09 ms^{-1}]

Question 5

Calculate the pressure exerted by hydrogen gas if the density of hydrogen gas is 0.1kgm^3 and rms speed of hydrogen molecule at that pressure is 1.65$km\, s^{-1}$.

[9.08 x 10^4 Nm^{-2}]

Question 6

A 2mol hydrogen gas has a temperature of 410K. Assuming the gas behaves ideally, calculate the internal energy of the gas.

[10221 J]

Question 7

A closed cylinder contains 0.2mole of nitrogen gas. What is the internal energy, U, of the system if the root mean square velocity of nitrogen molecules is 650ms^{-1}?

Molar mass of nitrogen= 28$gmol^{-1}$.

[11830 J]

Question 8

A 1.6mol ideal monoatomic gas is stored in a container at 27°C. Calculate the

(i) translational kinetic energy per molecule.

[6.21 x 10^{-21} J]

(ii) internal energy of the gas.

[5. x 10^3J]

Question 9

A cylinder of volume 0.06 m^3 contains oxygen gas at a temperature of 280 K and pressure of 100 kPa. Calculate the

(i) root mean square speed of the oxygen molecules in the cylinder.

[750 ms^{-1}]

(ii) mass of oxygen in the cylinder.

[82.5 g]

(iii) translational kinetic energy of an oxygen molecule.

[5.80 x 10^{-21} J]

[Given: molar mass of oxygen = 32 g mol^{-1}]

Question 10

An ideal polyatomic gas of molar mass 46 g mol^{-1} is cooled from 35 ºC to –8 ºC at constant volume 80L. If there are 1000 moles of the gas, determine the

(i) root mean square speed of the molecules at −10 ºC.
[377.53 m s^{-1}]

(ii) change in its internal energy.
[-5.36 x 10^5 J]

Question 11

The temperature in outer space is about 5.3K with about one hydrogen molecule per cm^3. The mass of a hydrogen molecule is 4.57 x 10^{-27} kg. Calculate the

(i) rms speed of the hydrogen molecules.
[219.2 m s^{-1}]

(ii) hydrogen density in outer space.
[4.57 x 10^{-21} kg m^{-3}]

(iii) pressure of hydrogen gas at the outer space.
[7.32 x 10^{-17} N m^{-2}]

(iii) mean translational kinetic energy of the hydrogen molecules.
[7.25 x 10^{-22} J]

Question 12

A gas confined in a container undergoes a thermodynamic process where it absorbs 2500 J of heat from its surroundings. If the internal energy decreases by 1300 J calculate the work done by the gas during the process.

[3800 J]

Question 13

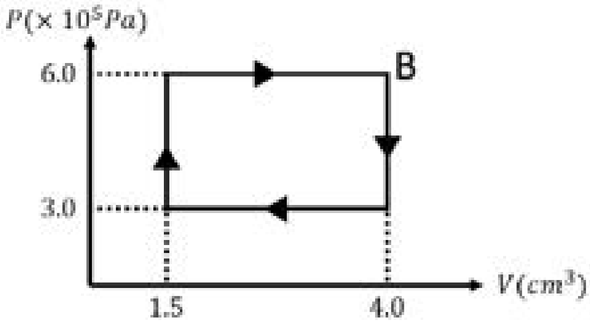
A system absorbs 1380 J of heat and at the same time 520 J of work is done on it. Calculate the change in internal energy of the system.

[1900 J]

Question 14

The graph shows a monoatomic gas that contained in a piston undergoes various processes. Determine its internal energy at point B.

[3.6 J]

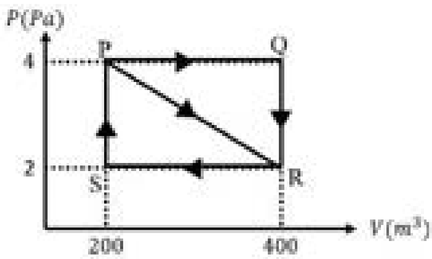


Question 15

The figure shows a $P-V$ graph of an ideal gas. If the change of an internal energy from **P** to **R** is +300 J. Determine

i) the work done by the system during the process of R to S
[-400 J]

ii) the heat energy during the process RSP
[-700 J]

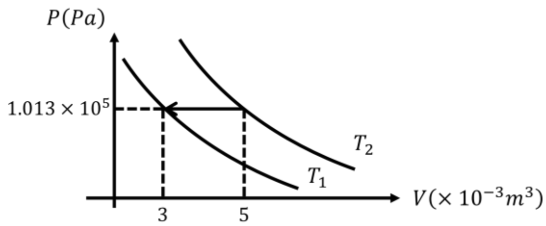


Question 16

A gas is compressed at a constant pressure of 1atm from 5L to 3L. In the process, 500 J of heat is leaving the gas.

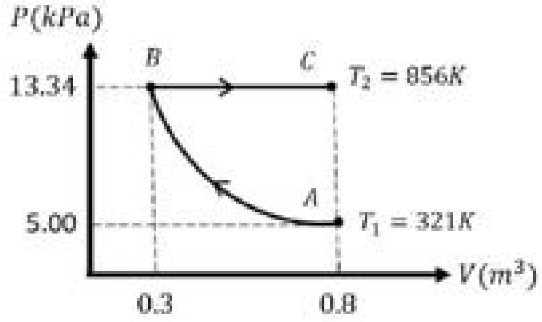
(i) Sketch a P-V graph for the process.

(ii) Calculate the change in internal energy.
[-297.4 J]



Question 17

The figure shows a 1.5 mole diatomic gas is filled in a 0.8 m^3 container at 321 K and pressure of 1.45 kPa. The gas is isothermally compressed to a volume of 0.3 m^3 and a pressure of 3.22 kPa. Then the gas expands isobarically to its original volume, and the final temperature of the gas is 500 K. Calculate the



i total work done in the whole process.
[-245.4 J]

ii change in the internal energy of the gas for the isobaric process.
[1.67 x 10^4 J]

Question 18

Three moles of an ideal gas are compressed isothermally from 900 cm^3 to 300 cm^3 at 100 °C. What is the work done on the gas?

[-10215.9 J]

Question 19

A 1.5 mol gas is compressed at a constant temperature of 222 K from 9 L to 5 L.

(i) State the type of thermodynamic process.
[Isothermal compression]

(ii) Calculate the work done on the gas.
[-1626.54 J]

(iii) Calculate the heat transferred during this process.
[-1626.54 J]

===End of Workbook===

SP015	SP015
Physics 1	Fizik 1
Semester 1	Semester 1
Session 2024/2025	Sesi 2024/2025
2 hours	2 jam

KOLEJ MATRIKULASI SARAWAK
SARAWAK MATRICULATION COLLEGE

PRA PEPERIKSAAN SEMESTER PROGRAM MATRIKULASI
MATRICULATION PROGRAMME PRE-EXAMINATION

JANGAN BUKA KERTAS SOALAN INI SEBELUM DIBERITAHU
DO NOT OPEN THIS QUESTION PAPER UNTIL YOU ARE TOLD TO DO SO.

Kertas soalan ini mengandungi 14 halaman bercetak.
This question paper consists of 14 printed pages.

INSTRUCTIONS TO CANDIDATE:

This question paper consists of **8** questions.

Answer **all** questions.

A new page is used for each question.

The use of non-programmable scientific calculate is permitted.

LIST OF SELECTED CONSTANTS VALUES

Speed of light in vacuum	c	$= 3.00 \times 10^{8}\, ms^{-1}$
Permeability of free space	μ_o	$= 4\pi \times 10^{-7}\, H\, m^{-1}$
Permittivity of free space	ε_o	$= 8.85 \times 10^{-12}\, F\, m^{-1}$
Electron charge magnitude	e	$= 1.6 \times 10^{-19}\, C$
Planck constant	h	$= 6.63 \times 10^{-34}\, Js$
Electron mass	m_e	$= 9.11 \times 10^{-31} kg$
		$= 5.49 \times 10^{-4}\, u$
Neutron mass	m_n	$= 1.674 \times 10^{-27} kg$
		$= 1.008665u$
Proton mass	m_p	$= 1.672 \times 10^{-27} kg$
		$= 1.007277u$
Hydrogen mass	m_H	$= 1.673 \times 10^{-27} kg$
		$= 1.007825u$
Deuteron mass	m_d	$= 3.34 \times 10^{-27} kg$
		$= 2.014102u$
Molas gas constant	R	$= 8.31\, J\, K^{-1}\, mol^{-1}$
Avogadro constant	N_A	$= 6.02 \times 10^{23}\, mol^{-1}$
Boltzmann constant	k	$= 1.38 \times 10^{-23} JK^{-1}$
Free-fall acceleration	g	$= 9.81 ms^{-2}$
Atomic mass unit	$1u$	$= 1.66 \times 10^{-27} kg$
		$= 931.5 \frac{MeV}{c^2}$

LIST OF SELECTED CONSTANTS VALUES

Electron volt	$1eV$	$= 1.6 \times 10^{-19}\, J$
Constant of proportionality for Coulomb's Law	$k = \dfrac{1}{4\pi\varepsilon_o}$	$= 9.0 \times 10^{9}\ N\ m^{2}\ C^{-2}$
Atmospheric pressure	$1atm$	$= 1.013 \times 10^{5} Pa$
Density of water	ρ_w	$= 100kgm^{-3}$

LIST OF SELECTED FORMULAE

1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3. $v^2 = u^2 + 2as$
4. $s = \frac{1}{2}(u + v)t$
5. $p = mv$
6. $J = F\Delta t$
7. $J = \Delta p = mv - mu$
8. $f = \mu N$
9. $W = \vec{F} \cdot \vec{s} = Fs\cos\theta$
10. $K = \frac{1}{2}mv^2$
11. $U = mgh$
12. $U_s = \frac{1}{2}kx^2 = \frac{1}{2}Fx$
13. $W = \Delta K$
14. $P_{av} = \frac{\Delta W}{\Delta t}$
15. $P = \vec{F} \cdot \vec{v} = Fv\cos\theta$
16. $a_c = \frac{v^2}{r} = r\omega^2 = v\omega$
17. $F_c = \frac{mv^2}{r} = mr\omega^2 = mv\omega$
18. $s = r\theta$
19. $v = r\omega$
20. $a_t = r\alpha$
21. $\omega = \omega_o + \alpha t$
22. $\theta = \omega_o t + \frac{1}{2}\alpha t^2$
23. $\theta = \frac{1}{2}(\omega_o + \omega)t$
24. $\omega^2 = \omega_o^2 + 2\alpha\theta$
25. $\tau = rF\sin\theta$
26. $I = \Sigma mr^2$
27. $I_{\text{solid sphere}} = \frac{2}{5}MR^2$
28. $I_{\text{solid cylinder/disc}} = \frac{1}{2}MR^2$
29. $I_{ring} = MR^2$
30. $I_{\text{rod}} = \frac{1}{12}ML^2$
31. $\Sigma\tau = I\alpha$
32. $L = I\omega$
33. $y = A\sin\omega t$
34. $v = \omega A\cos\omega t = \pm\omega\sqrt{A^2 - y^2}$
35. $a = -\omega^2 A\sin\omega t = -\omega^2 y$
36. $K = \frac{1}{2}m\omega^2(A^2 - y^2)$
37. $U = \frac{1}{2}m\omega^2 y^2$
38. $E = \frac{1}{2}m\omega^2 A^2$
39. $\omega = \frac{2\pi}{T} = 2\pi f$
40. $T = 2\pi\sqrt{\frac{l}{g}}$
41. $T = 2\pi\sqrt{\frac{m}{k}}$
42. $k = \frac{2\pi}{\lambda}$

LIST OF SELECTED FORMULAE

43. $v = f\lambda$

44. $y(x,t) = A\, sin\,(\omega t \pm kx)$

45. $v_y = A\omega\, cos\,(\omega t \pm kx)$

46. $y = 2A\, cos\, kx\ \ sin\,\omega t$

47. $f_n = \frac{nv}{2L}$

48. $f_n = \frac{n}{2L}\sqrt{\frac{T}{\mu}}$

49. $f_n = \frac{nv}{4L}$

50. $v = \sqrt{\frac{T}{\mu}}$

51. $\mu = \frac{m}{L}$

52. $f_a = \left(\frac{v \pm v_o}{v \mp v_s}\right) f$

53. $\sigma = \frac{F}{A}$

54. $\varepsilon = \frac{\Delta L}{L_o}$

55. $Y = \frac{\sigma}{\varepsilon}$

56. $U = \frac{1}{2}F\Delta L$

57. $\frac{U}{V} = \frac{1}{2}\sigma\varepsilon$

58. $\frac{Q}{t} = -kA\left(\frac{\Delta T}{L}\right)$

59. $\Delta L = \alpha L_o \Delta T$

60. $\Delta A = \beta A_o \Delta T$

61. $\Delta V = \gamma V_o \Delta T$

62. $\beta = \ 2\,\alpha$

63. $\gamma = 3\alpha$

64. $n = \frac{m}{M} = \frac{N}{N_A}$

65. $v_{rms} = \sqrt{< v^2 >}$

66. $v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$

67. $PV = \frac{1}{3}Nmv_{rms}^2$

68. $P = \frac{1}{3}\rho v_{rms}^2$

69. $K_{tr} = \frac{3}{2}\left(\frac{R}{N_A}\right)T = \frac{3}{2}kT$

70. $U = \frac{1}{2}fNkT = \frac{1}{2}fnRT$

71. $\Delta U = Q - W$

72. $W = nRT\, ln\left(\frac{V_f}{V_i}\right) = nRT ln\left(\frac{P_i}{P-f}\right)$

73. $W = \int P\, dV = P\left(V_f - V_i\right)$

74. $W = \int P\, dV = 0$

1 Show that the expression $V = \frac{4}{3}\pi r^3$ is homogenous.

[2 marks]

2 (a) An athlete throws a shot at an angle 35° with the horizontal and the shot lands at a distance of 17.5m. Calculate

i) the initial speed of the shot.

ii) the time of flight of the shot.

iii) the maximum height of the shot.

[6 marks]

(b) FIGURE 1 shows a graph of displacement, *s* against time, *t* of an object moving along the x-axis.

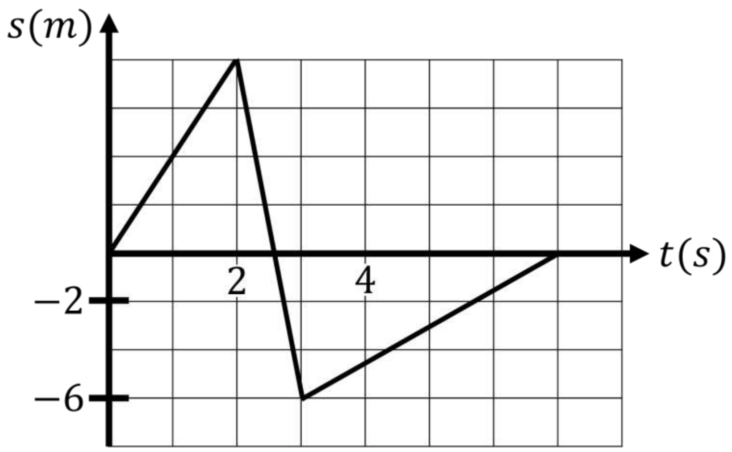


FIGURE 1

i) Determine the instantaneous velocity at $t = 4s$.

ii) Calculate the average velocity in the first 3 seconds.

[4 marks]

3 (a) A 6kg object moves towards the north with a momentum of $35kgms^{-1}$. A 6N force acts on the object in the south direction for some time t. Determine the

i) the impulse of the object if the force was applied for 15s.

ii) time it takes the force to fully stop the object.

iii) velocity of the object after 2s.

[5 marks]

(b) **FIGURE 2** shows a smooth inclined plane making an angle of 30^o with the horizontal has a pulley at its top. A 40kg block A, on the plane is connected to a freely hanging 28kg block B by a string passing over the frictionless pulley.

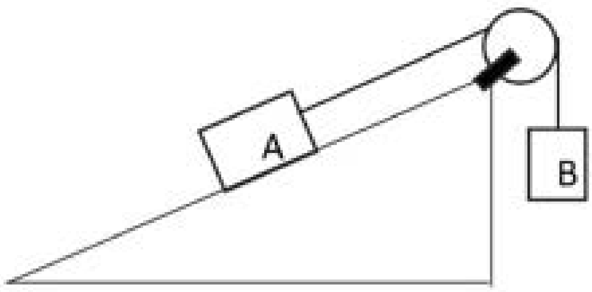


FIGURE 2

i) Calculate the tension and acceleration of the blocks.

ii) If the inclined plane now has a coefficient of kinetic friction of 0.2, determine the change in the acceleration of the blocks.

[8 marks]

4 (a)

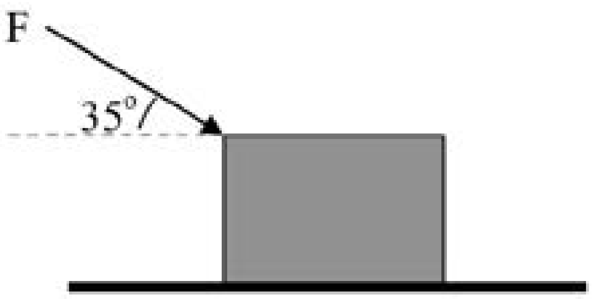


FIGURE 3

FIGURE 3 shows a force of 25 N pushing a 5 kg box and displacing it by 4.0 m across a rough horizontal surface. If the frictional force is 3 N, calculate the total work done.

[2 marks]

(b)

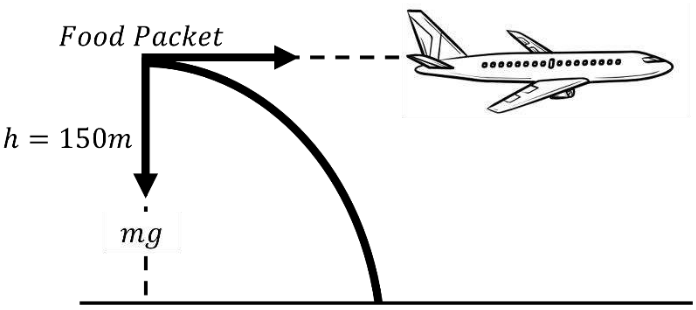


FIGURE 4

An airplane drops a food package from a height of 150 m with a horizontal velocity of 30 m s^{-1}. By ignoring air resistance, find the speed with which the food package strikes the ground.

[4 marks]

(c) Calculate the power output of an ant with a mass of 0.5 g climbing a wall at a rate of 1.5 cm/s.

[2 marks]

5

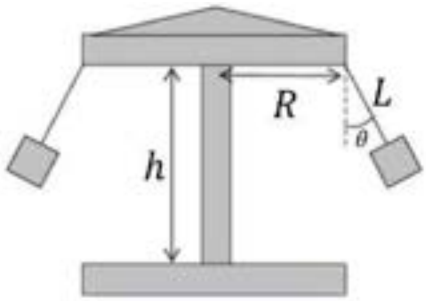


FIGURE 5

In an amusement park ride, seats are suspended from chains of length, L = 5.5m attached to the edge of rotating disk of diameter 12.0m, as shown in **FIGURE 5** above. We observe that the chains make at angle, θ of 25^0 with the vertical when the ride is operating at its full speed. The passenger and seat shown in the picture has a mass of 72kg.

(a) Determine the tension in the cable attached to the chair.

(b) Find the period of rotation for the ride.

[5 marks]

6 (a) A $0.5\ kg$ block is attached to a spring with a spring constant of $200\ Nm^{-1}$. The block is displaced from its equilibrium position by 5 cm and released from rest. Assume the surface is frictionless.

i) Calculate the period of the oscillations.

ii) Determine the maximum velocity of the block during its motion.

iii) Calculate the total mechanical energy of the system.

[4 marks]

(b) Given the progressive wave equation:

$$y(x,t) = 0.05\sin(200\pi t - 50\pi x)$$

Where x and y are in centimetres and t is in seconds.

i) Calculate the velocity of the wave.

ii) If the wave is superposed with another identical wave but moving in an opposite direction, write the new equation for the standing wave produced.

iii) Calculate the distance between two consecutive antinodes based on the equation produced in (ii).

[6 marks]

(c) A tube open at both ends has a length of $L = 1.2m$. Assume the speed of sound in air is $v = 340\ ms^{-1}$.

i) Determine the frequency of the 2^{nd} overtone in this air column.

ii) If the tube is closed at one end and open at the other end, what is the wavelength and fundamental frequency for this closed pipe?

iii) If the air column length of the closed pipe is increased to $1.5\ m$, does the new fundamental frequency of the closed pipe increase or decrease? Explain quantitatively.

[8 marks]

(d)

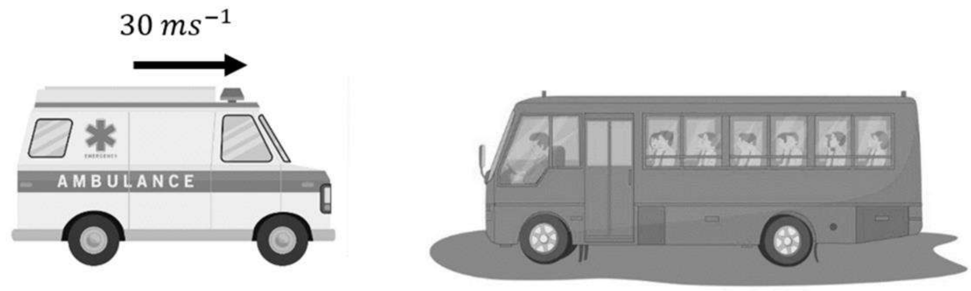


FIGURE 6

An ambulance is moving towards a stationary observer with a speed of $30\ ms^{-1}$. The stationary observer is inside a stationary school bus. The ambulance is emitting sound waves with a frequency of $600\ Hz$. The speed of sound in air $340\ ms^{-1}$.

i) Calculate the observed frequency of the sound heard by the stationary observer.

ii) If the ambulance is moving away from the stationary observer at the same speed, what would be the observed frequency of the sound?

[5 marks]

7 (a) The variation of stress with strain for two different materials, X and Y, until the breaking point of the materials is shown in **FIGURE 7** below.

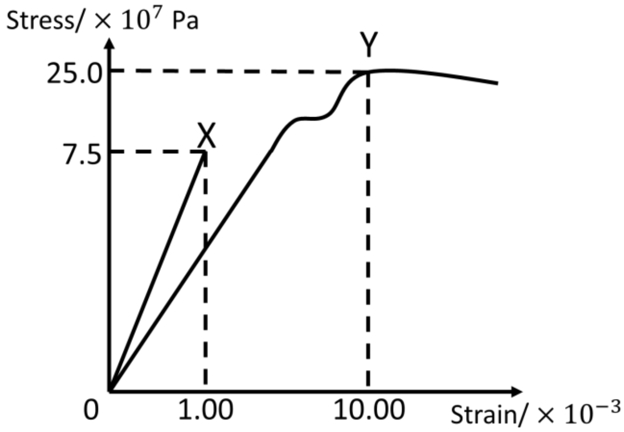


FIGURE 7

(i) Determine the Young's modulus of X.

(ii) Determine the required tensile force to break Y if the cross-sectional area is $6.85 \times 10^{-7} m^2$.

[3 marks]

(b) In a state of steady state, a well-insulated copper rod of length 28.0 cm and diameter of 1.5 cm. One end held at 100 °C while the opposite end remains at 0 °C. Calculate the rate of heat flow through the rod.

[Thermal conductivity copper is 380 $W\ m^{-1}K^{-1}$]

[3 marks]

(c) A metal coin having a coefficient of linear expansion 2.5×10^{-5} °C^{-1} with diameter of 4.00 cm at a temperature of 20 °C, determine the coin's diameter when the temperature is raised to 60 °C.

[2 marks]

8 (a) A container contains 2.5 mol of nitrogen gas at 32°C. If nitrogen gas behaves like an ideal gas, calculate the

(i) total translational kinetic energy of the gas molecules.

(ii) internal energy of the gas.

(iii) root mean square speed of the nitrogen molecules if the mass is 28 g mol^{-1} .

[6 marks]

(b) The pressure of a tyre rises from 220 kPa to 440 kPa at constant temperature 35°C. Assuming the air in the tyre acts as an ideal gas, calculate the

(i) work done per mole of the air.

(ii) heat transferred in this process.

[5 marks]

END OF QUESTION PAPER

KOLEJ MATRIKULASI SARAWAK

SKEMA JAWAPAN DAN PEMARKAHAN PRA-PSPM *PHYSICS* 1 SEMESTER I, SESI 2024/2025

NO.		SKEMA JAWAPAN	MARKAH
1		V = $\frac{4}{3}\pi r^3$	
		[length][width][height] = [radius][radius][radius]	
		$L^3 = L^3$	G1
		LHS = RHS	J1
		This expression is homogeneous.	
		Total	**2**
2	a)	$s_y = 0 = (u\,sin\,35^o)t - \frac{9.81}{2}t^2$	G1
		$s_x = 17.5 = (u\,cos\,35^o)t$	G1
	a) i)	$u = 13.5164ms^{-1}$	JU1
	a) ii)	$t = 1.581s$	JU1
	a) iii)	$v_y^2 = u_y^2 - 2gh$	
		$0 = (13.5164\,sin\,35^o)^2 - 2(9.81)h$	G1
		$h = 3.06m$	JU1
	b) i)	$v_{instant} = m(t = 4s) = \frac{x_f - x_i}{t_f - t_i}$	
		$v_{instant} = \frac{0-(-6)}{7-3}$	G1
		$v_{instant} = 1.5ms^{-1}$	JU1
	b) ii)	$v_{ave} = \frac{s}{t}$	
		$v_{ave} = \frac{-6}{3}$	G1
		$v_{ave} = -2ms^{-1}$	JU1
		Total	**10**

NO.		SKEMA JAWAPAN	MARKAH
3	a) i)	$J = \Delta p = F\Delta t$ $J = -6(15)$ $J = -90Ns$	 G1 JU1
	a) ii)	$35 = 6(\Delta t)$ $\Delta t = 5.83s$ $\Delta p = F\Delta t$	G1 JU1
	a) iii)	$m(v) - p_i = F\Delta t \Rightarrow v = \frac{F\Delta t + p_i}{m}$ $v = \frac{-6(2) + 35}{6} = 3.83ms^{-1}$	 GJU1
	b) i)	Block A: $\Sigma F_x = m_A a = T - W_A sin\theta$ Block B: $\Sigma F_y = m_B a = W_B - T$ $40a = T - (40)(9.81)sin(30^o)$ $28a = 28(9.81) - T$ $a = 1.15ms^{-2}$ $T = 242.365N$	 K1 G1 G1 J1 J1
	b) ii)	Block A: $\Sigma F_x = m_A a = T - W_A sin\theta - \mu W_A cos\theta$ $40a = T - (40)(9.81)sin(30^o) - (0.2)(40)(9.81)cos(30^o)$ $a_{new} = 0.155ms^{-2}$ $\Delta a = a_{new} - a$ $\Delta a = 0.155 - 1.15$ $\Delta a = -0.995ms^{-2}$	 G1 G1 JU1
		Total	**13**
4	a)	$W = F \cdot s = \left(Fcos35^{\circ} + fcos(-180^o)\right)s$ $W = (25\, cos\, 35^{\circ} - 3)4$ $W = 69.92\, J$	 G1 JU1
	b)	$\sum E_i = \sum E_f \Rightarrow (U + K)_i = (\mathrm{U} + \mathrm{K})_f$ $mgh_i + \frac{1}{2}mu^2 = mgh_f + \frac{1}{2}mv^2$ $(9.81)(150) + \frac{1}{2}(30)^2 = 0 + \frac{1}{2}v^2$ $v = 61.99ms^{-1}$	K1 K1 G1 JU1
	c)	$P = F \cdot v$ $P = mgv\, cos\, 0$ $P = (0.5 \times 10^{-3})9.81(1.5 \times 10^{-2})$ $P = 7.36 \times 10^{-5}W$	 G1 JU1
		Total	**8**

5	a)	$\sum F = 0$ $T \cos 25^{\circ} = W$ $T \cos 25^{\circ} = 72(9.81)$ $T = 779.34\, N$	 G1 JU1
	b)	Radius,r = 6 + 5.5sin 25° = 8.32m $\sum F_x = ma_x$ $T \sin 25^{\circ} = m\,(\frac{4\pi^2 r}{(Period, P)^2})$ $(Period, P)^2 = \frac{4\pi^2 rm}{\text{T} \sin 25^{\circ}}$ $P = \sqrt{\frac{4\pi^2 rm}{T \sin 25^{\circ}}}$ $P = \sqrt{\frac{4\pi^2(8.32)(72)}{779.34 \sin 25^{\circ}}}$ $P = 8.47s$	 G1 G1 JU1
		Total	**8**

6	a) i)	$T = 2\pi\sqrt{\frac{0.5}{200}} \Rightarrow T = 0.314\ s$	GJU1
	a) ii)	$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.314}$ $\omega = 20.01\ rad\ s^{-1}$ $V_{max} = Aw = (0.05)(20.01) = 1.0\ ms^{-1}$	 G1 GJU1
	a) iii)	$E = \frac{1}{2}mw^2A^2$ $E = \frac{1}{2}(0.5)(20.01)^2(0.05)^2 = 0.0125\ J$	 GJU1
	b) i)	$f = \frac{w}{2\pi} = \frac{200\pi}{2\pi} = 100\ Hz$ $\lambda = \frac{2\pi}{k} = \frac{2\pi}{50\pi} = 0.04\ m$ $v = f\lambda = 100(0.04) = 4\ cm\ s^{-1}$	G1 G1 GJU1
	b) ii)	$y(x,t) = 2(0.05)\cos(50\pi x)\sin(200\pi t)$ $y(x,t) = 1.0\cos(50\pi x)\sin(200\pi t)$, where *y* and *x* is centimetres and t is in second	 GJU1
	b) iii)	Distance between two antinodes = $\frac{\lambda}{2}$ $d = \frac{0.04}{2} = 0.02\ m$	K1 GJU1
	c) i)	2nd overtone, n= 3 $f_n = \frac{nv}{2L} = \frac{(3)(340)}{2(1.2)}$ $f_3 = 425\ Hz$	K1 G1 JU1
	c) ii)	n=1 $f_1 = \frac{nv}{4L} = \frac{(1)(340)}{4\ (1.2)} = 70.83Hz\ Hz$ $\lambda = \frac{v}{f} \Rightarrow \lambda = \frac{340}{70.83} = 4.8\ m$	K1 G1 GJU1
	c) iii)	$f_{new} = \frac{nv}{4L} = \frac{(1)340}{4(1.5)} = 56.67Hz$ The new fundamental frequency decrease because the frequency is inversely proportional to length of pipe	G1 J1
	d) i)	$f_a = (\frac{v+v_0}{v-v_s})f_s$ $f_a = \left(\frac{340+0}{340-30}\right)600$ $f_a = 658.06Hz$	K1 G1 JU1
	d) ii)	$f_a = (\frac{v+v_0}{v+v_s})f_s$ $f_a = (\frac{340+0}{340+30})600$ $f_a = 551.35\ Hz$	 G1 JU1
		Total	**23**

7	a) i)	$\gamma = \frac{\sigma}{\varepsilon}$ $\gamma = \frac{7.5x10^{7}}{1x10^{-3}}$ $\gamma = 7.5x10^{10} Pa$	 G1 JU1
	a) ii)	$\sigma = \frac{F}{A} \Rightarrow 25x10^{7} = \frac{F}{6.85x10^{-7}} \Rightarrow F = 171.25\ N$	GJU1
	b)	$\frac{Q}{t} = -kA(\frac{\Delta T}{L})$ $A = \frac{\pi(1.5x10^{-2})^{2}}{4} = 1.761x10^{-4}$ $\frac{Q}{t} = -\frac{(380)(1.761x10^{-4})(100)}{0.28}$ $\frac{Q}{t} = 23.982W$	 G1 G1 JU1
	c)	$\Delta d = \alpha do \Delta T$ $\Delta d = (2.5x10 - 5)(4)(60 - 20)$ $\Delta d = 0.004$ $d = do + \Delta d$ $d = 4.004\ cm$	 G1 JU1
		Total	**8**
8	a) i)	$U = \frac{1}{2} fnRT$ $U = \frac{3}{2}(2.5)(8.31)(305)$ $U = 9504.56\ J$	 G1 JU1
	a) ii)	$U = \frac{1}{2} fnRT$ $U = \frac{5}{2}(2.5)(8.31)(305)$ $U = 15840.94\ J$	 G1 JU1
	a) iii)	$v_{rms} = \sqrt{\frac{3RT}{M}}$ $v_{rms} = \sqrt{\frac{3(8.31)(305)}{0.028}}$ $v_{rms} = 521.11ms^{-1}$	 G1 JU1
	b) i)	$W = nRT\ ln\ ln\left(\frac{P_i}{P_f}\right)$ n = 1 mole $W = (1)(8.31)(308)\ ln\frac{220}{440}$ $W = -1774.096\ J$	 G1 G1 JU1
	b) ii)	$\Delta U = Q - W$ $\Delta U = 0$ $Q = W$ $Q = -1774.096\ J$	 K1 JU1
		Total	**8**

KOLEJ MATRIKULASI SARAWAK

SKEMA JAWAPAN DAN PEMARKAHAN PRA-PSPM *PHYSICS* 1 SEMESTER I, SESI 2024/2025

NO.		SKEMA JAWAPAN	MARKAH
2	a) i)	$u = 13.5164ms^{-1}$	3
	a) ii)	$t = 1.581s$	1
	a) iii)	$h = 3.06m$	2
	b) i)	$v_{instant} = 1.5ms^{-1}$	2
	b) ii)	$v_{ave} = -2ms^{-1}$	2
		Total	**10**

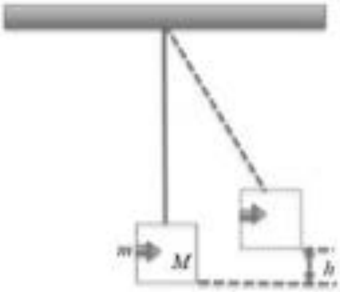
NO.		SKEMA JAWAPAN	MARKAH
3	a) i)	$J = -90Ns$	2
	a) ii)	$\Delta t = 5.83s$	2
	a) iii)	$v = 3.83ms^{-1}$	1
	b) i)	$a = 2.066ms^{-2}$	4
	b) ii)	$\Delta a = -1.085ms^{-2}$	3
		Total	**13**
4	a)	$W = 69.92\,J$	2
	a)	$v = 61.99ms^{-1}$	4
	c)	$P = 7.36 \times 10^{-5}W$	2
		Total	**8**

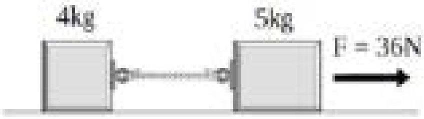
5	a)	$T = 779.34\,N$	2
	b)	$P = 8.47s$	3
		Total	**5**

6	a) i)	$T = 0.314\,s$	1
	a) ii)	$V_{max} = 1.0\,ms^{-1}$	2
	a) iii)	$E = 0.0125\,J$	1
	b) i)	$v = 4\,cm\,s^{-1}$	3
	b) ii)	$y(x,t) = 1.0\cos(50\pi x)\sin(200\pi t)$, where *y* and *x* is centimeters and t is in second	1
	b) iii)	$d = 0.02\,m$	2
	c) i)	$f_3 = 425\,Hz$	3
	c) ii)	$\lambda = \frac{340}{141.67} = 2.4\,m$	2
	c) iii)	f=56.67 Hz The new fundamental frequency decrease because the frequency is inversely proportional to length of pipe	2
	d) i)	$f_a = 658.06Hz$	3
	d) ii)	$f_a = 551.35\,Hz$	3
		Total	**23**

7	a) i)	$\gamma = 7.5x10^{10}Pa$	2
	a) ii)	$F = 171.25\,N$	1
	b)	$\frac{Q}{t} = 23.982W$	3
	c)	$d = 4.004\,cm$	2
		Total	**8**
8	a) i)	$U = 9504.56\,J$	2
	a) ii)	$U = 15840.94\,J$	2
	a) iii)	$v_{rms} = 521.11ms^{-1}$	2
	b) i)	$W = -1774.096\,J$	3
	b) ii)	$Q = -1774.096\,J$	2
		Total	**11**

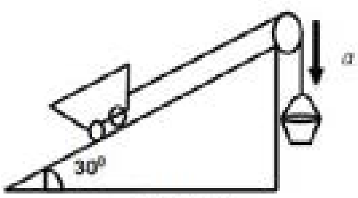
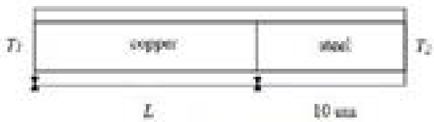
12 Nov 2024

<table>
<tr><th>No</th><th>Questions</th></tr>
<tr><td>1</td><td>a.
In a block-bullet experiment, $h = 5.00$ cm, $m = 5.00$ g and $M = 1.00$ kg.
Find the common velocity after the bullet embedded into the block, v


b.
A 1000 kg car is travelling at a constant speed of 15 m s^{-1} enters the circular curve of a flat road with radius 50 m. Show by calculation whether the car can go round the curve safely when the road is wet with the coefficient of static friction $\mu_s = 0.30$.</td></tr>
<tr><td>2</td><td>a. The figure shows two blocks of masses 4 kg and 5 kg are connected with each other and moves with the same acceleration on a frictionless horizontal surface. A constant horizontal force 36N is applied to the block of mass 5 kg. Find the acceleration of the blocks and calculate the tension in the cord connecting them.


b. A 500g block travels on rough surface with an initial speed of 0.5m/s. How far will it go if the coefficient of friction between it and the surface is 0.150?</td></tr>
<tr><td>3</td><td>a. A conical pendulum with a bob of mass 0.5kg and string of length 0.75m swings in a horizontal circle of radius 30cm. Find the angle which string make with horizontal axis and the tension in the string.
b. A particle vibrates and executes simple harmonic motion. The amplitude of the motion is 3m and the frequency is 15Hz. Calculate the velocity of the particle at time t = 1.5s and the speed of the particle 1m from one end.</td></tr>
<tr><td>4</td><td>a. A piano string, 1.5 m long, has a mass of 5g. How much tension must the string be under for it to vibrate at a fundamental frequency of 100 Hz? What is the frequency of the seventh overtone?
b.
The steel bed of a suspension bridge is 200 m long at 32°C. If the extremes of temperature to which it might be exposed are -30 °C to 42 °C, how much will it contract and expand? Given coefficient of linear expansion of steel is 12 x 10^{-6} K^{-1}.</td></tr>
<tr><td>5</td><td>

FIGURE 7.2
FIGURE 7.2 shows a 5.0 m section of steel railroads track when they are installed at temperature 32^{0}C. A gap of 4 mm is left between the sections. Calculate the temperature at which the rail sections will just touch. (Given the coefficient of linear expansion of the steel is $12 \times 10^{-6}\,C^{-1}$).</td></tr>
<tr><td>6</td><td>A 0.5 mole monoatomic ideal gas is filled in a 2.2 m^3 container at 313 K and pressure of 2.25 kPa. The gas is isothermally compressed to a half it original volume. Then the gas expands isobarically to its original volume at the final temperature of the gas is 515 K. Calculate the
(i) total work done in the processes.
(ii) heat transfer during isothermal process
(iii) change in the internal energy of the gas for isobaric process.</td></tr>
</table>

7	 FIGURE 3	**FIGURE 3** shows a 12.0 kg wheelbarrow placed on a frictionless plane inclined at 30° with the horizontal connected to a 7.0 kg hanging bucket by a string that passes over a pulley. (i) Sketch a labelled free body diagram showing all the forces on the 12.0 kg wheelbarrow. (ii) Calculate the acceleration of the system.
8	 FIGURE 4	**FIGURE 4** shows two insulated plates, one made of copper and the other of steel, each with an area of 50.0 cm^2 and joined together at their ends. The steel rod has a length of 10 cm, while the copper rod has a length of L. At the steady state, the temperatures at the ends of copper and steel are T_1 = 100 °C and T_2 = 0 °C and temperature at the joint is 60 °C. Given the thermal conductivity for both plates are k_{copper} = 380 W m^{-1} K^{-1} and k_{steel} = 46 W m^{-1} K^{-1}. (i) Calculate the temperature gradient of the steel rod. (ii) Determine L.

13 Nov 2024

<table>
<tr><th>No</th><th>Questions</th></tr>
<tr><td>1</td><td>

a.

A tennis ball is thrown horizontally from the top of a building of height 45 m. The ball strikes the ground at a horizontal distance of 20 m from the building. Calculate the

(a) the time of flight.

(b) initial speed of the ball.

(c) angle at which the trajectory of the ball makes with the ground just before the impact.

(d) If a man of 1.8 m tall is standing 15 m from the edge of the building. Will he be hit by the ball? Justify your answer.

b.

FIGURE 2 shows the velocity-time graph as a part of the performance data of the car.

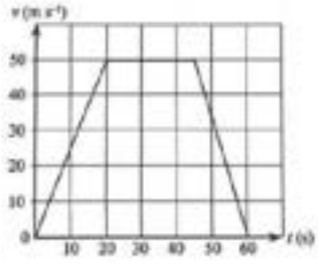


FIGURE 2

Calculate

i) the total distance travelled by the car.

ii) the average speed of the car.

iii) the acceleration of the car at t = 10 s.

</td></tr>
<tr><td>2</td><td>

a.

FIGURE 1 shows ball 1 of mass 150 g and velocity 5 m s^{-1} collides obliquely with a stationary ball 2 of mass 200 g. After the collision, ball 1 moves with velocity of 9 m s^{-1} at an angle 60° from its initial direction.

Calculate the velocity of ball 2 after collision

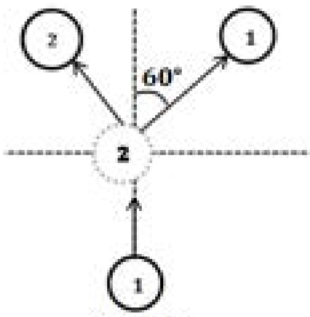


FIGURE 1

b.

FIGURE 3.1 shows an object A moving in horizontal with speed 8 m s^{-1} collide with an object B moving downward with speed 10 m s^{-1}. Mass of object A and B are 7 kg and 5 kg respectively. Determine the magnitude of velocity and its direction if the objects stick and move together after collision.

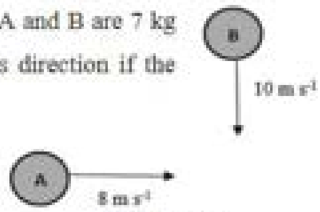
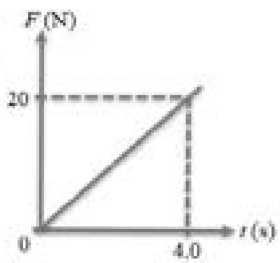


FIGURE 3.1

</td></tr>
<tr><td>3</td><td>

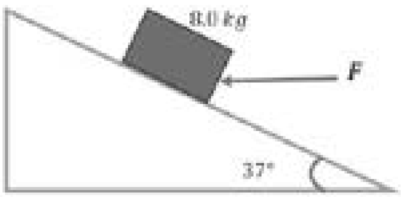
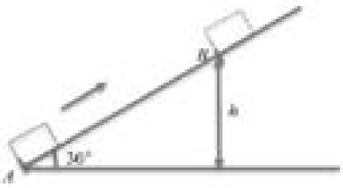
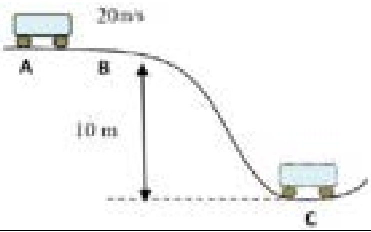
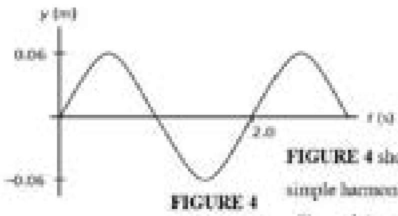
a.

An object with mass 5.0 kg at rest is acted on by a force which increases uniformly from zero to 20 N in 4.0 s. Calculate the speed of the object at the end of the four seconds interval.



b.

</td></tr>
</table>

		A 8 kg box is held in equilibrium on a rough slope by a horizontal force F as shown in **FIGURE 2**. The coefficient of friction between the box and the slope is 0.15. The magnitude of force F may vary from a certain minimum value to a maximum value. (i) Sketch a free body diagram for the box when force F has its minimum value. Label all forces. (ii) Determine the minimum magnitude of the force F **and** the normal force act on the box.  **FIGURE 2**
4	a.	An object of mass 2 kg moves up a rough inclined plane with an initial velocity of 14.14 m s^{-1}, which makes an angle 30° with the horizontal. The coefficient of kinetic friction between the object and the plane is 0.20. By using work-energy theorem, calculate the kinetic energy of the object at point B if the height h = 1.5 m. 
	b.	 In **FIGURE 3**, a small cart of mass 8 kg moves on the frictionless track with a speed of 20 m s^{-1} along **AB** and down to **C**. Calculate the (i) kinetic energy of the cart as it moves along **AB**. (ii) potential energy of the cart at point **B**. (iii) speed of the cart at point **C**.
5	a.	A ball of a mass 4.0 kg is attached to the end of a 1.2 m long string and whirled around in a circle that describes a **vertical plane**. (a) Calculate the minimum speed that the ball can be moving at and still maintain a circular path? Sketch a **free body diagram**. (b) At this speed, calculate the maximum tension in the string?
	b.	A 1000 kg car is travelling at a constant speed of 15 m s^{-1} enters the circular curve of a flat road with radius 50 m. Show by calculation whether the car can go round the curve safely when the road is wet with the coefficient of static friction μ_s = 0.30.
6	a.	 **FIGURE 4** **FIGURE 4** shows the displacement versus time graph for an object performing a simple harmonic motion. Based on the graph, (i) determine the angular frequency. (ii) determine the maximum velocity (iii) write the simple harmonic motion equation.
	b.	A 50 g object connected to a spring with a spring constant 35 N m^{-1} oscillates with amplitude 4 cm on a horizontal frictionless surface. Calculate the (i) total energy of the system. (ii) speed of the object at displacement 1.6 cm. (iii) change in the period of oscillation if a load of 6 g is added to the object.

7

a.

A transverse sine wave with an amplitude of 3.50 mm and a wavelength of 1.60 m travels from left to right, along a horizontal stretched string with a speed of 30 ms^{-1}. Take the origin at the left end of the undisturbed string. At time $t = 0$, the left end of the string has no upward displacement. Determine the

(i) frequency, angular frequency, and wave number of the wave.

(ii) displacement equation for the wave.

(iii) displacement equation for a particle at $x = 0$.

(iv) displacement equation for a particle $x = 1.40$ m.

(v) maximum magnitude of transverse velocity of any particle of the string.

(vi) transverse displacement and the transverse velocity of a particle 1.40 m to the right of the origin at time $t = 0.05$ s.

b.

A piano string, 1.5 m long, has a mass of 5 g.

(i) How much tension must the string be under for it to vibrate at a fundamental frequency of 100 Hz?

(ii) What is the frequency of the seventh overtone?

c.

The length of a closed pipe is 18.0 cm. If the speed of sound in air is 330 m s^{-1}.

i. Determine the two lowest frequencies.
ii. Sketch and label the wave pattern for the lowest frequency.

8

a.

A wire of cross-sectional area 0.52 mm^2 with a length of 60.0 cm is pulled by a force of 50 N as shown in the **FIGURE 7.**

i. Calculate the stress of the wire.
ii. If the extension is 0.12 cm, calculate the Young's modulus.
iii. Calculate the strain energy of the stretched wire.

FIGURE 7

b.

A 1.5 meters high water tank with a square base of sides 2 meters is filled with a liquid at 87 °C. The wall of the tank is 10 mm thick. If the temperature outside the tank is 28 °C, calculate the rate of heat loss due to conductivity through the base of the tank.
[Thermal conductivity of tank = $3.78 \times 10^{-2} W m^{-1} K^{-1}$]

c.

Two moles of monoatomic gas argon expand isothermally at 295 K, from an initial volume of $V_i = 0.025$ m^3 to a final volume of $V_f = 0.050$ m^3. Assuming that argon is an ideal gas. Calculate the heat transferred during the expansion. Is heat absorbed or released by the system.

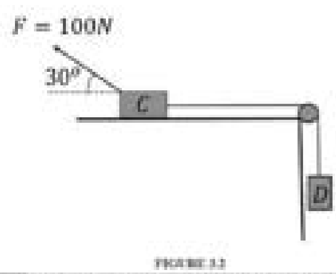
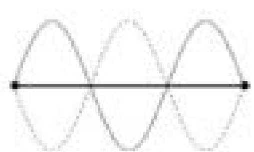
d.

Two moles of an ideal gas are compressed isothermally from 800 cm^3 to 200 cm^3 at 80 °C.

(i) Calculate the work done on the gas.

(ii) What does a negative work implies?

Weekend Homework Part 2 10/11/2024

No	Questions
1	 **FIGURE 3.2** shows box C of mass 10 kg pulled by a force of 100 N, 30^0 above horizontal connected to box D with unknown mass. Coefficient of kinetic friction between the surface and box C is 0.3. This boxes are moving with a constant velocity. (i) Draw two separate free body diagram shows all forces acting on box C and D. (ii) Calculate the tension of the string connected box C and D. (iii) Calculate mass of box D.
2	**(a)** A horizontal spring attached to a wall has a force constant of 850 N m^{-1}. A block of mass 1.50 kg is attached to the spring and rests on a frictionless surface. The block is pulled to a position of 6.00 cm from equilibrium and released. Calculate the speed of the block as it passes through the equilibrium point. **(b)** The motor of a vacuum cleaner has a net power output of 746 W. Calculate the work done by the motor in 3.0 minutes.
3	(a) A progressive wave can be represented by the equation $y(x,t) = (0.55)\sin\left(80\pi t - \frac{\pi}{0.15}x\right)$ where y and x are in centimeters and t is in seconds. For the wave, calculate (i) wavelength. (ii) particle vibrational velocity at x =2.0 m and t = 0.1 s (iii) speed of wave propagation. (b) A closed pipe makes a humming sound at frequency 282 Hz when the wind blows across the open end produce three nodes of standing wave. The speed of sound in air is 343 m s^{-1}. Determine (i) length of the pipe. (ii) wavelength of the wave
4	a) A gas is compressed at a constant pressure of 1 atm from 5 L to 3 L. In the process, 400 J of heat is leaving the gas. (i) Sketch a P-V graph for the process. (ii) Calculate the change in internal energy. [Given: 1 atm = 1.013×10^5 Pa, 1 L = 0.001 m^3] b)  **FIGURE 6** Two sinusoidal waves with the same amplitude and wavelength travel in opposite direction along a string that is stretched along an axis. Their resultant wave is shown in **FIGURE 6**. The distance between nodes and adjacent antinodes is 2 cm. The mass of the string is 35 g and the tension force applied is 50 N. Determine (i) the speed of waves travelling along the string. (ii) the wavelength and frequency of the standing waves formed.

5

(a)

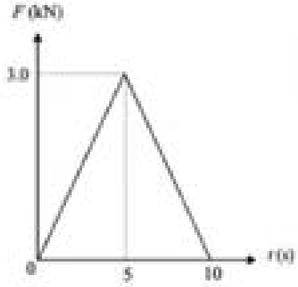


FIGURE 2 shows a variation of force with time when a car hits a wall. Calculate the impulse of the car.

(b) A 15.0 g bullet moving 250 m s^{-1} to the right strikes a log. Assume that the bullet undergoes uniform deceleration and stops in 10 s. Find the average force experienced by the bullet and state its direction.

6

A simple harmonic oscillator consists of a block attached to a spring with spring constant, $k = 250$ N m^{-1}. The block slides back and forth along a straight line on a frictionless surface. A graph of the block's velocity against time is shown as in **FIGURE 5**.

Determine

(i) the angular frequency,

(ii) the amplitude,

(iii) the mass, and

(iv) the maximum kinetic energy of the block.

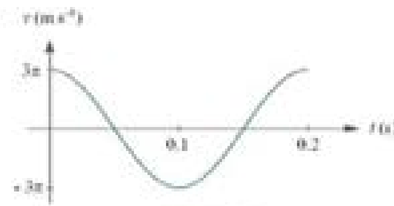


FIGURE 5

7

A 55 m^2 composite wall of a building consists of brick and concrete with the thickness of 12.0 cm and 24.0 cm respectively. The temperature of the outer surface of the brick and concrete is 40 °C and 20 °C respectively. (Given coefficient of thermal conductivity of brick and concrete are 0.6 W m^{-1} °C^{-1} and 0.8 W m^{-1} °C^{-1} respectively.)

(i) Determine the temperature of the interface between the brick and the concrete.

(ii) How much heat flows through the concrete in 1 hour?

8

The temperature in outer space is about 3.5 K and it is estimated that there is about one hydrogen molecule per cm^3. The mass of a hydrogen molecule is 3.346×10^{-27} kg.

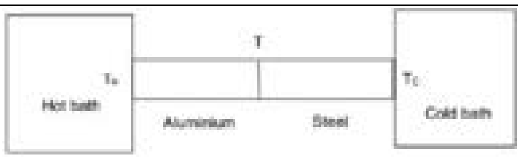
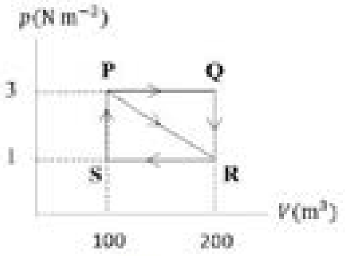
Calculate the

(i) rms speed of the hydrogen molecules.

(ii) hydrogen density in outer space.

(iii) pressure of hydrogen gas at the outer space.

(iv) mean translational kinetic energy of the hydrogen molecules.

No	Questions
1	(a) A spring is mounted horizontally, with its right end held stationary and a 0.40 kg body is attached to the left end. The body is freely oscillating with a period of 0.50 s and maximum displacement is 0.020 m. (i) Calculate the spring constant. (ii) Calculate the angular frequency of the oscillation. (iii) Write the equation of motion of the body. (iv) Calculate velocity **and** acceleration of the body at displacement 0.010 m. (v) Calculate kinetic **and** potential energies at maximum displacement.
	$T = 2\pi\sqrt{\frac{m}{k}}$ $k = \left(\frac{2\pi}{T}\right)^2 m$ $k = \left(\frac{2\pi}{0.50}\right)^2 (0.40)$ G1 $k = 63\ Nm^{-1}$ JU1 $\omega = \frac{2\pi}{T} = \frac{2\pi}{0.50}$ $\omega = 12.566\ rads^{-1}$ GJU1 $A = 0.02\ m$ $y = A\sin\omega t = 0.02\sin 12.566t$ GJU 1 where y in m, t in s. $v = \pm\omega\sqrt{A^2 - y^2}$ $v = \pm 12.566\sqrt{0.02^2 - 0.01^2}$ G1 $v = \pm 0.2176\ ms^{-1}$ JU1 $a = -\omega^2 y$ $a = -(12.566)^2(0.01)$ G1 $a = -1.579\ ms^{-1}$ JU1 $K = \frac{1}{2}m\omega^2(A^2 - y^2)$ $K = \frac{1}{2}(0.4)(12.566)^2(0.02^2 - 0.02^2) = 0J$ GJU1 $U = \frac{1}{2}m\omega^2 y^2$ $U = \frac{1}{2}(0.4)(12.566)^2(0.02^2) = 0.01263J$ GJU1
2	 An aluminium bar is welded to a steel bar of the same dimension. The other end of the aluminium bar is placed in a hot bath of temperature T_H while the end of the steel bar is placed in a cold bath of temperature T_c as shown in **FIGURE 4**. The system is in steady state and is properly insulated. Determine the temperature **T** at the interface of the aluminium-steel bar in terms of T_H, T_c, k_A (thermal conductivity of aluminium) and k_S (thermal conductivity of steel).
	$\left(\frac{dQ}{dt}\right)_H = \left(\frac{dQ}{dt}\right)_C$ K1 $-k_A A\left(\frac{T - T_H}{L}\right)_H = -k_S A\left(\frac{T_C - T}{L}\right)_S$ G1 $T = \frac{k_A T_H + k_S T_C}{k_A + k_S}$ J1
3	 **FIGURE 8.2** **FIGURE 8.2** shows a $P - V$ graph of an ideal gas. If the change of an internal energy from **P** to **R** is +300 J. Determine (i) the work done by the system during the process of **R** to **S** (ii) the heat energy during the process **RSP**
	$\Delta U_{PQR} = \Delta U_{RP} = -\Delta U_{PR} = -300\ J$ K1 $W_{RSP} = W_{RS} + W_{SP} = -100 + 0 = -100\ J$ $Q_{RSP} = W_{RSP} + \Delta U_{PQR}$ $Q_{RSP} = -100 + (-300)$ $Q_{RSP} = -400\ J$ GJU1
4	(a) A 2 mol hydrogen gas has a temperature of 380.26 K. Assuming the gas behaves ideally, calculate the internal energy of the gas. (b) A gas is confined in a container undergoes A thermodynamic process where it absorbs 1500 J of heat from its surroundings. If the internal energy decreases by 800 J calculate the work done by the gas during the process.
	(a) $U = \frac{f}{2}nRT$ $U = \frac{5}{2}(2)(8.31)(380.26)$ G1 $U = 15800\ J$ JU1 (b) $Q = +1500\ J,\ \Delta U = -800\ J$ $\Delta U = Q - W$ $-800 = 1500 - W$ G1 $W = 2300\ J$ JU1

5

A lorry producing 1.00 kHz waves moves toward a stationary listener at one-half the speed of sound. Does the apparent frequency of the sound wave heard by the listener increase or decrease when the lorry moves toward him? Given the speed of the sound in air is 340 $m\,s^{-1}$.

$$v_s = \frac{1}{2}(340) = 170\ m\,s^{-1}$$ K1

$$f_a = \frac{v}{v - v_s} f$$

$$f_a = \frac{340}{340 - 170}(1 \times 10^3)$$ G1

$$f_a = 2000\ Hz$$ JU1

The apparent frequency increases J1

6

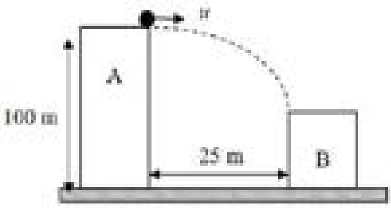


FIGURE 2.2 shows a ball is thrown from the top of the building A with an initial horizontal speed of u. The ball reaches the top of another building B after 1.8 s. The height of building A is 100 m. Calculate the

(i) initial speed, u of the ball.

(ii) height of building B.

$$s_x = u_x t$$
$$25 = (u_x)(1.8)$$
$$u_x = 13.89\ m\,s^{-1}$$

$$s_y = u_y t - \frac{1}{2} g t^2$$
$$-(100 - s_{yB}) = 0 - \frac{1}{2}(9.81)(1.8)^2$$
$$s_{yB} = 84.11\ \text{m}$$

7

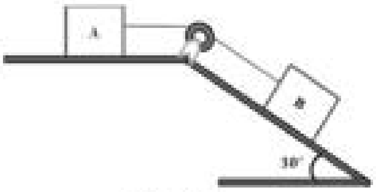


FIGURE 2

FIGURE 2 shows two boxes have identical masses of 40 kg. Both experience a sliding friction force on a rough floor of $\mu_k = 0.15$.

(i) sketch a free body diagram for boxes **B.**

(ii) when the box is moving, calculate the tension of the string **and** the acceleration of the boxes.

$(ii)\ \Sigma F_x = ma\ (blok\ B)$
$$mg \sin 30 - f - T = m_B a$$
$$mg \sin 30 - \mu N - T = 40a$$
$$40(9.81) \sin 30 - 0.15(40)(9.81)\cos 30 - T = 40a$$
$$145.23 - T = 40a \_\_\_\_\_ (eq\ 1)$$

$$T - 0.15(40)(9.81) = 40a\ (blok\ A)$$
$$T - 58.86 = 40a \_\_\_\_\_\_ (eq2)$$

$$sub(1) = (2)$$
$$145.23 - T = T - 58.86$$
$$\boldsymbol{T = 102.05\ N}$$

$$from\ eq(2)\ T - 58.86 = 40a$$
$$102.05 - 58.86 = 40a$$
$$\boldsymbol{a = 1.08\ m\,s^{-2}}$$

8

(a) A stretched wire has strain energy per unit volume of 2.87 kJ m^{-2}. The wire has extension per unit length of 1.25×10^{2}. Determine

(i) the Young's Modulus for the metal wire.

(ii) the stress in the wire.

(b) The diameter of a hole in a steel plate is 1.35 cm at 25 °C. The coefficient of linear thermal expansion of steel is 1.2×10^{-5} K^{-1}. Calculate the

(i) coefficient of area thermal expansion of steel.

(ii) cross-sectional area of the hole when the temperature of the plate is increased to 175 °C.

(a) (i) $\frac{U}{V} = 2.87 \times 10^3\ J\,m^{-3}$

$\frac{\Delta l}{l} = 1.25 \times 10^{-2}$

$\frac{U}{V} = \frac{1}{2}\sigma\varepsilon$

$Y = \left(\frac{F}{A}\right)\left(\frac{l_0}{\Delta l}\right)$

$\frac{U}{V} = \frac{1}{2}\sigma\varepsilon$

$\frac{U}{V} = \frac{1}{2}Y\varepsilon.\varepsilon$

$Y = \frac{\sigma}{\varepsilon}$

$$Y = \frac{2\left(\frac{U}{V}\right)}{\varepsilon^2}$$
$$= \frac{2(2.87 \times 10^3)}{(1.25 \times 10^{-2})^2}$$
$$= 3.67 \times 10^7\ N\,m^{-2}$$

(ii) $Y = \frac{\sigma}{\varepsilon}$

$$\sigma = 3.67 \times 10^7\ (1.25 \times 10^{-2})$$
$$= 4.592 \times 10^5\ N\,m^{-2}$$

(i) $\beta = 2\alpha$
$$= 2(1.2 \times 10^{-5})$$
$$= 2.4 \times 10^{-5}\ K^{-1}$$

(ii) $A = A_0(1 + \beta\Delta T)$
$$= \frac{\pi d^2}{4}[1 + 2.4 \times 10^{-5}(175 - 25)]$$
$$= 1.43 \times 10^{-4}(1 + 3.6 \times 10^{-3})$$
$$= 1.44 \times 10^{-4}\ m^2$$

Weekend Homework 9th Nov Solution

<table>
<tr><th>No</th><th>Questions</th></tr>
<tr><td>1</td><td>

(a) A spring is mounted horizontally, with its right end held stationary and a 0.40 kg body is attached to the left end. The body is freely oscillating with a period of 0.50 s and maximum displacement is 0.020 m.

(i) Calculate the spring constant.

(ii) Calculate the angular frequency of the oscillation.

(iii) Write the equation of motion of the body.

(iv) Calculate velocity **and** acceleration of the body at displacement 0.010 m.

(v) Calculate kinetic **and** potential energies at maximum displacement.

</td></tr>
<tr><td></td><td>

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$k = \left(\frac{2\pi}{T}\right)^2 m$$

$$k = \left(\frac{2\pi}{0.50}\right)^2 (0.40)$$ G1

$$k = 63\ Nm^{-1}$$ JU1

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.50}$$

$$\omega = 12.566\ rads^{-1}$$ GJU1

$$A = 0.02\ m$$

$y = A\sin\omega t = 0.02\sin 12.566t$ where y in m, t in s. GJU 1

$$v = \pm\omega\sqrt{A^2 - y^2}$$

$$v = \pm 12.566\sqrt{0.02^2 - 0.01^2}$$

$$v = \pm 0.2176\ ms^{-1}$$ G1 JU1

$$a = -\omega^2 y$$

$$a = -(12.566)^2(0.01)$$

$$a = -1.579\ ms^{-2}$$ G1 JU1

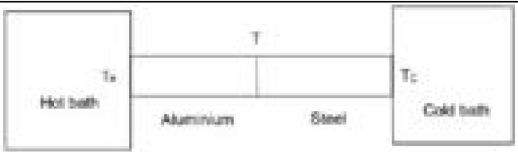
$$K = \frac{1}{2}m\omega^2(A^2 - y^2)$$

$$K = \frac{1}{2}(0.4)(12.566)^2(0.02^2 - 0.02^2) = 0J$$ GJU1

$$U = \frac{1}{2}m\omega^2 y^2$$

$$U = \frac{1}{2}(0.4)(12.566)^2(0.02^2) = 0.01263J$$ GJU1

</td></tr>
<tr><td>2</td><td>



An aluminium bar is welded to a steel bar of the same dimension. The other end of the aluminium bar is placed in a hot bath of temperature T_H while the end of the steel bar is placed in a cold bath of temperature T_c as shown in **FIGURE 4**. The system is in steady state and is properly insulated. Determine the temperature **T** at the interface of the aluminium-steel bar in terms of T_H, T_c, k_A (thermal conductivity of aluminium) and k_s (thermal conductivity of steel).

</td></tr>
<tr><td></td><td>

$$\left(\frac{dQ}{dt}\right)_a = \left(\frac{dQ}{dt}\right)_s$$ K1

$$-k_A A\left(\frac{T - T_H}{L}\right)_a = -k_s A\left(\frac{T_C - T}{L}\right)_s$$ G1

$$T = \frac{k_A T_H + k_s T_C}{k_A + k_s}$$ J1

</td></tr>
<tr><td>3</td><td>

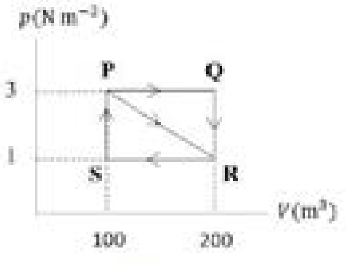


FIGURE 8.2

FIGURE 8.2 shows a $P - V$ graph of an ideal gas. If the change of an internal energy from **P** to **R** is +300 J. Determine

(i) the work done by the system during the process of **R** to **S**

(ii) the heat energy during the process **RSP**

</td></tr>
<tr><td></td><td>

$$\Delta U_{PQR} = \Delta U_{RP} = -\Delta U_{PR} = -300\ J$$ K1

$$W_{RSP} = W_{RS} + W_{SP} = -100 + 0 = -100\ J$$

$$Q_{RSP} = W_{RSP} + \Delta U_{PQR}$$

$$Q_{RSP} = -100 + (-300)$$

$$Q_{RSP} = -400\ J$$ GJU1

</td></tr>
<tr><td>4</td><td>

(a) A 2 mol hydrogen gas has a temperature of 380.26 K. Assuming the gas behaves ideally, calculate the internal energy of the gas.

(b) A gas is confined in a container undergoes A thermodynamic process where it absorbs 1500 J of heat from its surroundings. If the internal energy decreases by 800 J calculate the work done by the gas during the process.

</td></tr>
</table>

(a)

$$U = \frac{f}{2}nRT$$

$$U = \frac{5}{2}(2)(8.31)(380.26) \qquad \text{G1}$$

$$U = 15800\ J \qquad \text{JU1}$$

(b)

$$Q = +1500\ J,\ \Delta U = -800\ J$$

$$\Delta U = Q - W$$

$$-800 = 1500 - W \qquad \text{G1}$$

$$W = 2300\ J \qquad \text{JU1}$$

5

A lorry producing 1.00 kHz waves moves toward a stationary listener at one-half the speed of sound. Does the apparent frequency of the sound wave heard by the listener increase or decrease when the lorry moves toward him? Given the speed of the sound in air is 340 $m\ s^{-1}$.

$$v_s = \frac{1}{2}(340) = 170\ m\ s^{-1} \qquad \text{K1}$$

$$f_a = \frac{v}{v - v_s}f$$

$$f_a = \frac{340}{340 - 170}(1 \times 10^3) \qquad \text{G1}$$

$$f_a = 2000\ Hz \qquad \text{JU1}$$

The apparent frequency increases. J1

6

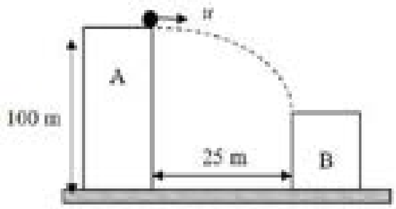


FIGURE 2.2 shows a ball is thrown from the top of the building A with an initial horizontal speed of u. The ball reaches the top of another building B after 1.8 s. The height of building A is 100 m. Calculate the

(i) initial speed, u of the ball.

(ii) height of building B.

$$s_x = u_x t$$

$$25 = (u_x)(1.8)$$

$$u_x = 13.89\ m\ s^{-1}$$

$$s_y = u_y t - \frac{1}{2}gt^2$$

$$-(100 - s_{yB}) = 0 - \frac{1}{2}(9.81)(1.8)^2$$

$$s_{yB} = 84.11\ \text{m}$$

7

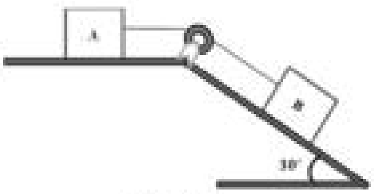


FIGURE 2

FIGURE 2 shows two boxes have identical masses of 40 kg. Both experience a sliding friction force on a rough floor of $\mu_k = 0.15$.

(i) sketch a free body diagram for boxes **B.**

(ii) when the box is moving, calculate the tension of the string **and** the acceleration of the boxes.

(ii) $\Sigma F_x = ma$ (blok B)

$$mg\sin 30 - f - T = m_B a$$

$$mg\sin 30 - \mu N - T = 40a$$

$$40(9.81)\sin 30 - 0.15(40)(9.81)\cos 30 - T = 40a$$

$$145.23 - T = 40a \_\_\_\_ (eq\ 1)$$

$$T - 0.15(40)(9.81) = 40a\ (blok\ A)$$

$$T - 58.86 = 40a \_\_\_\_ (eq2)$$

sub(1) = (2)

$$145.23 - T = T - 58.86$$

$$\boldsymbol{T = 102.05\ N}$$

from eq(2) $T - 58.86 = 40a$

$$102.05 - 58.86 = 40a$$

$$\boldsymbol{a = 1.08\ m\ s^{-2}}$$

8

(a) A stretched wire has strain energy per unit volume of 2.87 kJ m^{-3}. The wire has extension per unit length of 1.25 × 10^{-2}. Determine

(i) the Young's Modulus for the metal wire.

(ii) the stress in the wire.

(b) The diameter of a hole in a steel plate is 1.35 cm at 25 °C. The coefficient of linear thermal expansion of steel is 1.2 × 10^{-5} K^{-1}. Calculate the

(i) coefficient of area thermal expansion of steel.

(ii) cross-sectional area of the hole when the temperature of the plate is increased to 175 °C.

(a) (i) $\frac{U}{V} = 2.87 \times 10^3\ J\ m^{-3}$

$$\frac{\Delta l}{l} = 1.25 \times 10^{-2}$$

$$\frac{U}{V} = \frac{1}{2}\sigma\varepsilon$$

$$Y = \frac{\sigma}{\varepsilon}$$

$$Y = \left(\frac{F}{A}\right)\left(\frac{l_0}{\Delta l}\right)$$

$$\frac{U}{V} = \frac{1}{2}\sigma\varepsilon$$

$$\frac{U}{V} = \frac{1}{2}Y\varepsilon.\varepsilon$$

$$Y = \frac{2\left(\frac{U}{V}\right)}{\varepsilon^2}$$

$$= \frac{2(2.87 \times 10^3)}{(1.25 \times 10^{-2})^2}$$

$$= 3.67 \times 10^7\ N\ m^{-2}$$

(ii) $Y = \frac{\sigma}{\varepsilon}$

$$\sigma = 3.67 \times 10^7\ (1.25 \times 10^{-2})$$

$$= 4.592 \times 10^5\ N\ m^{-2}$$

(b) (i) $\beta = 2\alpha$

$$= 2(1.2 \times 10^{-5})$$

$$= 2.4 \times 10^{-5}\ K^{-1}$$

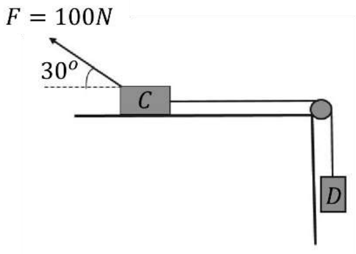
(ii) $A = A_0(1 + \beta\Delta T)$

$$= \frac{\pi d^2}{4}[1 + 2.4 \times 10^{-5}(175 - 25)]$$

$$= 1.43 \times 10^{-4}(1 + 3.6 \times 10^{-3})$$

$$= 1.44 \times 10^{-4}\ m^2$$

Weekend Homework Part 2 10/11/2024

No	Questions
1	 FIGURE 3.2 **FIGURE 3.2** shows box C of mass 10 kg pulled by a force of 100 N, 30^0 above horizontal connected to box D with unknown mass. Coefficient of kinetic friction between the surface and box C is 0.3. This boxes are moving with a constant velocity. (i) Draw two separate free body diagram shows all forces acting on box C and D. (ii) Calculate the tension of the string connected box C and D. (iii) Calculate mass of box D.
	(ii) $\sum F_y = 0$ $Fsin\theta^0 + N - W_A = 0$ $100sin30^0 + N - (10)(9.81) = 0$ — G1 $N = 48.1\ N$ $\sum F_x = 0$ $100cos30^0 - T - (0.3)(48.1) = 0$ — G1 $T = 72.17\ N$ — JU1 (iii) $\sum F_y = 0$ $T - mg = 0$ — GJU1 $m = \frac{T}{g} = \frac{72.17}{9.81} = 7.36\ kg$
2	(a) A horizontal spring attached to a wall has a force constant of 850 N m^{-1}. A block of mass 1.50 kg is attached to the spring and rests on a frictionless surface. The block is pulled to a position of 6.00 cm from equilibrium and released. Calculate the speed of the block as it passes through the equilibrium point. (b) The motor of a vacuum cleaner has a net power output of 746 W. Calculate the work done by the motor in 3.0 minutes.
	(a) $\sum E_i = \sum E_f$ $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$ $\frac{1}{2}(850)(6\ x10^{-2})^2 = \frac{1}{2}(1.5)v^2$ $\boldsymbol{v = 1.43\ ms^{-1}}$ (b) $P = \frac{W}{t}$ $746 = \frac{W}{3x60}$ $\boldsymbol{W = 134\ 280\ J}$
3	(a) A progressive wave can be represented by the equation $y(x,t) = (0.55)\sin\left(80\pi t - \frac{\pi}{0.15}x\right)$ where y and x are in centimeters and t is in seconds. For the wave, calculate (i) wavelength. (ii) particle vibrational velocity at x =2.0 m and t = 0.1 s (iii) speed of wave propagation. (b) A closed pipe makes a humming sound at frequency 282 Hz when the wind blows across the open end produce three nodes of standing wave. The speed of sound in air is 343 m s^{-1}. Determine (i) length of the pipe. (ii) wavelength of the wave

(a)

$$k = \frac{2\pi}{\lambda} = \frac{\pi}{0.15}$$
$$\lambda = 0.3\ cm$$

$$v(x,t) = (44\pi)\cos(80\pi t - \frac{\pi}{0.15}x)$$
$$v(2.0,0.1) = (44\pi)\cos(80\pi(0.1) - \frac{\pi}{0.15}(200))$$
$$v = -69.12\ c\ ms^{-1}$$

$$v = f\lambda$$
$$= \frac{80\pi}{2\pi}(0.3)$$
$$= 12.0\ c\ ms^{-1}\ @0.12\ m\ s^{-1}$$

(b)

$$f_n = \frac{nv}{4L}$$

3 nodes; n=5

$$282 = \frac{5(343)}{4(L)}$$
$$L = 1.52\ m$$

$$L = \frac{5\lambda}{4}$$
$$1.52 = \frac{5\lambda}{4}$$
$$\lambda = 1.216\ m$$

4 a)

A gas is compressed at a constant pressure of 1 atm from 5 L to 3 L. In the process, 400 J of heat is leaving the gas.

(i) Sketch a P-V graph for the process.

(ii) Calculate the change in internal energy.

[Given: 1 atm = 1.013 x 10 ^{5} Pa, 1 L = 0.001 m^3]

b)

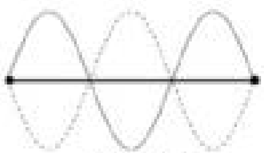


FIGURE 6

Two sinusoidal waves with the same amplitude and wavelength travel in opposite direction along a string that is stretched along an axis. Their resultant wave is shown in **FIGURE 6**. The distance between nodes and adjacent antinodes is 2 cm. The mass of the string is 35 g and the tension force applied is 50 N.

Determine

(i) the speed of waves travelling along the string.

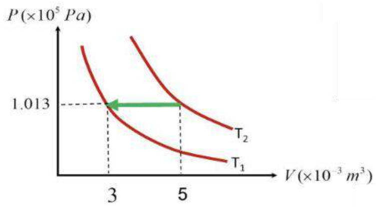
(ii) the wavelength and frequency of the standing waves formed.

a)

$$W = p\Delta V = p(V_f - V_i)$$
$$= 1.013\times10^5(3\times10^{-3} - 5\times10^{-3})$$
$$= -202.6\ J$$

$$\Delta U = Q - W$$
= -400-(-202.6)

= -197.4 J



b)

$$l = 6\times0.02 = 0.12\ m$$
$$\mu = \frac{m}{l} = \frac{0.035}{0.12} = 0.29\ kg\ m^{-1}$$
$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{50}{0.29}} = 13.13\ m\ s^{-1}$$

wavelength:
$$\lambda = 2\times4$$
$$= 8\ cm \text{ or } 0.08\ m$$

frequency:
$$f = \frac{v}{\lambda} = \frac{13.13}{0.08}$$
$$= 164.13\ Hz$$

5

(a)

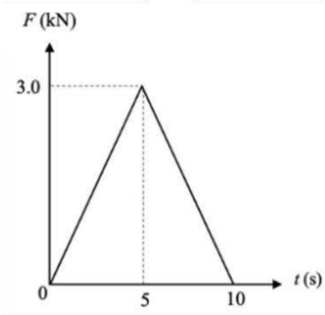


FIGURE 2 shows a variation of force with time when a car hits a wall. Calculate the impulse of the car.

(b) A 15.0 g bullet moving 250 m s^{-1} to the right strikes a log. Assume that the bullet undergoes uniform deceleration and stops in 10 s. Find the average force experienced by the bullet and state its direction.

(a) Impluse = Area under the graph

$$= \frac{1}{2}(10)(3x10^3)$$

$$= 15000 \text{ N s}$$

(b)

$$F = \frac{J}{t}$$

$$J = \frac{mv - mu}{t}$$

$$J = \frac{0.015\,(0 - 250)}{10}$$

$$F = \frac{(-3.75)}{10}$$

$$F = -0.375 \text{ N}$$

6

A simple harmonic oscillator consists of a block attached to a spring with spring constant, $k = 250$ N m^{-1}. The block slides back and forth along a straight line on a frictionless surface. A graph of the block's velocity against time is shown as in **FIGURE 5**.

Determine

(i) the angular frequency,

(ii) the amplitude,

(iii) the mass, and

(iv) the maximum kinetic energy of the block.

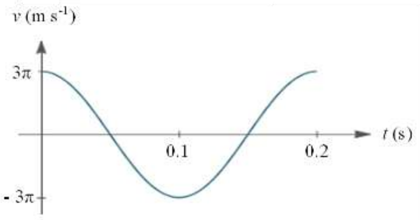


FIGURE 5

(i)
$$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.2}$$
$$\omega = 10\pi \ rad\ s^{-1}$$

(ii)
$$A = \frac{v_{max}}{\omega} = \frac{3\pi}{10\pi}$$
$$A = 0.3\ m$$

(iii)
$$m = \frac{k}{\omega^2} = \frac{250}{(10\pi)^2}$$
$$m = 0.253\ kg$$

(iv)
$$K_{max} = \frac{1}{2}mv_{max}{}^2 = \frac{1}{2}(0.253)(3\pi)^2$$
$$= 11.24\ J$$

7

A 55 m^2 composite wall of a building consists of brick and concrete with the thickness of 12.0 cm and 24.0 cm respectively. The temperature of the outer surface of the brick and concrete is 40 °C and 20 °C respectively. (Given coefficient of thermal conductivity of brick and concrete are 0.6 W m^{-1} °C^{-1} and 0.8 W m^{-1} °C^{-1} respectively.)

(i) Determine the temperature of the interface between the brick and the concrete.

(ii) How much heat flows through the concrete in 1 hour?

$$k_B A\left(\frac{dT}{x}\right) = k_C A\left(\frac{dT}{x}\right)$$

$$0.6(55)\left(\frac{T-40}{12}\right) = 0.8(55)\left(\frac{20-T}{24}\right)$$

$$0.05(T-40) = 0.03(20-T)$$

$$0.08T = 2.6$$

$$T = 32.5\ °C$$

$$\frac{Q}{t} = -kA\left(\frac{dT}{x}\right)$$

$$Q = -0.6(55)\left(\frac{32.5-40}{12\times10^{-2}}\right)(3600)$$

$$Q = 7.43\times10^6\ J$$

8	The temperature in outer space is about 3.5 K and it is estimated that there is about one hydrogen molecule per cm^3. The mass of a hydrogen molecule is 3.346×10^{-27} kg. Calculate the (i) rms speed of the hydrogen molecules. (ii) hydrogen density in outer space. (iii) pressure of hydrogen gas at the outer space. (iv) mean translational kinetic energy of the hydrogen molecules.
	(i) $v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3(1.38 \times 10^{-23})(3.5)}{3.346 \times 10^{-27}}} = 208.1\ m\ s^{-1}$ (iii) $pV = nRT$, $p = \frac{nRT}{V}$, $p = \frac{1}{3}\rho(v_{rms})^2 = \frac{1}{3}(3.346 \times 10^{-21})(208.1)^2 = 4.83 \times 10^{-17}\ N\ m^{-1}$ (ii) $\rho = \frac{m}{V} = \frac{3.346 \times 10^{-27}}{1 \times 10^{-6}} = 3.346 \times 10^{-21} kg\ m^{-3}$ (iv) $K_{Trans} = \frac{3}{2}kT = \frac{3}{2}(1.38 \times 10^{-23})(3.5) = 7.25 \times 10^{-23} J$

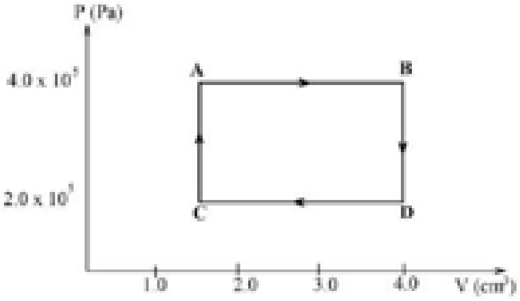
11 Nov 2024

<table>
<tr><th>No</th><th>Question</th></tr>
<tr><td>1</td><td>

a) A 3 mole hydrogen gas has a temperature of 420K. Assuming the gas behaves ideally, calculate the internal energy of the gas.

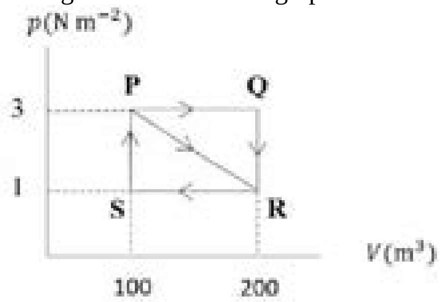
b) A gas is confined in a container undergoes A thermodynamic process where it absorbs 1700 J of heat from its surroundings. If the internal energy decreases by 600 J calculate the work done by the gas during the process.

c) The figure shows a monoatomic gas that contained in a piston undergoes various processes.



Determine its internal energy at point B.

d) The figure shows a $P - V$ graph of an ideal gas. If the change of an internal energy from P to R is +300 J.



Determine the work done by the system during the process of R to S and the heat energy during the process RSP.

</td></tr>
<tr><td></td><td>

$$U = \frac{5}{2}nRT = \frac{5}{2}(3)(8.31)(420) = 26.1765kJ$$
$$\Delta U = Q - W \Rightarrow -600 = 1700 - W \Rightarrow W = 2.3kJ$$
$$U = \frac{3}{2}pV = 1.5(4 \times 10^5)(4 \times 10^{-6}) = 2.4J$$
$$W_{RS} = p\Delta V = 1(100 - 200) = -100J$$
$$\Delta U_{PQR} = \Delta U_{RP} = -\Delta U_{PR} = -300J$$
$$Q_{RSP} = W_{RSP} + \Delta U_{RSP} = -100 + (-300) = -400J$$

</td></tr>
<tr><td>2</td><td>

a) The rms speed of helium gas is 1600m/s. When the pressure and volume of the gas are made to be half each while the number of moles of the gas was kept constant, calculate the new rms speed of the gas and the new temperature of the gas if the molar mass of helium gas is $4gmol^{-1}$.

b) A 0.6mole monoatomic gas fills a $2.5m^3$ container at 320K at 2.5kPa. The gas isothermally compressed to half its original volume. The gas is then allowed to expand isobarically to its original volume at the final temperature of the gas 520K. Calculate the total work done in the process, the heat transfer during the isothermal process and the change in internal energy of the gas for isobaric process.

</td></tr>
<tr><td></td><td>

a)

$$\frac{p_iV_i}{p_fV_f} = 4 = \frac{v_{rms-old}^2}{v_{rms-new}^2} = \frac{1600^2}{v_{rms-new}^2} \Rightarrow v_{rms-new} = \sqrt{\frac{1600^2}{4}} = 800ms^{-1}$$
$$v_{rms-new} = \sqrt{\frac{3RT}{M}} \Rightarrow 800 = \sqrt{\frac{3(8.31)T}{0.004}} \Rightarrow T = 102.69K$$

b)

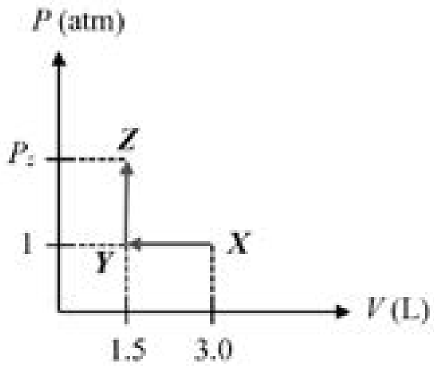
$$W_1 = nRT\ ln\left(\frac{V_2}{V_1}\right) = 0.6(8.31)(320)\ ln\left(\frac{1}{2}\right) = -1105.93J$$
$$p_2 = 2p_1 = 2(2.5kPa) = 5kPa$$
$$W_2 = p_2(V_3 - V_2) = 5(10^3)(2.5 - 1.25) = 6250J$$
$$W_{total} = -1105.93 + 6250 = 5144.07J$$

heat transfer during the isothermal process,

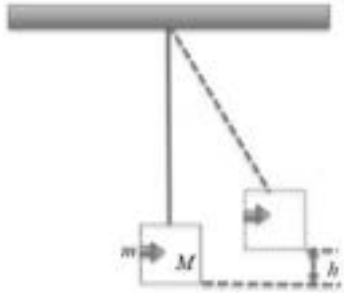
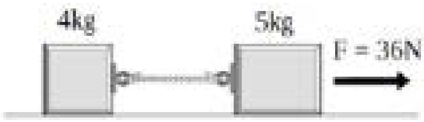
$$Q = W = -1105.93J$$

change in internal energy,

</td></tr>
</table>

	$$\Delta U = \frac{3}{2}nR\Delta T = 1.5(0.6)(8.31)(520-320) = 1495.8J$$
3	a) What is the rms speed of nitrogen molecules contained in $15m^3$ at 3.2atm, given that the total amount of nitrogen is 2700mol and the molar mass of nitrogen as is 28g/mol? b) An ideal gas expands at a constant total pressure of 3atm from 350 mL to 670 mL. Heat then flows out of the gas at constant volume, and the pressure and temperature are allowed to drop until the temperature reaches its original value. Sketch the P-V graph for the process and label each process. Calculate the total work done in the process and the total heat flow during this process.
	a) $$v_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3R\left(\frac{pV}{nR}\right)}{M}} = \sqrt{\frac{3\left(\frac{3.2(101325)(15)}{2700}\right)}{0.028}} = 484.723m/s$$ b) $$W_{total} = W_{isobaric} = p_1(V_2 - V_1) = 3(101325)(3)(0.00067 - 0.00035) = 97.3J$$ $$\Delta U_{total} = Q_{total} + W_{total} \Rightarrow 0 = Q_{total} + 97.3J$$ $$Q_{total} = 97.3J$$
4	a) The temperature of two samples of the same gas are 90^oC and 30^oC respectively. Calculate the ratio of the root mean square speeds of the gas molecules in the two samples. b) A container has a volume of $1.02m^3$, containing 1.7mol of a monoatomic gas at 5^oC. Calculate the total translational kinetic energy of the gas molecules and the average molecular kinetic energy. c) The figure shows an ideal gas which is initially compressed from a volume of 3L to 1.5 L at a constant pressure of 1atm. Heat is then supplied to the system at a constant volume while the pressure and temperature are allowed to fluctuate until the system reaches point Z, which has the same temperature as the temperature at X. Calculate the total work done in the above process and value of final pressure in atm. 
	a) $$\frac{v_{rms-1}}{v_{rms-2}} = \sqrt{\frac{90+273.15}{30+273.15}} = 1.0945$$ b) $$\Sigma K = \frac{3}{2}nRT = 1.5(1.7)(8.31)(5+273.15) = 5.894kJ$$ $$K = \frac{3}{2}k_BT = 1.5(1.38\times10^{-23})(5+273.15) = 5.76\times10^{-21}J$$ c) $$W_{total} = p\Delta V + 0 = (101325)(1.5-3)(10^{-3}) = -151.98J$$ $$p_XV_X = p_ZV_Z \Rightarrow (1)(3) = p_Z(1.5) \Rightarrow p_Z = 2atm$$

12 Nov 2024

No	Questions
1	a. In a block-bullet experiment, h = 5.00 cm, m = 5.00 g and M = 1.00 kg. Find the common velocity after the bullet embedded into the block, v  b. A 1000 kg car is travelling at a constant speed of 15 m s^{-1} enters the circular curve of a flat road with radius 50 m. Show by calculation whether the car can go round the curve safely when the road is wet with the coefficient of static friction μ_s = 0.30.
	a. $\Sigma E_i = \Sigma E_f$ $K = U_g$ $\left(\frac{1}{2}\right)(m)(v) = mgh$ $\left(\frac{1}{2}\right)(m+M)(v)^2 = (m+M)gh$ $\left(\frac{1}{2}\right)(1.005)(v)^2 = (1.005)(9.81)(0.05)$ $v = 0.981\ m\ s^{-1}$ b. $\sum F_r = F_c$ $F_c = \frac{mv^2}{r}$ $= \frac{(1000)(15)^2}{(50)}$ $= 4500N$ $f_s = \mu_s N$ $= (0.30)(mg)$ $= (0.30)(1000)(9.81)$ $= 2943N$ $f_s < F_c$ $2943N < 4500N$ ∴ The car **cannot go round the curve safely** when the road is wet with the coefficient of static friction $\mu_s = 0.30$
2	a. The figure shows two blocks of masses 4 kg and 5 kg are connected with each other and moves with the same acceleration on a frictionless horizontal surface. A constant horizontal force 36N is applied to the block of mass 5 kg. Find the acceleration of the blocks and calculate the tension in the cord connecting them.  b. A 500g block travels on rough surface with an initial speed of 0.5m/s. How far will it go if the coefficient of friction between it and the surface is 0.150?
	a. $m_5 a = F - T, T = m_4 a$ $m_5 a = F - m_4 a \Rightarrow a = \frac{F}{m_4 + m_5}$ $a = \frac{36}{4+5} = 4ms^{-2}$ $T = (4)(4) = 16N$ b. $a = \frac{F}{m} = \frac{f}{m} = \frac{\mu N}{m} = \frac{\mu mg}{m} = (0.15)(9.81) = 1.472ms^{-2}$ $v^2 = u^2 + 2as \Rightarrow 0^2 = 0.5^2 + 2(-1.472)(s) \Rightarrow s = 0.085m$
3	a. A conical pendulum with a bob of mass 0.5kg and string of length 0.75m swings in a horizontal circle of radius 30cm. Find the angle which string make with horizontal axis and the tension in the string. b. A particle vibrates and executes simple harmonic motion. The amplitude of the motion is 3m and the frequency is 15Hz. Calculate the velocity of the particle at time t = 1.5s and the speed of the particle 1m from one end.

a.

$cos\theta = \frac{0.3}{0.75} \Rightarrow \theta = 66.422^o$

$T\sin\theta = mg; T\cos\theta = \frac{mv^2}{r} \Rightarrow T\sin(66.422^o) = (0.5)(9.81) \Rightarrow T = 5.3518N$

b. $x = A\sin(\omega t) \Rightarrow v = \omega A\cos(\omega t),\ \omega = 2\pi f = 2\pi(15) = 30\pi\ rads^{-1}$

$$v = (30\pi)(3)\cos(30\pi t)$$

$$v(t = 1.5s) = 90\pi\cos\left(30\pi(1.5)\right) = -282.74ms^{-1}$$

$$v(x) = \pm\omega\sqrt{A^2 - y^2} \Rightarrow v(x = 2m) = \pm(30\pi)\sqrt{3^2 - 2^2} = 210.74ms^{-1}$$

4

a. A piano string, 1.5 m long, has a mass of 5g. How much tension must the string be under for it to vibrate at a fundamental frequency of 100 Hz? What is the frequency of the seventh overtone?

b. The steel bed of a suspension bridge is 200 m long at 32°C. If the extremes of temperature to which it might be exposed are -30 °C to 42 °C, how much will it contract and expand? Given coefficient of linear expansion of steel is $12 \times 10^{-6}\ K^{-1}$.

a.

$\mu = \frac{m}{l} = \frac{5x10^{-3}}{1.5} = 3.33x10^{-3}$

$f_n = \frac{nv}{2l}$, n=1

$100 = \frac{1v}{2(1.5)}$

$V = 300\ m\ s^{-1}$

$v = \sqrt{\frac{T}{\mu}}$

$v^2 = \frac{T}{\mu}$

$300^2 = \frac{T}{3.33x10^{-3}}$

T = 299.7 N

$f_n = \frac{nv}{2l}$, n = 8

$f_8 = \frac{8(300)}{2(1.5)} = 800\ Hz$

b.

Contract:

$$\Delta l = \alpha l_0 \Delta T$$
$$\Delta l = 12x10^{-6}(200)(-30 - 32)$$
$$\Delta l = -0.15\ m$$

Expand:

$$\Delta l = \alpha l_0 \Delta T$$
$$\Delta l = 12x10^{-6}(200)(42 - 32)$$
$$\Delta l = 0.024\ m$$

5

FIGURE 7.2

FIGURE 7.2 shows a 5.0 m section of steel railroads track when they are installed at temperature 32°C. A gap of 4 mm is left between the sections. Calculate the temperature at which the rail sections will just touch. (Given the coefficient of linear expansion of the steel is $12 \times 10^{-6}\,C^{-1}$).

$$\Delta L = \alpha L_o \Delta T$$
$$\Delta L = 4 \times 10^{-3} m$$
$$4 \times 10^{-3} = (12 \times 10^{-6})(5)(T - 32)$$
$$T = 98.67°C$$

6

A 0.5 mole monoatomic ideal gas is filled in a 2.2 m³ container at 313 K and pressure of 2.25 kPa. The gas is isothermally compressed to a half it original volume. Then the gas expands isobarically to its original volume at the final temperature of the gas is 515 K. Calculate the

(i) total work done in the processes.

(ii) heat transfer during isothermal process

(iii) change in the internal energy of the gas for isobaric process.

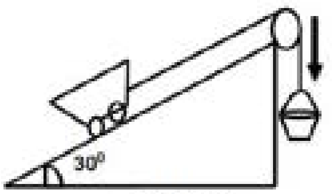
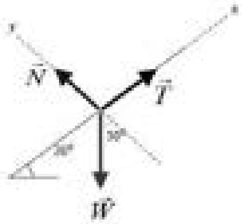
<table>
<tr><td></td><td>
$W_{isotermal} = nRT\ln\frac{V_f}{V_i} = 0.5(8.31)(313)\ln(\frac{1.1}{2.2})$
$W_{isotermal} = -901.45\ J$
$W_{isobaric} = P(V_f - V_i) = 4.20\times10^3\ (2.2 - 1.1) = 4620 J$
$W_{total} = W_{isothermal} + W_{isobaric}$
$W_{total} = -901.45\ J + 4620 \rightarrow W_{total} = 3718.55\ J$
$\Delta U = Q - W$
Isothermal, $\Delta U = 0$
$Q = W$
$= -901.45\ J$
Monoatomic : $f = 3$
$\Delta U = U_f - U_i = 1/2\ fnR(T_f - T_i)$
$½\ (3)0.5(8.31)(515 - 313) \rightarrow \Delta U = 1258.97\ J$
</td></tr>
<tr><td>7</td><td>


FIGURE 3
FIGURE 3 shows a 12.0 kg wheelbarrow placed on a frictionless plane inclined at 30° with the horizontal connected to a 7.0 kg hanging bucket by a string that passes over a pulley.
(i) Sketch a labelled free body diagram showing all the forces on the 12.0 kg wheelbarrow.
(ii) Calculate the acceleration of the system.
</td></tr>
<tr><td></td><td>


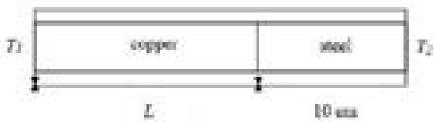
For m₁ :
$\Sigma F_x = ma$
$T - mg\sin 30^0 = m_1 a$
$T - (12)(9.81)\sin 30^0 = 12a$
$-12a + T = (12)(9.81)\sin 30^0$ ....(1)
For m_2 :
$\Sigma F_y = ma$
$m_2 g - T = m_2 a$
$(7)(9.81) - T = 7a$
$7a + T = (7)(9.81)$ ..... (2)
$a = 0.52\ ms^{-2}$
$T = 65.06\ N$
$\therefore a = 0.52\ ms^{-2}$
</td></tr>
<tr><td>8</td><td>


FIGURE 4
FIGURE 4 shows two insulated plates, one made of copper and the other of steel, each with an area of 50.0 cm² and joined together at their ends. The steel rod has a length of 10 cm, while the copper rod has a length of L. At the steady state, the temperatures at the ends of copper and steel are $T_1 = 100$ °C and $T_2 = 0$ °C and temperature at the joint is 60 °C. Given the thermal conductivity for both plates are $k_{copper} = 380\ W\ m^{-1}\ K^{-1}$ and $k_{steel} = 46\ W\ m^{-1}\ K^{-1}$.
(i) Calculate the temperature gradient of the steel rod.
(ii) Determine L.
</td></tr>
<tr><td></td><td>
$\frac{\Delta T}{L} = \frac{(0-60)}{0.1} = -600\ °C\ m^{-1}$
$\left(\frac{Q}{t}\right)_{Cu} = \left(\frac{Q}{t}\right)_{Steel}$
$-k_{Cu}A\left(\frac{\Delta T}{L}\right)_{Cu} = -k_{steel}A\left(\frac{\Delta T}{L}\right)_{steel}$
$(380)\left(\frac{60-100}{L}\right)_{Cu} = 46(-600)$
$L = 0.55\ m$
</td></tr>
</table>

13 Nov 2024

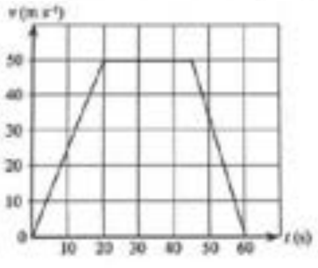
<table>
<tr><th>No</th><th>Questions</th></tr>
<tr><td>1</td><td>a.
A tennis ball is thrown horizontally from the top of a building of height 45 m. The ball strikes the ground at a horizontal distance of 20 m from the building. Calculate the
(a) the time of flight.
(b) initial speed of the ball.
(c) angle at which the trajectory of the ball makes with the ground just before the impact.
(d) If a man of 1.8 m tall is standing 15 m from the edge of the building. Will he be hit by the ball? Justify your answer.
b.
FIGURE 2 shows the velocity-time graph as a part of the performance data of the car.


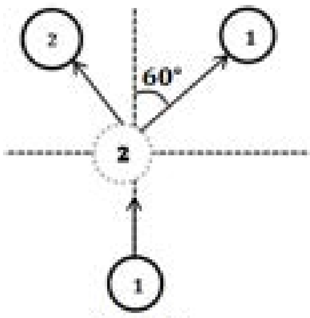
FIGURE 2
Calculate
i) the total distance travelled by the car.
ii) the average speed of the car.
iii) the acceleration of the car at t = 10 s.</td></tr>
<tr><td></td><td>a.
$S_y = U_y - \frac{1}{2}gt^2$
$-45 = 0 - \frac{1}{2}(9.81)t^2$
$t = 3.03\ s$
$s_x = u_x t$
$20 = u(3.03)$
$u = 6.60\ ms^{-1}$
$v_x = u$
$v_y = u_y - gt$
$v_y = 0 - (9.81)(3.03) = -29.7 ms^{-1}$
$angle, \theta = tan^{-1}\frac{v_y}{v_x} = tan^{-1}\frac{\lvert -29.7 \rvert}{\lvert 6.60 \rvert}$
$\theta = 77.5°$
$s_x = u_x t$
$t = \frac{15}{6.60} = 2.27\ s$
$S_y = U_y t - \frac{1}{2}gt^2$
$S_y = 0 - \frac{1}{2}(9.81)(2.27)^2 = -25.27\ m$
Height of the ball from ground at 15 m is 45-25.27=19.73 m which is greater than height of the man, thus the ball **does not hit** the man
b.
Total distance, d = Area under the graph
$= \frac{1}{2}(60 + 25)(50)$
$= 2125\ m$
Average speed, $v = \frac{Total\ distance}{Total\ time}$
$= \frac{2125}{60}$
$= 35.42\ m\ s^{-1}$
Acceleration, a = Gradient of the graph (from t = 0 s to t = 20 s)
$a = \frac{50 - 0}{20 - 0}$
$= 2.5\ m\ s^{-2}$</td></tr>
<tr><td>2</td><td>a.
FIGURE 1 shows ball 1 of mass 150 g and velocity 5 m s^{-1} collides obliquely with a stationary ball 2 of mass 200 g. After the collision, ball 1 moves with velocity of 9 m s^{-1} at an angle 60° from its initial direction.
Calculate the velocity of ball 2 after collision


FIGURE 1
b.</td></tr>
</table>

<table>
<tr><td></td><td>

FIGURE 3.1 shows an object A moving in horizontal with speed 8 m s^{-1} collide with an object B moving downward with speed 10 m s^{-1}. Mass of object A and B are 7 kg and 5 kg respectively. Determine the magnitude of velocity and its direction if the objects stick and move together after collision.

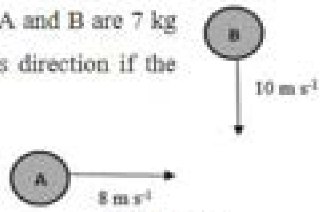


FIGURE 3.1

</td></tr>
<tr><td></td><td>

a.

$\sum p_i = \sum p_f$

$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

$x - component$

$m_1u_{1x} + m_2u_{2x} = m_1v_{1x}\sin 60^\circ + m_2v_{2x}$

$0 = (0.15)(9)(\sin 60^\circ) + 0.20v_{2x}$

$v_{2x} = -5.85$ m s^{-1}

$y - component$

$m_1u_{1y} + m_2u_{2y} = m_1v_{1y}\cos 60^\circ + m_2v_{2y}$

$(0.15)(5) + 0 = (0.15)(9)(\cos 60^\circ) + 0.20v_{2y}$

$v_{2y} = 0.38$ m s^{-1}

$v_2 = \sqrt{v_{2x}^2 + v_{2y}^2}$

$v_2 = \sqrt{(-5.85)^2 + (0.38)^2}$

$v_2 = 5.86$ m s^{-1}

b.

$\sum p_{ix} = \sum p_{fx}$

$m_A u_{Ax} + m_B u_{Bx} = (m_A + m_B)v_{ABx}$

$7(8) + 0 = (7+5)v_{ABx}$

$v_{ABx} = 4.67\ m\ s^{-1}$

$\sum p_{iy} = \sum p_{fy}$

$m_A u_{Ay} + m_B u_{By} = (m_A + m_B)v_{ABy}$

$0 + (5)(-10) = (7+5)v_{ABy}$

$v_{ABy} = -4.17\ m\ s^{-1}$

$v_{AB} = \sqrt{4.67^2 + (-4.17)^2}$

$v_{AB} = 6.26\ m\ s^{-1}$

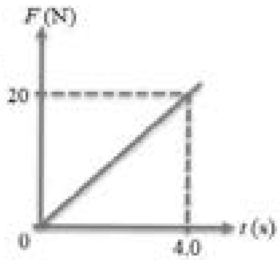
$\theta = tan^{-1}\frac{(-4.17)}{4.67}$

$\theta = -41.8^\circ$, below positive x-axis

</td></tr>
<tr><td>3</td><td>

a.

An object with mass 5.0 kg at rest is acted on by a force which increases uniformly from zero to 20 N in 4.0 s. Calculate the speed of the object at the end of the four seconds interval.



b.

A 8 kg box is held in equilibrium on a rough slope by a horizontal force F as shown in **FIGURE 2**. The coefficient of friction between the box and the slope is 0.15. The magnitude of force F may vary from a certain minimum value to a maximum value.

(i) Sketch a free body diagram for the box when force F has its minimum value Label all forces.

(ii) Determine the minimum magnitude of the force F **and** the normal force act on the box.

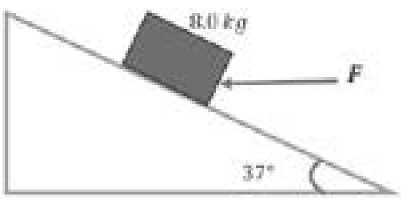


FIGURE 2

</td></tr>
<tr><td></td><td>

a.

$J = Area\ under\ F - t\ graph$

$(m)(v-u) = \left(\frac{1}{2}\right)(20)(4)$

$(5)(v-u) = 40$

$v = 8\ m\,s^{-1}$

b.

$\Sigma F_y = 0$

$N - F\sin 37 - mg\cos 37 = 0$

$N = F\sin 37 + mg\cos 37$

$\Sigma F_x = 0$

$F\cos 37 - f - mg\sin 37 = 0$

$0.7986F - 0.15[0.6018F + 62.68] - 47.23 = 0$

$0.7986F - 0.09027F - 9.402 - 47.23 = 0$

$0.70833F = 56.632$

$F = 79.95\ N$

$\Sigma F_y = 0$

$N = F\sin 37 + mg\cos 37$

$N = 0.6018(79.95) + 62.68$

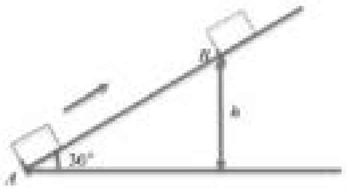
$N = 110.79\ N$

</td></tr>
<tr><td>4</td><td>

a.

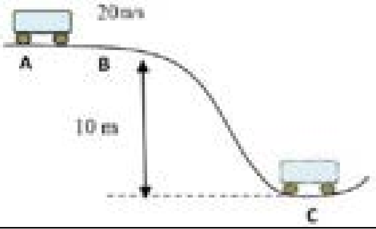
</td></tr>
</table>

b.



An object of mass 2 kg moves up a rough inclined plane with an initial velocity of 14.14 m s^{-1}, which makes an angle 30° with the horizontal. The coefficient of kinetic friction between the object and the plane is 0.20. By using work-energy theorem, calculate the kinetic energy of the object at point B if the height $h = 1.5$ m.

b.



In **FIGURE 3**, a small cart of mass 8 kg moves on the frictionless track with a speed of 20 m s^{-1} along **AB** and down to **C**. Calculate the

(i) kinetic energy of the cart as it moves along **AB**.

(ii) potential energy of the cart at point **B**.

(iii) speed of the cart at point **C**.

a.

$$\sin 30° = \frac{h}{s}$$
$$0.5 = \frac{1.5}{s}$$
$$s = 3m$$

$$W = \Delta K$$
$$\left(\sum F_s\right)s = K_f - K_i$$
$$(-f_k - W_x)s = K_B - K_A$$
$$(-f_k - W\sin\theta)s = K_B - K_A$$
$$[(-\mu_k N)(s) - mg\sin 30°(s)] = K_B - \frac{1}{2}mv^2$$
$$[-(0.20)(mg\cos 30°)(3) - mg\sin 30°(3)] = K_B - \frac{1}{2}(2)(14.14)^2$$
$$[-(0.20)(2.0)(9.81)\cos 30° - (2)(9.81)(\sin 30°)(3)] = K_B - 199.94$$
$$-10.19 - 29.43 + 199.94 = K_B$$
$$K_B = 160.32 J$$

b.

$$(i)\ K = \frac{1}{2}mv^2 = \frac{1}{2}(8)(20)^2 = 1600\,J$$

$$(ii)\ U = mgh = (8)(9.81)(10) = 784.8\,J$$

$$(iii)\ \Sigma E_i = \Sigma E_f$$
$$K_c = U + K$$
$$\frac{1}{2}mv^2 = 784.8 + 1600$$
$$v = 24.42\ m\,s^{-1}$$

5 a.

A ball of a mass 4.0 kg is attached to the end of a 1.2 m long string and whirled around in a circle that describes a **vertical plane.**

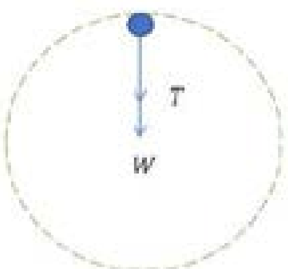
(a) Calculate the minimum speed that the ball can be moving at and still maintain a circular path? Sketch a **free body diagram**.

(b) At this speed, calculate the maximum tension in the string?

b.

A 1000 kg car is travelling at a constant speed of 15 m s^{-1} enters the circular curve of a flat road with radius 50 m. Show by calculation whether the car can go round the curve safely when the road is wet with the coefficient of static friction $\mu_s = 0.30$.

a.



v_{min}, T = 0,

$$\Sigma F_y = \frac{mv^2}{r}$$
$$T + mg = \frac{mv^2}{r}$$
$$0 + mg = \frac{mv^2}{r}$$
$$v = \sqrt{rg} = \sqrt{(1.2)(9.81)} = 3.43\ m\,s^{-1}$$

$$(ii)\ T - mg = \frac{mv^2}{r}$$
$$T_{min} = \frac{mv^2}{r} + mg = \frac{(4)(3.43)^2}{1.2} + (4)(9.81) = 78.46\ N$$

b.

$$\sum F_x = F_c \qquad f_s = \mu_s N$$

$$F_c = \frac{mv^2}{r} = \frac{(1000)(15)^2}{(50)} = 4500N$$

$$f_s = (0.30)(mg) = (0.30)(1000)(9.81) = 2943N$$

$$f_s < F_c \qquad 2943N < 4500N$$

∴ The car **cannot go round the curve safely** when the road is wet with the coefficient of static friction $\mu_s = 0.30$

6

a.

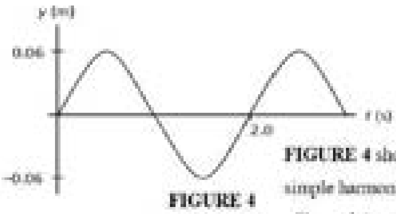


FIGURE 4

FIGURE 4 shows the displacement versus time graph for an object performing a simple harmonic motion. Based on the graph,

(i) determine the angular frequency.

(ii) determine the maximum velocity

(iii) write the simple harmonic motion equation.

b.

A 50 g object connected to a spring with a spring constant 35 N m^{-1} oscillates with amplitude 4 cm on a horizontal frictionless surface. Calculate the

(i) total energy of the system.

(ii) speed of the object at displacement 1.6 cm.

(iii) change in the period of oscillation if a load of 6 g is added to the object.

a.

(i) $\omega = \frac{2\pi}{T} = \frac{2\pi}{\pi} = \pi\ rad\ s^{-1}$

(ii) $v_{max} = A\omega = (0.06)(\pi)$, $v = 0.06\pi\ m\ s^{-1}$

(iii) $y = A\sin\omega t$

$y = 0.06\sin\pi t$

where y in m and t in second

b.

(i) $E = \frac{1}{2}kA^2 = \frac{1}{2}(35)(4\times10^{-2})^2 = 0.028\ J$

(ii) $v = \omega\sqrt{A^2 - y^2}$

$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{35}{50\times10^{-3}}} = 26.46\ rad\ s^{-1}$

$v = 26.46\sqrt{(4\times10^{-2})^2 - (1.6\times10^{-2})^2}$

$v = 0.97\ m\ s^{-1}$

(iii) $T_1 = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{50\times10^{-3}}{35}} = 0.24\ s$

$T_2 = 2\pi\sqrt{\frac{m_1 + m_2}{k}} = 2\pi\sqrt{\frac{56\times10^{-3}}{35}} = 0.25\ s$

$\Delta T = T_2 - T_1 = 0.25 - 0.24 = 0.01\ s$

7

a.

A transverse sine wave with an amplitude of 3.50 mm and a wavelength of 1.60 m travels from left to right, along a horizontal stretched string with a speed of 30 ms^{-1}. Take the origin at the left end of the undisturbed string. At time t = 0, the left end of the string has no upward displacement. Determine the

(i) frequency, angular frequency, and wave number of the wave.

(ii) displacement equation for the wave.

(iii) displacement equation for a particle at $x = 0$.

(iv) displacement equation for a particle $x = 1.40$ m.

(v) maximum magnitude of transverse velocity of any particle of the string.

(vi) transverse displacement and the transverse velocity of a particle 1.40 m to the right of the origin at time $t = 0.05$ s.

b.

A piano string, 1.5 m long, has a mass of 5 g.

(i) How much tension must the string be under for it to vibrate at a fundamental frequency of 100 Hz?

(ii) What is the frequency of the seventh overtone?

c.

The length of a closed pipe is 18.0 cm. If the speed of sound in air is 330 m s^{-1}.

i. Determine the two lowest frequencies.
ii. Sketch and label the wave pattern for the lowest frequency.

a.

$v = f\lambda$

$30 = f(1.6)$

$f = 18.75$ Hz

$\omega = 2\pi f$

$= 2\pi(18.75)$

$= 37.5\pi$ rad s^{-1} or 117.81 rad s^{-1}

$k = \frac{2\pi}{\lambda}$

$= \frac{2\pi}{1.6}$

$= 1.25\pi$ m^{-1} or 3.93 m^{-1}

(ii) $y(x,t) = 3.5\times10^{-3}\sin(37.5\pi t - 1.25\pi x)$
where x and y in meters and t in seconds.

(iii) The left-hand end is located at $x = 0$.
$y(t) = 3.5\times10^{-3}\sin(37.5\pi t)$
where x and y in meters and t in seconds.

(iv) Particle at $x = 1.40\,m$,
$y(x,t) = 3.5\times10^{-3}\sin(37.5\pi t - 1.25\pi(1.4))$
$y(t) = 3.5\times10^{-3}\sin(37.5\pi t - 1.75\pi)$
where x and y in meters and t in seconds.

(v) $v_{max} = \omega A$

$= 37.5\pi(3.5\times10^{-3})$

$= 0.41$ m s^{-1}

(vi) At $t = 0.05\,s$ and $x = 1.40\,m$,

$y = 3.5\times10^{-3}\sin(37.5\pi(0.05) - 1.25\pi(1.40))$

$y = 1.34\times10^{-3}$ m

$v_y = 0.412\cos(37.5\pi t - 1.25\pi x)$

$= 0.412\cos(37.5\pi(0.05) - 1.25\pi(1.40))$

$v_y = 0.381$ m s^{-1}

b.

i) $\mu = \frac{m}{l} = \frac{5x10^{-3}}{1.5} = 3.33x10^{-3}$

$f_n = \frac{nv}{2l}$, n=1

$100 = \frac{1v}{2(1.5)}$

V = 300 m s^{-1}

$v = \sqrt{\frac{T}{\mu}}$

$v^2 = \frac{T}{\mu}$

$300^2 = \frac{T}{3.33x10^{-3}}$

T = 299.7 N

ii) $f_n = \frac{nv}{2l}$, n = 8

$f_8 = \frac{8(300)}{2(1.5)} = 800\ Hz$

c.

Two lowest frequencies:

$f = \frac{nv}{4l}$

$= \frac{1(330)}{4(0.18)}$

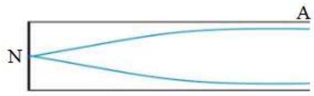
$= 458.33$ Hz

$f = \frac{nv}{4l}$

$= \frac{3(330)}{4(0.18)}$

$= 1375$ Hz

Fundamental wave pattern:



8 a.

A wire of cross-sectional area 0.52 mm^2 with a length of 60.0 cm is pulled by a force of 50 N as shown in the **FIGURE 7.**

i. Calculate the stress of the wire.
ii. If the extension is 0.12 cm, calculate the Young's modulus.
iii. Calculate the strain energy of the stretched wire.

FIGURE 7

b.

A 1.5 meters high water tank with a square base of sides 2 meters is filled with a liquid at 87 °C. The wall of the tank is 10 mm thick. If the temperature outside the tank is 28 °C, calculate the rate of heat loss due to conductivity through the base of the tank.
[Thermal conductivity of tank = 3.78×10^{-2} W m^{-1}K^{-1}]

c.

Two moles of monoatomic gas argon expand isothermally at 295 K, from an initial volume of $V_i = 0.025$ m^3 to a final volume of $V_f = 0.050$ m^3. Assuming that argon is an ideal gas. Calculate the heat transferred during the expansion. Is heat absorbed or released by the system.

d.

Two moles of an ideal gas are compressed isothermally from 800 cm^3 to 200 cm^3 at 80 °C.

(i) Calculate the work done on the gas.

(ii) What does a negative work implies?

a.

$$\sigma = \frac{F}{A}$$
$$= \frac{50}{0.52 \times 10^{-6}}$$
$$= 9.62 \times 10^{7}\ \text{N m}^{-2}$$

$$Y = \frac{FL_0}{A\Delta L}$$
$$= \frac{50(0.6)}{(0.52 \times 10^{-6})(0.12 \times 10^{-2})}$$
$$= 4.81 \times 10^{10}\ \text{Pa}$$

$$U = \frac{1}{2}F\Delta L$$
$$= \frac{1}{2}(50)(0.12 \times 10^{-2})$$
$$= 0.03\ \text{J}$$

b.

$$\frac{Q}{t} = -kA\left(\frac{\Delta T}{L}\right)$$
$$= -(3.78 \times 10^{-2})(2 \times 2)\left(\frac{28 - 87}{10 \times 10^{-3}}\right)$$
$$= 892.08\ \text{W}$$

c.

$$\Delta U = 0\ \text{J}$$
$$W = nRT\ ln\left(\frac{V_f}{V_i}\right)$$
$$= (2)(8.31)(295)\ ln\left(\frac{0.050}{0.025}\right)$$
$$= 3.398 \times 10^{3}\ \text{J}$$

$$\Delta U = Q - W$$
$$Q = 0 + (3.398 \times 10^{3})$$
$$= 3.398 \times 10^{3}\ \text{J}$$

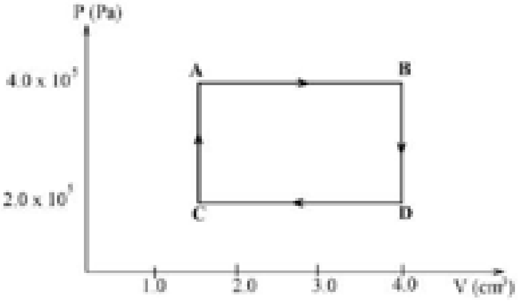
System absorb heat

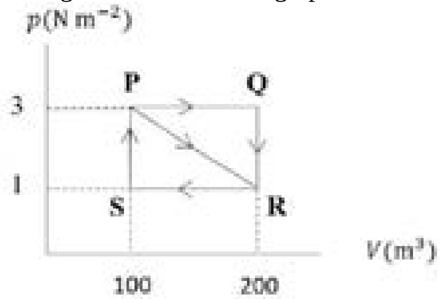
d.

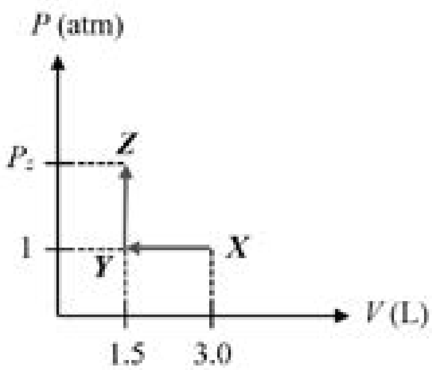
$$W = nRT \ln\frac{V_2}{V_1}$$
$$W = (2)(8.31)(80 + 273.15)\ln\frac{200}{800}$$
$$W = -8136.65\ \text{J}$$

Negative work implies the work is done on the system.

11 Nov 2024

<table>
<tr><th>No</th><th>Question</th></tr>
<tr><td>1</td><td>
a) A 3 mole hydrogen gas has a temperature of 420K. Assuming the gas behaves ideally, calculate the internal energy of the gas.
b) A gas is confined in a container undergoes A thermodynamic process where it absorbs 1700 J of heat from its surroundings. If the internal energy decreases by 600 J calculate the work done by the gas during the process.
c) The figure shows a monoatomic gas that contained in a piston undergoes various processes.


Determine its internal energy at point B.
d) The figure shows a $P - V$ graph of an ideal gas. If the change of an internal energy from P to R is +300 J.


Determine the work done by the system during the process of R to S and the heat energy during the process RSP.
</td></tr>
<tr><td>2</td><td>
a) The rms speed of helium gas is 1600m/s. When the pressure and volume of the gas are made to be half each while the number of moles of the gas was kept constant, calculate the new rms speed of the gas and the new temperature of the gas if the molar mass of helium gas is $4gmol^{-1}$.
b) A 0.6mole monoatomic gas fills a $2.5m^3$ container at 320K at 2.5kPa. The gas isothermally compressed to half its original volume. The gas is then allowed to expand isobarically to its original volume at the final temperature of the gas 520K. Calculate the total work done in the process, the heat transfer during the isothermal process and the change in internal energy of the gas for isobaric process.
</td></tr>
<tr><td>3</td><td>
a) What is the rms speed of nitrogen molecules contained in $15m^3$ at 3.2atm, given that the total amount of nitrogen is 2700mol and the molar mass of nitrogen as is 28g/mol?
b) An ideal gas expands at a constant total pressure of 3atm from 350 mL to 670 mL. Heat then flows out of the gas at constant volume, and the pressure and temperature are allowed to drop until the temperature reaches its original value. Sketch the P-V graph for the process and label each process. Calculate the total work done in the process and the total heat flow during this process.
</td></tr>
<tr><td>4</td><td>
a) The temperature of two samples of the same gas are 90^oC and 30^oC respectively. Calculate the ratio of the root mean square speeds of the gas molecules in the two samples.
b) A container has a volume of $1.02m^3$, containing 1.7mol of a monoatomic gas at 5^oC. Calculate the total translational kinetic energy of the gas molecules and the average molecular kinetic energy.
c) The figure shows an ideal gas which is initially compressed from a volume of 3L to 1.5 L at a constant pressure of 1atm. Heat is then supplied to the system at a constant volume while the pressure and temperature are allowed to fluctuate until the system reaches point Z, which has the same temperature as the temperature at X.
Calculate the total work done in the above process and value of final pressure in atm.


</td></tr>
</table>

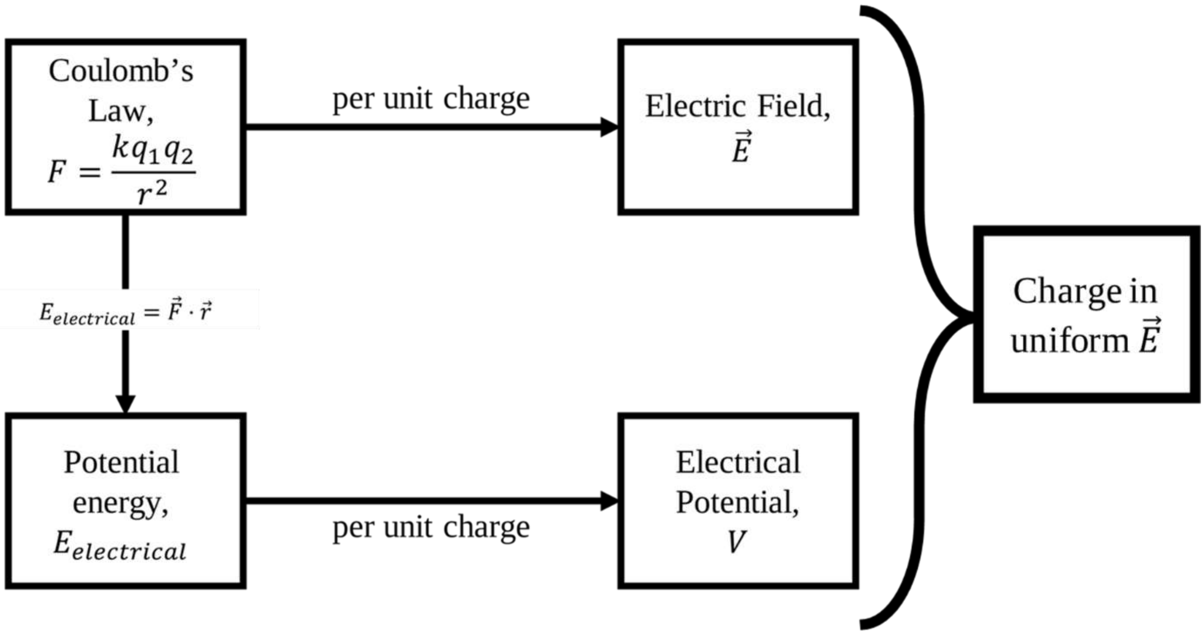
Matriculation Physics (SP025)

Short notes

Shafiq R

Table of Contents

Chapter 1: Electrostatics



Coulomb's Law

Let it be known that Coulomb's Law allows us to measure forces between charged particles, this force is known as **Coulomb Force**. Mathematically, Coulomb's Law is

$$F_{Coulomb} = \frac{kq_1q_2}{r_{12}^2}$$

where q_i are the charges of interacting particles, r_{12} is the distance between the particles and k is the electrostatic constant. The electrostatic constant is

$$k = \frac{1}{4\pi\epsilon} = 8.98 \times 10^9 \, kg \, m^3 \, s^{-4} \, A^{-2}$$

On the note of direction of the Coulomb force,

Condition	Direction
$F_{Coulomb} < 0$	Towards each other
$F_{Coulomb} > 0$	Away from each other

For more than 2 particles, the Coulomb Force on particle j becomes

$$F_{Coulomb} = kq_j \sum_i \frac{q_i}{r_{ij}^2}$$

Electric Field

The electric field at a point in space $E(r)$, is defined as the electric force acting on a positive test charge placed at that point $F(r)$, divided by the test charge, q_{test}.

$$E(r) = \frac{F(r)}{q_{test}}$$

Rearranging this equation yields,

$$F(r) = q_{test}E(r)$$

which tells us that particle of charge q_{test} placed in a region of electric field $E(r)$ will experience a force of $F(r)$.

If the source of electric field has a charge of q_{source}, then the electric field at point r, $\mathrm{E}(r)$ is

$$E(r) = \frac{kq_{source}}{r^2}$$

As in the case for Coulomb Force, for multiple, the electric field from multiple sources is simply additive,

$$E(r) = k\sum_i \frac{q_i}{r_i^2}$$

Electric Potential

Electric potential is the amount of work done to bring a test charge q_{test} from an infinite distance to a point at distance r from the source charged particle of charge q_{source}. This is found to be

$$V = \frac{W_{\infty\to r}}{q_{test}} = \frac{kq_{source}}{r}$$

Potential difference between positions $x = A$ and $x = B$ is then

$$V_{AB} = V_A - V_B = \frac{W_{\infty\to A}}{q_{test}} - \frac{W_{\infty\to B}}{q_{test}} = \frac{W_{\mathrm{A}\to B}}{q_{test}}$$

Electric potential energy is the energy a test charge would have positioned r distance away from a source,

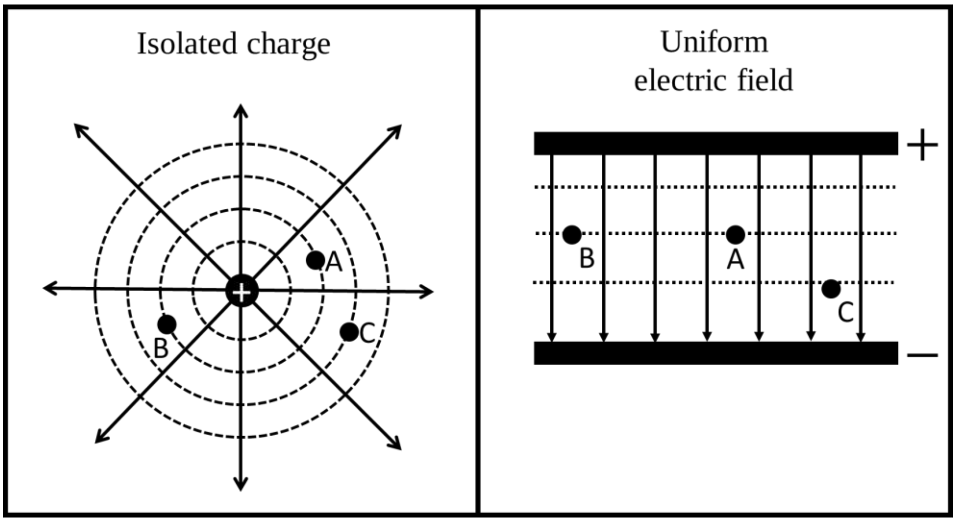
$$U = q_{test}V$$

For multiple sources, the potential and electrical potential energy at point r is simply,

$$V_{total} = k\sum_i \frac{q_i}{r_i};\ U_{total} = kq_j\sum_i \frac{q_i}{r_{ij}}$$

Equipotential lines and surfaces are graphical representation on which a particle on the line or surfaces is at the same potential.

- This means no work is done by the electric field when a charged particles are moved from on point of the equipotential line (or surface) to another point on the same line (or surface).
- Equipotential lines are always perpendicular to the electric field at all points.
- Examples:



In both examples,

$$V_A = V_B \neq V_C$$

Charge in Uniform Electric Field

For a uniform electric field produced by parallel plates of potential difference V, electric field strength is simply

$$E = \frac{V}{d}$$

where d is the distance between the parallel plates.

The following case studies involves a charged particle in a uniform electric field:

Case 1: Stationary charge

A stationary charged particle of charge q and mass m, placed in a uniform electric field E will experience force only from the electric field and therefore will move towards plate of its opposite charge (i.e. positive charged particle will move towards the negatively charged plate and vice versa).

Its motion will have the acceleration equivalent to

$$a = \frac{qE}{m}$$

Case 2: Charge moving parallel to the field

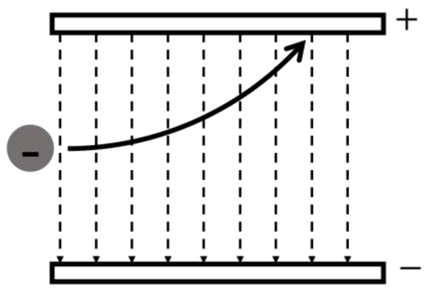
A charged particle of charge q and mass m, entering a uniform electric field E in a direction parallel to the field line, will experience force from the electric field in the direction of its opposite charge. It will either decelerate (if its velocity is in the opposite direction of its acceleration) or accelerate.

Its motion will have the acceleration equivalent to

$$a = \frac{qE}{m}$$

Case 3: Charge moving perpendicularly to the field

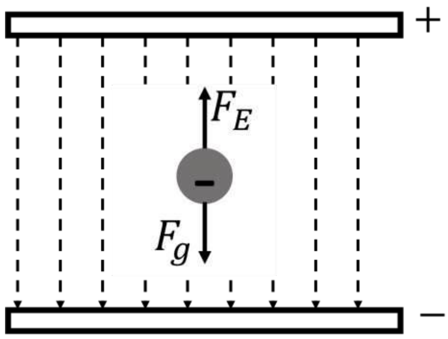
A charged particle of charge q and mass m, entering a uniform electric field E in a direction parallel to the field line, will experience force from the electric field in the direction of its opposite charge. Because of its initial velocity direction, it will follow a parabolic path, moving towards the plate of its opposite charge.



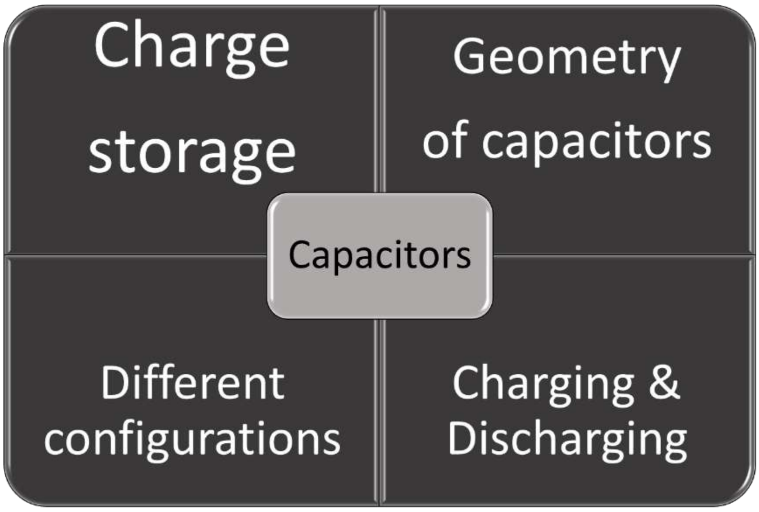
Case 4: Charge in dynamic equilibrium

In the case of dynamic equilibrium, the attractive Coulomb Force between the charged particle and the plate of opposite charge cancels out the weight of the charged particle,

$$F_{Coulomb} = W_{particle} \Rightarrow qE = mg$$



Chapter 2: Capacitors and Dielectrics



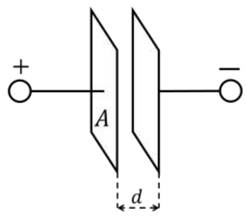
Parallel & Series

Capacitors are essentially batteries. Their ability to store charge is quantified by ***capacitance.*** Capacitance *C*, is the amount of charge *q* stored in one plate of a capacitor per unit potential difference between the plates, *V*,

$$C = \frac{Q_{single\ plate}}{V}$$

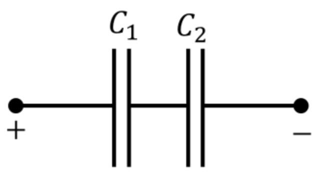
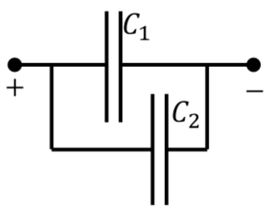
As a function of its geometry, capacitance of a parallel plate capacitor is

$$C = \frac{\varepsilon A}{d}$$



where ε is the permittivity of the space between the plates, A is the area of each plate and d is the distance between the parallel plates.

Multiple capacitors can be arranged either in parallel or series or combinations of them, and their effective capacitance can be calculated depending on their arrangement:

Arrangement	Effective Capacitance
Series 	$\frac{1}{C_{eff}} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots + \frac{1}{C_n}$ $C_{eff} = \left(\sum_{i=1}^{n} \frac{1}{C_i}\right)^{-1}$
Parallel 	$C_{eff} = C_1 + C_2 + \cdots + C_n$ $C_{eff} = \sum_{i=1}^{n} C_i$

Energy Stored in a Capacitor

Consider a pair of charged plate with charge

$$Q = CV$$

To deliver a small charge dq at constant variable V, we require the amount of work

$$dW = V\,dQ = \left(\frac{Q}{C}\right) dQ$$

The total word done (i.e. energy stored in the capacitor) is then

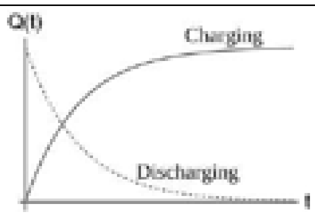
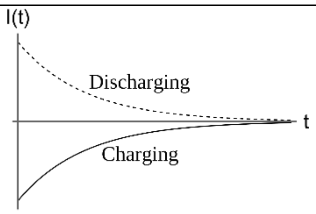
$$W = U = \int dW = \int_0^q \left(\frac{Q}{C}\right) dQ = \frac{Q^2}{2C}$$

Considering $Q = CV$, energy stored in a capacitor can be expressed as

$$U = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

Charging & Discharging Capacitors

Capacitors stores charges, now the question is how fast to charge it? Consider a simple circuit consisting of a power supply, a resistor of resistance *R* and a capacitor of capacitance *C*. Accumulation of charge with time for charging and discharging are as follows:

$Q - t$ graph	$I - t$ graph
 Discharging: $Q(t) = Q_o e^{-\frac{t}{RC}}$ Charging: $Q(t) = Q_o\left(1 - e^{-\frac{t}{RC}}\right)$	 Discharging: $I(t) = -\frac{dQ}{dt} = -\frac{Q_o}{RC}e^{-\frac{t}{RC}} = I_o e^{-\frac{t}{RC}}$ Charging: $I(t) = \frac{Q_o}{RC}e^{-\frac{t}{RC}} = -I_o e^{-\frac{t}{RC}}$

Time constant, τ is defined as the time for the exponential term to drop to e^{-1} for discharging, or, for the charge to increase to $1 - e^{-1}$ for charging process, and is calculate by multiplying the *R* and *C*,

$$\tau = RC \text{ [seconds]}$$

Dielectrics

Dielectrics are electrically non-conductive materials placed in between the plates of capacitors to increase the capacitance of the capacitor.

We quantify the increase in capacitance as the **dielectric constant $\boldsymbol{\varepsilon_r}$**, define as the ratio of capacitance of capacitor with dielectric C, to the capacitance of capacitor with no dielectric (vacuum) C_o,

$$\varepsilon_r = \frac{C}{C_o} = \frac{\left(\frac{\varepsilon A}{d}\right)}{\left(\frac{\varepsilon_0 A}{d}\right)} = \frac{\varepsilon}{\varepsilon_o}$$

Chapter 3: Current and DC Circuits

Electric Current

Current is the amount of charge ΔQ that passes through a surface area in time Δt,

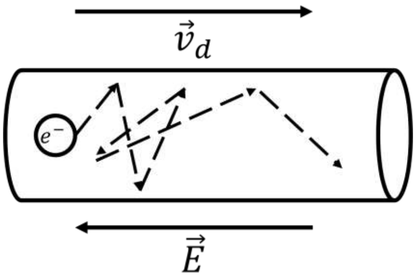
$$I = \frac{dQ}{dt}$$

Total charge Q is simply n multiples of electron charge e,

$$Q = ne$$

Without external electric field, the electron will drift through a conductor with kinetic energy equivalent to Fermi energy, which results in a net velocity of zero. With external electric field, the electron as a whole now gains a net velocity along the electric field. This 'net velocity' is what is known as 'drift velocity'.

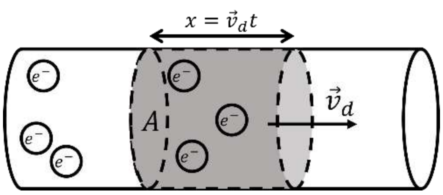
Consider an electron travelling through a conductor, on which an electric field of $\vec{E}$ is applied. The force on the electron is then $F = -qE \Rightarrow a = -\frac{eE}{m}$. Assuming the average time between collision is τ, we can show that



$$v_d = a\tau = \left(-\frac{eE}{m}\right)\tau$$

This means that applying a larger electric field, the larger the kinetic energy obtained by the electron due to a larger drift velocity. This also means that an increase in temperature, increases the collision frequency, decreases collision time and decreases drift velocity of the electrons.

Relating the idea of drift velocity to current can be done by considering a volume section of the conductor V, and the number of charges that flows through that section, n. We can work out that the amount of charge going through V is simply



$$\Delta Q = (ne)A\Delta x$$

where $\Delta x = v_d \Delta t$.

This means that current is

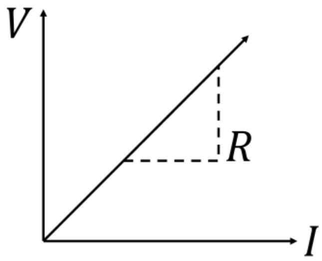
$$I = \frac{\Delta Q}{\Delta t} = neAv_d$$

Ohm's Law

Ohm's Law states that current I, is directly proportional to the potential difference V, is all conditions are constant.

$$V \propto I \ \Rightarrow V = IR$$

R, which is the proportionality constant to Ohm's Law, represents resistance which opposes current flow in a circuit.



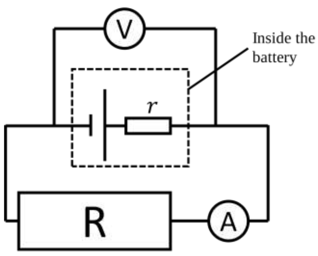
Resistance (Geometry & Temperature)

Resistance of a conductor in a circuit depends on 3 factors – geometry of the conductor, material of the conductor and the temperature of the conductor.

Factor	Equations
Material	For a resistor of resistivity ρ, length L and cross-sectional area A, the resistance is then
Geometry	$R = \frac{\rho L}{A}$
Temperature	When temperature of a conductor with coefficient of resistivity α (at $20^{o}C$), changes by ΔT, resistance changes by $\Delta R = \alpha \Delta T$

EMF, Internal Resistance and Potential Difference

Electromotive force (emf) is the electrical energy per unit charge generated by a power source generate current. Some of that electrical energy is used to overcome **internal resistance** within the power supply, the rest is then used for the rest of the circuit. That means the potential difference across the circuit is always less than the emf. This internal resistance may exist for a few reasons – distance between electrodes, temperature of the cell, effective area of the electrodes, irregularities found in the cell, etc.

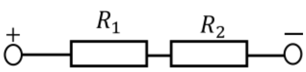
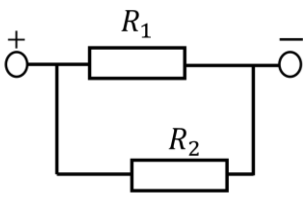


Consider a circuit consisting a voltmeter of reading V, an ammeter of reading I, a battery and a resistor of resistance R. The emf of the source is then

$$\varepsilon = IR + Ir = V + Ir$$

Parallel & Series

For systems of multiple resistors, they can be arranged in parallel, series or any combinations of the two. The effective resistance can then be calculated according to their arrangement.

<table>
<tr><td>Arrangement</td><td>Effective Capacitance</td></tr>
<tr><td>Series
</td><td>$$R_{eff} = R_1 + R_2$$ For n number of resistors in series, $$R_{eff} = R_1 + R_2 + \cdots + R_n = \sum_i^n R_i$$</td></tr>
<tr><td>Parallel
</td><td>$$\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2}$$ For n number of resistors in parallel, $$R_{eff} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_n}\right)^{-1} = \left(\sum_i^n \frac{1}{R_i}\right)^{-1}$$</td></tr>
</table>

Kirchhoff's Rules

Kirchhoff's Rules allows us to determine current flow around a circuit. The two rules are as follows:

Rules	Statement
First Rule – Junction Rule (Conservation of Charge)	Algebraic sum of currents in a network of conductors meeting at a junction is zero. $\sum_i I_i = 0$
Second Rule – Loop Rule (Conservation of Energy)	Algebraic sum of potential difference in any loop must equal to zero. $\sum_i V_i = 0$

Electrical Energy and Power

Since work done (amount of energy) to deliver a small charge dq at constant variable V is $W = E = VQ$, and that current by definition is $Q = It$, we can see that energy will simply be

$$E = (VI)t$$

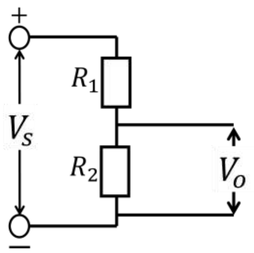
Since $E = Pt$ and taking Ohm's Law ($V = IR$) into consideration, electrical power is then

$$P = IV = I^2R = \frac{V^2}{R}.$$

Potential Divider

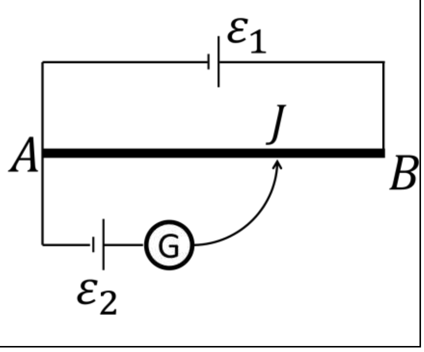
A potential divider is used to produce a voltage of a fraction of the voltage provided by the power supply. This is achieved by using resistors of different resistances.
If the power supply provides potential difference of V_s, then the output voltage is simple

$$V_o = \frac{R_1}{R_1 + R_2} V_s$$



Potentiometer

A potentiometer can be used to measure potential differences by two or more cells.

How it works
Wire AB has a resistance of R. This means if the jockey is at point B, then $R_{AJ} = R_{AB}$, and thus $I = I_{maximum}$. As the jockey is slid to towards A, the galvanometer will show zero reading which indicates no current passes through the galvanometer and that the potentiometer is balanced. This means $V_{AJ} = \varepsilon_2$. This happens when $\frac{V_{AJ}}{V_{AB}} = \frac{l_{AJ}}{l_{AB}}$ 

We can also use a potentiometer to compare emfs between two cells.

This is done by the following setup.

compare emfs between cell 2 and 3

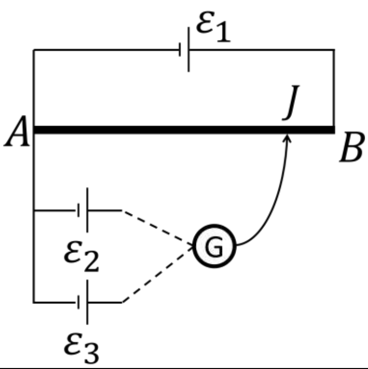
When the galvanometer is connected to ε_2 and balanced between A and J_1,

$$\varepsilon_2 = \frac{l_{AJ_1}}{l_{AB}}\varepsilon_1$$

When the galvanometer is connected to ε_2 and balanced between A and J_2,

$$\varepsilon_3 = \frac{l_{AJ_2}}{l_{AB}}\varepsilon_1$$

$$\Rightarrow \frac{\varepsilon_2}{\varepsilon_3} = \frac{l_{AJ_1}}{l_{AJ_2}}$$



Chapter 4: Magnetism

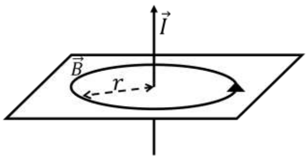
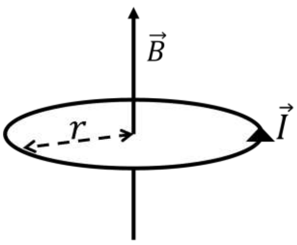
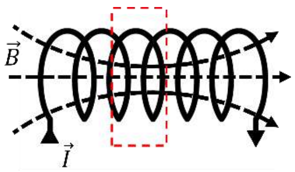
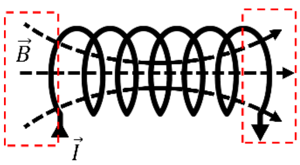
Magnetic Field

A magnetic field is a region of space in which a charged particle will experience magnetic force. They are generated by moving charged particles. Magnetic field lines are always drawn from its north pole to its south pole. When drawn on a 2D plane such as paper, we would generally represent a direction **into** the plane as $\otimes$, and direction **out** of the plane as $\odot$.

$\vec{B}$ from current-carrying conductor

Direction of magnetic field depends on the direction current flow – Right Hand Rule, where the thumb point to the current direction and curled fingers are the magnetic field lines.

4 cases to considering in calculating the magnitude of magnetic field

Situation	Equation
Long straight wire 	$B = \dfrac{\mu_o I}{2\pi r}$
Centre of circular coil 	$B = \dfrac{\mu_o I}{2r}$
Centre of solenoid 	$B = \mu_o I n$ Where *n* is the number of loops per unit length
End of solenoid 	$B = \dfrac{1}{2}\mu_o I n$ Where *n* is the number of loops per unit length

Magnetic Force

Force on a moving charged particle in uniform $\vec{B}$

Force on a particle with charge q moving at velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$, the magnetic force acting on it is

$$\vec{F}_{magnetic} = q(\vec{v} \times \vec{B}).$$

In the case of a large enough region, the magnetic force will cause the charged particle to travel in a circular motion. In such cases,

$$\vec{F}_{magnetic} = \vec{F}_{centripetal} \Rightarrow qvB = \frac{mv^2}{r^2}.$$

Force on a current carrying conductor in uniform $\vec{B}$

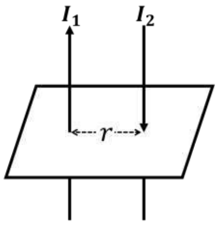
Consider a quantity of charge ΔQ travelling along a conductor of length *l* in a magnetic field $\vec{B}$ in time *t*. The magnetic force on the conductor is then

$$\vec{F}_{magnetic} = I(\vec{l} \times \vec{B}).$$

Force between two parallel current carrying conductors

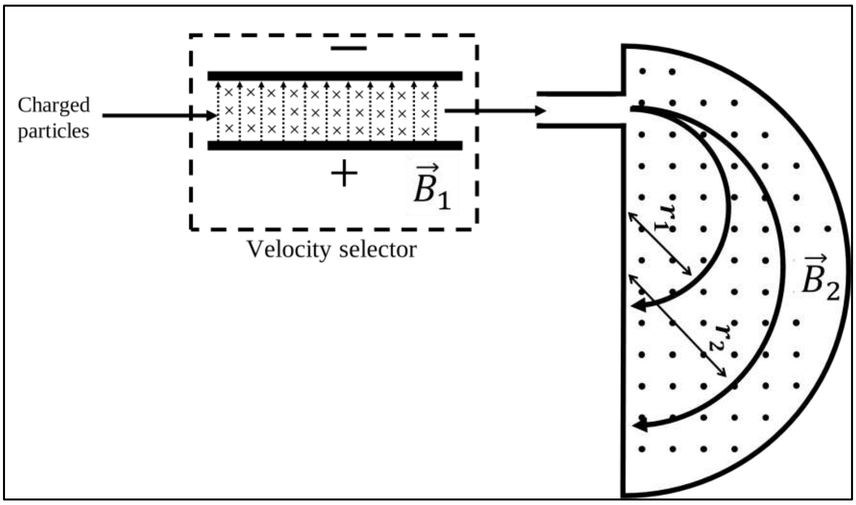
Consider two current carrying conductors of length *l* in proximity such that their magnetic fields overlap, their resultant magnetic force on each other is then

$$\vec{F}_{magnetic} = \frac{\mu_o I_1 I_2}{2\pi r} l$$



Bainbridge mass spectrometer

The Bainbridge mass spectrometer is used to accurately determine atomic mass.



The first part of the mass spectrometer is a velocity selector in which both electric field $\vec{E}$ and magnetic field $\vec{B}_1$. For charged particles to exit this velocity selector, their velocity must obey

$$v = \frac{E}{B_1}$$

This part of the mass spectrometer allows only charged particles with a certain velocity to enter the second region of only magnetic field $\vec{B}_2$.

The second part of the instrument takes advantage that charged particles of the same entry velocity but different mass will travel in circular path of different radius.

$$qvB_2 = \frac{mv^2}{r^2} \Rightarrow m = \frac{qB_2r^2}{v} = \frac{qB_1B_2r^2}{E}$$

Chapter 5: Electromagnetic Induction

Magnetic Flux

Magnetic flux is a measure of total magnetic field $\vec{B}$ passing through a given area $\vec{A}$, this is calculated with

$$\phi = \vec{B} \cdot \vec{A}.$$

In the case of N number of area of $\vec{A}$ of which $\vec{B}$ passes through, the total magnetic flux is called the **magnetic flux linkage Φ,** and is determine by

$$\Phi = N\phi = NBA\cos\theta$$

Induced EMF

EMF is induced when magnetic flux changes with time. This is the core of Faraday's and Lenz's law of electromagnetic induction.

- Faraday's law tells us how much it emf is induced (magnitude) and Lenz's law tells us in what direction will the force act upon (direction of induced current).
- Faraday's law tells us that the magnitude of induced emf is equal to the rate of magnetic flux change and Lenz's law tells us that the induced current will be in the direction opposing the initial magnetic field.

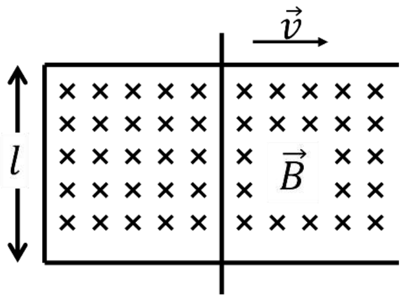
Together, they are simply written as

$$\varepsilon = -\frac{d\phi}{dt}$$

Induced emf in straight conductor

In a straight conductor, the area changes with time which causes the magnetic flux to change with time.

Consider a rectangular coil with one of its side movable and the opposite of the movable side has a length of l, in a region of magnetic field $\vec{B}$. If the movable side is moved at velocity $\vec{v}$, the area of the coil would change. The induced emf would then be



$$\varepsilon = -Bl\frac{dx}{dt} = Blv\sin\theta_{vB}$$

Induced emf in a coil

In a circular coil, the option for inducing emf comes from varying the magnetic field **and** the area of the coil, thus 2 equations can be found,

$$\varepsilon = -NB\frac{dA}{dt} \textbf{ or } \varepsilon = -NA\frac{dB}{dt}$$

Induced emf in a rotating coil

For a coil rotating at angular speed of ω, the emf induced is then

$$\varepsilon = NBA\omega\sin(\omega t)$$

Inductance

Self-induction

The idea of self-inductance is this – a magnetic field induces emf in a conductor, which in turns induces another magnetic field that opposes the initial induced emf. The conductor 'self induces' a magnetic field. The ability of a conductor to do this is quantified by ***self-inductance L,***

$$L = -\frac{\varepsilon}{\left(\frac{dI}{dt}\right)}$$

Generally, this means that

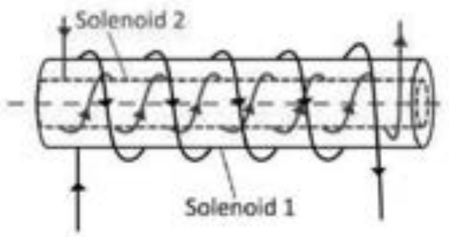
$$LI = N\phi$$

For more specific cases, 2 are considered:

1. For a coil of N turns with a cross sectional area of *A* and radius of *r*,
$$L = \frac{\mu_o N^2 A}{2r}$$
2. For a solenoid of N turns with a cross sectional area of *A* and length *l*,
$$L = \frac{\mu_o N^2 A}{l}$$

Mutual induction

Mutual inductance happens between 2 conductors, when the magnetic field induced by one conductor induces current in the other conductor. Consider two coaxial solenoids, a magnetic field is generated by solenoid 1 and thus solenoid 2 respond by an induced emf, if solenoid 2 has a cross sectional area of A_2, then the mutual inductance between solenoid 1 and 2 is



$$M_{21} = \frac{\mu_o N_1 N_2 A_2}{l},$$

where *l* is the length of the solenoid.

Energy Stored in Inductor

The energy stored in an inductor of inductance *L* and with current *I* running through it, is simply

$$U = \frac{1}{2} L I^2$$

Chapter 6: Alternating Current

Alternating Current

Alternating current (AC) is defined as an electric current that periodically reverses its direction with respect to time.

Root Mean Square Values

In AC circuits, rather than being of constant value (such found in DC Circuits), voltages and current now are functions of time:

$$I \mapsto I(t) = I_{peak}\, sin\,(\omega t)$$

$$V \mapsto V(t) = V_{peak}\, sin\,(\omega t)$$

Resistance is then defined as

$$R = \frac{V_o}{I_o}$$

In calculation of power, where $P_{DC} = IV$, for AC circuits,

$$P_{AC} = I_{rms}V_{rms}$$

where,

$$I_{rms} = \frac{I_o}{\sqrt{2}} \text{ and } V_{rms} = \frac{V_o}{\sqrt{2}}$$

Impedance

In DC circuit, our main concern for opposition of current flow is only resistance R.

In AC circuits, we now have what is known as **impedance *Z***, which is defined by

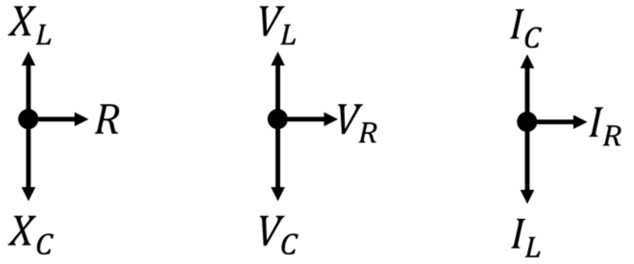
$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where R is the resistance, X_L is the inductive reactance and X_C is the capacitive reactance found in the circuit.

The following table shows how to calculate these values

Reactance	Equation
Capacitance reactance for a capacitor of capacitance C	$X_C = \frac{1}{2\pi f C}$
Inductive reactance for an inductor of inductance L	$X_L = 2\pi f L$

The phasor diagram for an RLC circuit is as follows,



Phasor Diagram
for RLC Circuit

Which means that the phase angle between current and voltage is

$$\theta_{IV} = tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

Resonance occurs when $X_L = X_C \Rightarrow \omega = \frac{1}{\sqrt{LC}} = 2\pi f$.

Power & Power Factor

2 types of power that be calculate in the case of AC circuits,

1. Instantaneous power

$$P = I(t) \times V(t)$$

2. Average power

$$P_{ave} = I_{rms}V_{rms} \cos(\theta_{IV})$$

The power factor is simply

$$\cos\theta_{IV} = \frac{P_{real}}{P_{apparent}} = \frac{P_{ave}}{I_{rms}V_{rms}}$$

Chapter 7: Optics

Geometrical Optics: Reflection

Definitions:

1. Centre of curvature, *C* = a point on the principal (or optical) axis that is positioned at distance equal to the radius of curvature *R*, of the spherical mirror.
2. Focal point, *f* = a point on the principal axis at which light rays travelling parallel to the principal axis will converge onto or diverge from, after reflecting on the surface of the spherical mirror.

f and *R* are related by the following equation:

$$R = 2f$$

2 types of mirrors:

1. **Convex mirror**, of which its radius is located behind the mirror.
2. **Concave mirror**, of which it's radius of curvature is located in front of the mirror.

Conventions	
Focal length, f	+ for concave; - for convex
Curvature Radius, R	

Lateral magnification m, refers to the ratio between the height of the image to the height if the object. In equation form,

$$m = \frac{h_i}{h_o}$$

$$m > 0 \Rightarrow \text{ upright image; } m < 0 \Rightarrow \text{ inverted image}$$

Geometrical Optics: Refraction

An extension to Snell's law will be the refraction at a spherical surface. The following equation allows us to relate distances, refractive indices and radius of curvature of the spherical surface:

$$\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$$

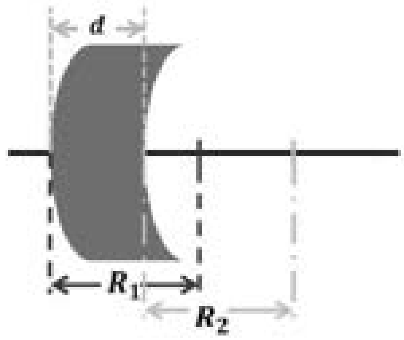
In the equation above n_i, refers to refractive indices, *u* and *v* refers to object and image distances respectively and *R* refers to the radius of curvature.

Conventions	
Curvature Radius, R	+ for convex, i.e. C opposite side as incoming light - for concave, i.e. C same side as incoming light

For the refractive indices, subscript 1 refers to the refractive index on the side of the incoming light rays and subscript 2 refers to the refractive index on the side of the outgoing rays.

Geometrical Optics: Thin lenses

The thin lens equation assumes that the thickness measured between two vertex of the spherical surface of a lens is much smaller than the product of the radii of the spherical lenses, that is $d \ll R_1 R_2$.



For thin lenses,

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

Conventions	
Focal length, f	+ for convex, i.e. same side as incoming light - for concave, i.e. opposite side as incoming light

On the other hand, using the lens maker's equation,

$$\frac{1}{f} = \left(\frac{n_{material}}{n_{medium}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

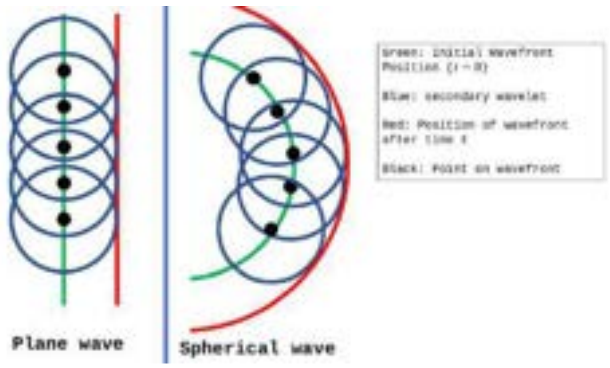
one can determine the focal length f, of the lens from

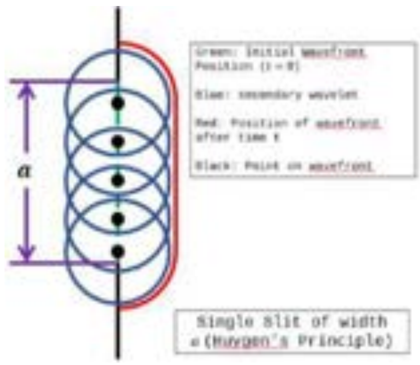
1. the radii of the lens surfaces, R_1 and R_2,
2. the ratio of the refractive index of the lens material to the refractive index of the surrounding, $\frac{n_{material}}{n_{medium}}$

Conventions	
Curvature Radius, R	- if curvature same side as incoming light + if curvature opposite side as incoming light

Physical Optics: Huygens's Principle

Huygen's Principle states that "each point on the wavefront acts as the source of secondary wavelets that spread out in all directions in spherical waves with a speed equal to the speed of wave propagation."



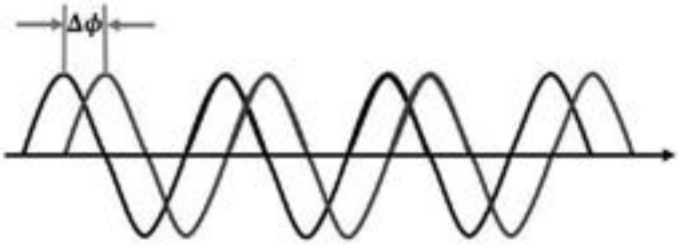


Physical Optics: Interferences

Coherence between 2 waves refers to the condition of constant phase difference between 2 waves with respect to time, that is to say $\frac{d\phi}{dt} = 0$. This property is the ideal property for stationary interference.

For a stable interference pattern, the following conditions are required:

1. Coherence, that is to say the two interacting light waves are of the same phase difference, $\frac{d\phi}{dt} = 0$.



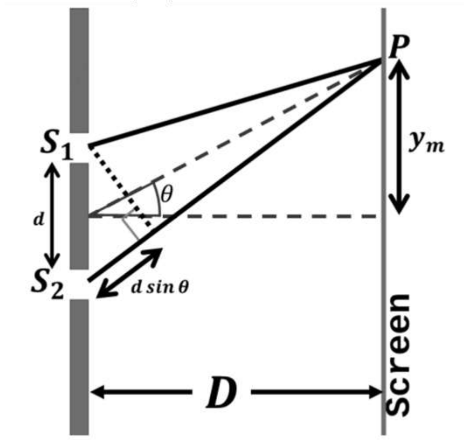
2. Monochromatic, that is to say that the two interacting light waves are of the same wavelength, i.e. $\lambda_1 = \lambda_2$

For purely **constructive interference**, it is empirical that the phase difference between the interacting waves is either 0 or $n\lambda$. On the other hand, for purely **destructive interference**, it is required that the phase difference between the two interacting wave is $\frac{n\lambda}{2}$.(n is both cases refers to integer values.)

Physical Optics: Slits

Double Slit

We now consider the case for Young's double slit experiment.



Here we define the following variables:

D	distance from slit to screen
d	slit separation
y_m	distance from central maximum tu the mth fringe

We know that in order to determine what type of fringe forms at P, we need to look at the path difference and from the figure, we can say that the figure,

$$\Delta\phi = S_2P - S_1P = dsin\theta = d\left(\frac{y_m}{D}\right)$$

For **bright fringes**,

$$\Delta\phi = \frac{y_m d}{D} = m\lambda$$

Rearranging this allows us to find fringe distance as a function of *d* and *D* with *m* having any integer value indicating **mth bright fringe** from central maximum:

$$y_m = \frac{m\lambda D}{d}$$

Shifting one the waves by 0.5λ give us the equation for **dark fringes**,

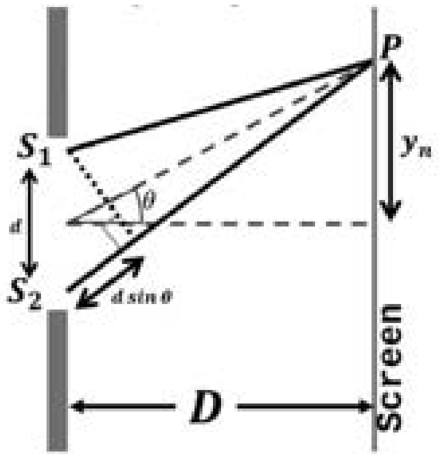
$$y_m = \frac{(m+0.5)\lambda D}{d}.$$

Lastly, we'd want to calculate the fringe separation. This can be done by considering $\Delta y = y_{m+1} - y_m$, which results in

$$\Delta y = \frac{\lambda D}{d}$$

Single Slit

Diffraction is defined as the spreading or bending of waves as they pass through an aperture of a barrier. The diffracted waves then interfere with each other to produce a diffraction pattern.



Light waves from one portion of the slit interacts with light waves from a different portion of the same slit to produce a diffraction pattern.

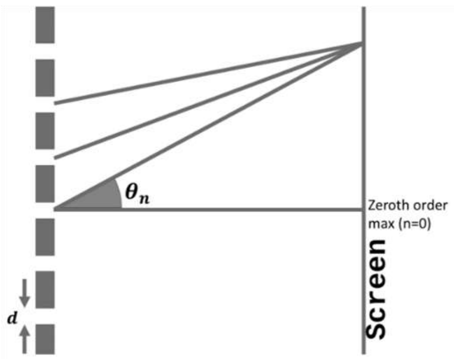
Here, we find that the dark fringes to forms when according to

$$d\,sin\,\theta = \,n\lambda.$$

Geometrically, we also find that $tan\theta \approx sin\theta \approx \frac{n\lambda}{d} \approx \frac{y_n}{D}$.

As such, we can say that **dark fringes** forms at $y_n = \frac{n\lambda D}{d}$. This would also mean that **bright fringes** forms at $y_n = \frac{(n+0.5)\lambda D}{d}$.

Diffraction Grating

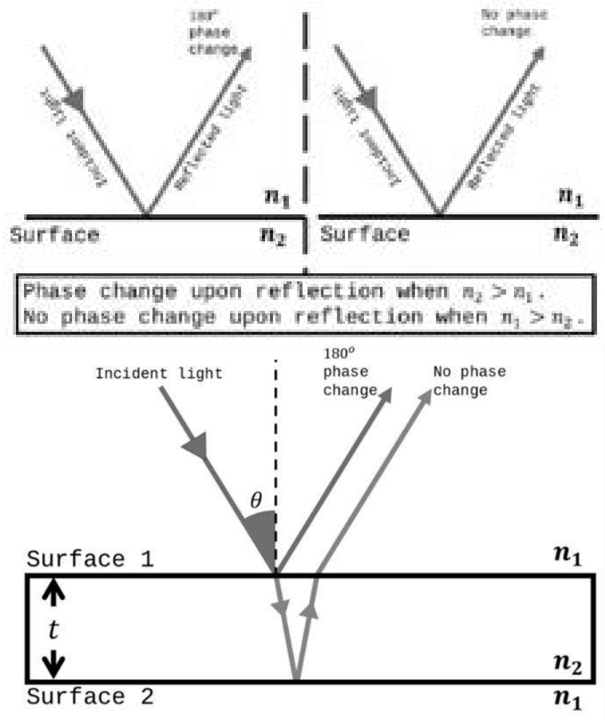


In the case for diffraction grating, light waves from many slits and interfere at the screen to form fringes of equal width. The equation by which the pattern follows is $d\,sin\,\theta_n = n$ for **bright fringes** and shifted by 0.5λ for **dark fringes**. Note that the angle θ_n is measured from the normal line formed at the zeroth order maximum. Also note that, **maximum number of fringes** can be calculated by considering that $sin\,\theta_n < 1$.

Physical Optics: Thin Films

Referring to figure on thin films, we can see that the two reflected light waves has a phase difference of 0.5λ from reflections at surface 1 and 2. One must also take into consideration of the extra distance that the second (green) wave travelled, that is $2nt$. Therefore, the total phase difference between the reflected waves is then

$$\Delta\phi = 2nt - \frac{1}{2}\lambda.$$



For **constructive interference**, $\Delta\phi = 2nt - \frac{1}{2}\lambda = n$, which gives us the equation

$$2nt = \left(n + \frac{1}{2}\right)\lambda.$$

Dark fringes then appear between the bright fringes, i.e. they follow the equation

$$2nt = n\,\lambda.$$

Main application for this concept of thin film interference is in **optical coatings** as one can manipulate the thickness of the coating as to choose the level of constructive or destructive interference. These optical coatings can be applied onto both for reflective as well as refractive systems.

Chapter 8: Particle Waves

De Broglie Wavelength

Like light, matter also exist in dual form – as particles **and** waves.

Matter waves, known as "de Broglie wavelength", are calculated with

$$\lambda_{matter} = \frac{h}{p} = \frac{h}{mv}$$

For a particle with of mass m charge q accelerated by electric field of V volts,

$$\lambda_{matter} = \frac{h}{\sqrt{2qVm}}$$

Electron Diffraction

On de Broglie wavelength:

1. To show that particles may exhibit wave-like characteristics, Davisson and Germer designed an experiment in which they show that electrons diffracted.
2. They achieve this by directing a beam of electrons onto a nickel crystal.

On electron microscope:

1. Because of their short wavelength (1nm for electrons vs 400nm – 700nm for light microscope), electronic microscopes can offer physicists a higher resolution in probing specimens.
2. Optical microscope is made up of glass lenses, whereas components of an electron microscope are electromagnetic.

Chapter 9: Nuclear & Particle Physics

Binding Energy & Mass Defect

Mass defect, Δm = mass difference between the actual mass of an atomic nucleus and the sum of its components, i.e. protons and neutrons.

For an atomic nucleus of mass $m_{nucleus}$ with Z number of protons of mass m_{proton} and N number of neutrons of mass $m_{neutron}$, its mass defect is

$$\Delta m = \left(Zm_{proton} + Nm_{neutron}\right) - m_{nucleus}$$

Binding energy, $E_{binding}$ = energy found in the nucleus of an atom that binds its components together. This energy can be calculated from the mass defect,

$$E_{binding} = \Delta mc^2$$

As the masses of atomic nucleus is well, very small, and the speed of light is astronomical, it may be easier to perform calculations using atomic mass unit (amu) or Dalton (u) and MeV/c^2

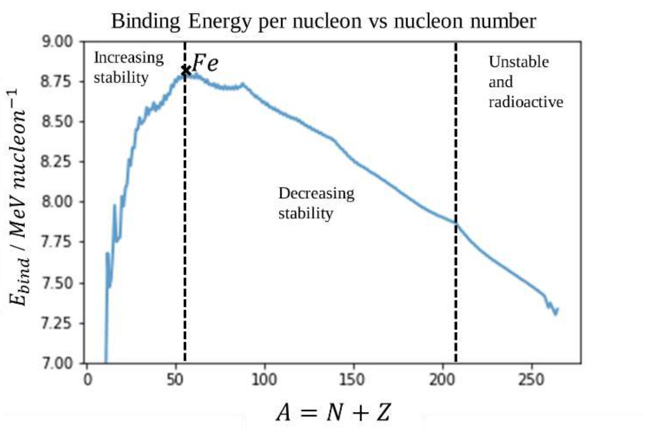
$$1kg = 6.022(10^{26})u = 5.60958(10^{29})\ MeV/c^2$$

$$1u = 1.66054(10^{-27})\ kg = 931.494\ MeV/c^2$$

Binding energy per nucleon, $\frac{E_{binding}}{A}$:

Nucleon number, A = Number of protons, Z + Number of neutrons, N

Binding energy per nucleon vs nucleon number graph:



- For nuclei lighter than that of iron (Fe), it is found that binding energy per nucleon increases with the nucleon number.
- After the iron limit, the binding energy per nucleon decreases.
- At $A \approx 209$ (nuclei of Bi), the binding energy per nucleon is too weak to keep the nuclei together and thus, are unstable and radioactive.

Radioactivity

The following table describes the types of decay of a radioactive substance

Type of decay	Process	Description
α	${}^{A}_{Z}P \rightarrow {}^{A-4}_{Z-2}D + {}^{4}_{2}He$ parent nucleus → daughter nucleus + α particle	In α decay, an α particle (Helium) is emitted when the parent nucleus decays into its daughter nucleus. Electrical charge is conserved throughout the process. Energy is released upon α decay.
β^{-}	$n \rightarrow p^{+} + e^{-} + \bar{\nu}$ ${}^{A}_{Z}P \rightarrow {}_{Z+1}^{A}D + {}_{-1}^{0}e + \bar{\nu}$ parent nucleus → daughter nucleus + β^{-} particle + antineutrino	In β^{-} decay, an electron e^{-} and an antineutrino $\bar{\nu}$ is emitted when the parent nucleus decays into its daughter nucleus.
β^{+}	$p^{+} \rightarrow n + e^{+} + \nu$ ${}^{A}_{Z}P \rightarrow {}_{Z-1}^{A}D + {}_{+1}^{0}e + \nu$ parent nucleus → daughter nucleus + β^{+} particle + neutrino	In β^{+} decay, a positron e^{+} and a neutrino ν is emitted when the parent nucleus decays into its daughter nucleus.
γ	${}^{A}_{Z}P * \rightarrow {}^{A}_{Z}P + \gamma$ nuclei of high energy state → nuclei of low energy state + γ ray	In γ decay, the emission is a photon (light ray). This happens because the nucleons lower its energy state.

In general, N number of radioactive particles will decay according to the **decay law**,

$$\frac{dN}{dt} = -\lambda N$$

where λ is the decay constant of the substance, which varies between isotopes.

The solution for the decay law is

$$N(t) = N_o e^{-\lambda t}$$

where $N_o = N(t = 0)$.

The rate of decay is known as **activity**

$$A = \left|\frac{dN}{dt}\right| = \left|\frac{dN_o}{dt}\right| e^{-\lambda t} = A_o e^{-\lambda t}$$

Half-life is simply the time it takes for the number of isotopes to decrease by half $T_{\frac{1}{2}}$,

$$N = \frac{1}{2}N_o = N_o e^{-\lambda T_{\frac{1}{2}}} \Rightarrow T_{\frac{1}{2}} = \frac{ln\,2}{\lambda}$$

Particle Accelerator

Thermionic emission (Edison Effect) = emission of electrons on the surface of a metal by providing it sufficient thermal energy.

As mentioned before, a charged particle may be accelerated by the help of an electric and magnetic field. The acceleration would stem from Lorentz Force.

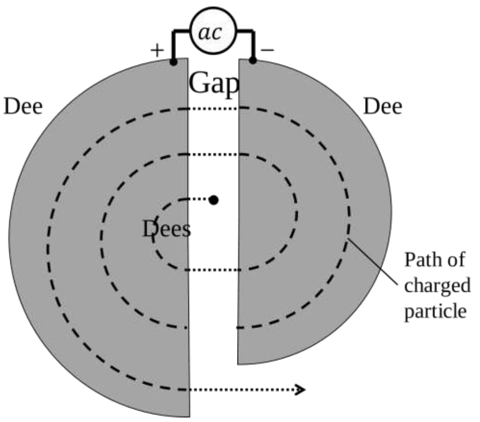
To probe subatomic particles, we need high energy because higher energy results in higher momentum which gives out smaller de Broglie wavelength. This means a higher resolution can be achieved.

2 types of particle accelerators:

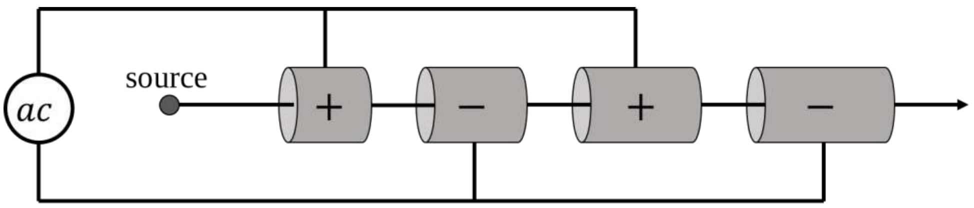
1. Cyclotron
   It uses magnetic field to maintain charged particles in nearly circular paths.

   A cyclotron is composed of 2 'dees', charged particles are accelerated in the region of space between the two 'dees', where an electric field is applied.

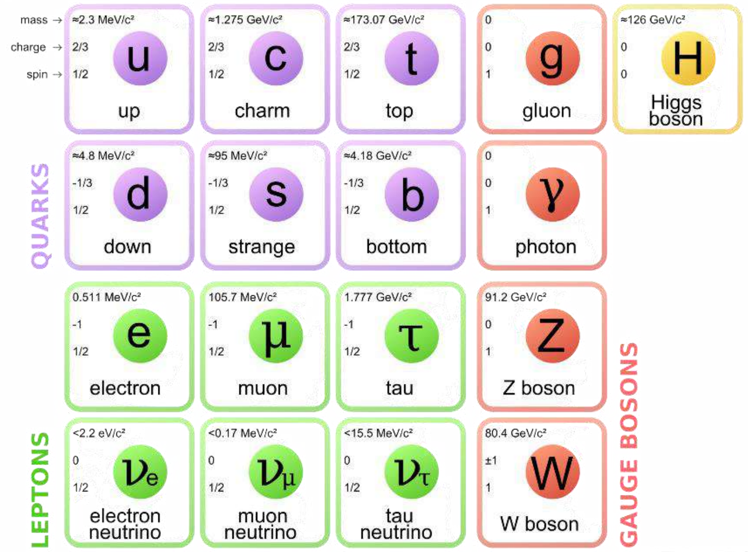
   Velocity of the charged particles when they are in the 'dees' is
   $$v = \frac{qBr}{m}$$
   Frequency of electric field is equal to the frequency of the circulating protons,
   $$f = \frac{qB}{2\pi m}$$
   which is known as the **cyclotron frequency**.

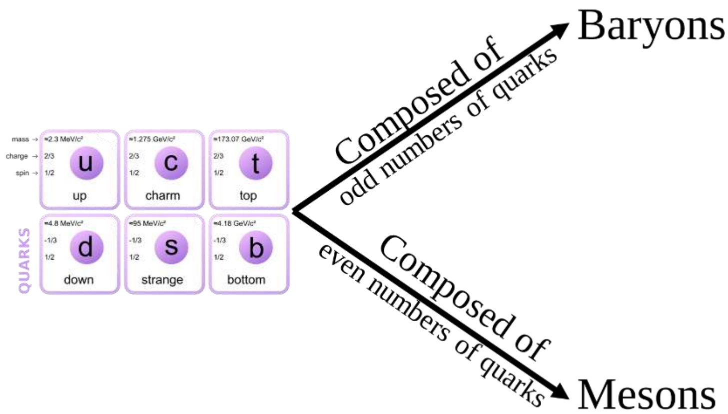


2. Linear Accelerator
   Charged particles are accelerated through a series of linear conductor tubes.
   Alternating voltage is applied to consecutive tubes so that when a charged particle reaches a gap, the tube they just left is now negatively charged and the tube they are heading into is positively charged.



Fundamental Particles





Particle-antiparticle pair:

They are pairs of particles that has opposite charge to each other. E.g., electron has a negative charge whereas its antiparticle, a positron has a positive charge. They interact by annihilating each other.

$$e^- + e^+ \rightarrow \gamma + \gamma$$

Sample question on electric force, electrical field, electric potential, electric potential energy.

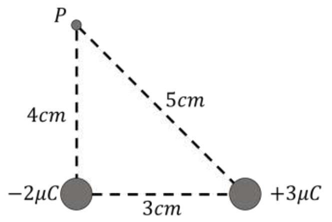
Problem:

The diagram shows two charged particles and a location in space P in a right-angled triangle formation.

a. Determine the electric field and electric potential at P.

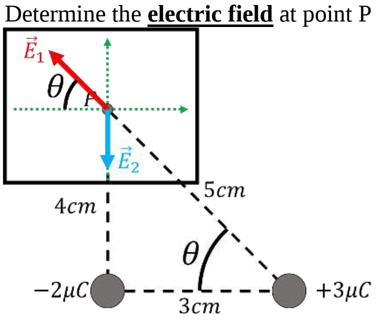
b. Calculate the electric force on a $0.5\mu C$ charged particle placed at P.

c. Calculate the energy needed to bring a $0.5\mu C$ charged particle from infinity to point P.

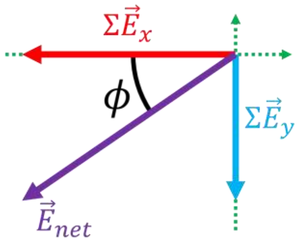


Solution:

Determine the **electric field** at point P



$$tan(\theta) = \frac{4}{3} \Rightarrow \theta = 53.13^o$$
$$|\vec{E}_1| = \frac{(9\times10^9)(3\times10^{-6})}{0.05^2} = 1.08\times10^7\,NC^{-1}$$
$$|\vec{E}_2| = \frac{(9\times10^9)(2\times10^{-6})}{0.04^2} = 1.125\times10^7\,NC^{-1}$$
$$\Sigma\vec{E}_x = |\vec{E}_1|\cos 53.13^o = 6.48\times10^6\,NC^{-1}$$
$$\Sigma\vec{E}_y = |\vec{E}_2| - |\vec{E}_1|\sin 53.13^o = 2.61\times10^6\,NC^{-1}$$

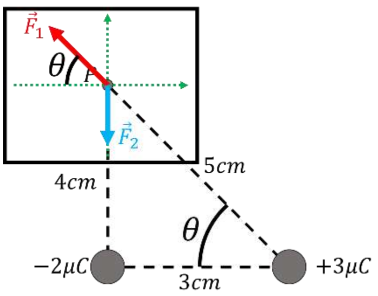


$$E_{net} = \sqrt{\left(\Sigma\vec{E}_x\right)^2 + \left(\Sigma\vec{E}_y\right)^2} = 6.986\times10^6\,NC^{-1}$$
$$tan\,\phi = \frac{\Sigma\vec{E}_y}{\Sigma\vec{E}_x} = \frac{2.61}{6.48} \Rightarrow \phi = 21.94^o$$

Determine the **electric potential** at point P

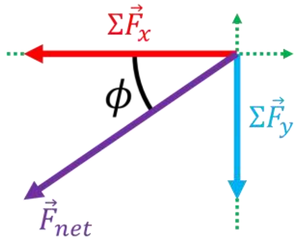
$$V_1 = \frac{kq_1}{r_1} = \frac{(9\times10^9)(-2\times10^{-6})}{0.04^2} = -4.5\times10^5V$$
$$V_2 = \frac{kq_2}{r_2} = \frac{(9\times10^9)(+3\times10^{-6})}{0.05^2} = 5.4\times10^5V$$
$$V_{net} = -4.5\times10^5V + 5.4\times10^5 = 0.9\times10^5V$$

Determine the **electric force** on a $0.5\mu C$ charged particle placed at P



$$tan(\theta) = \frac{4}{3} \Rightarrow \theta = 53.13^o$$
$$|\vec{F}_1| = \frac{(9\times10^9)(3\times10^{-6})(0.5\times10^{-6})}{0.05^2} = 5.4N$$
$$|\vec{F}_2| = \frac{(9\times10^9)(2\times10^{-6})(0.5\times10^{-6})}{0.04^2} = 5.625N$$
$$\Sigma\vec{F}_x = |\vec{F}_1|\cos 53.13^o = 3.24N$$
$$\Sigma\vec{F}_y = |\vec{F}_2| - |\vec{F}_1|\sin 53.13^o = 1.30N$$

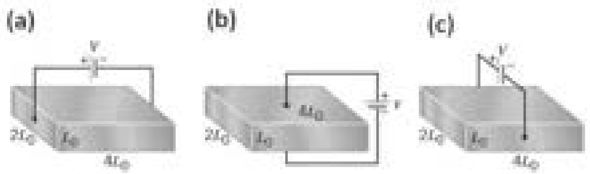
$$E_{net} = \sqrt{\left(\Sigma\vec{F}_x\right)^2 + \left(\Sigma\vec{F}_y\right)^2} = 3.49N$$
$$tan\,\phi = \frac{\Sigma\vec{F}_y}{\Sigma\vec{F}_x} = \frac{1.3N}{3.24N} \Rightarrow \phi = 21.94^o$$



Determine the **electric potential energy** needed to bring a $0.5\mu C$ charged particle from infinity to point P.

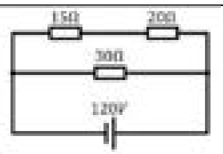
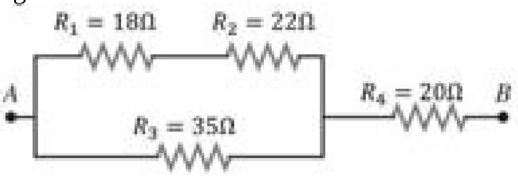
$$W_1 = \frac{kq_1q_t}{r_1} = \frac{(9\times10^9)(-2\times10^{-6})(0.5\times10^{-6})}{0.04^2} = -0.225J$$
$$W_2 = \frac{kq_2q_t}{r_2} = \frac{(9\times10^9)(+3\times10^{-6})(0.5\times10^{-6})}{0.05^2} = 0.27\text{J}$$
$$V_{net} = -0.225J + 0.27J = 0.045J$$

Chapter 3 – Part 1: Electric Current, Ohm's Law & Resistance

No	Questions	Solutions
1	A defibrillator passes 22A of current through the torso of a person in 1.6ms. a. How much charge moves during this time? b. How many electrons pass through the wires connected to the patient?	$n = \frac{\Delta q}{e} = \frac{I\Delta t}{e} = \frac{22(1.8 \times 10^{-3})}{1.602 \times 10^{-19}}$ $n = 2.197 \times 10^{17}$ electrons
2	A coffee-maker contains a heating element that has a resistance of 12Ω. This heating element is energized by a 240V outlet. What is the current in the heating element?	$V = IR$ $240 = I(12)$ $I = 20A$
3	The resistance across a cell wall of a cell is $5 \times 10^9 \Omega$. Determine the current and number of electrons flowing across the cell wall when the potential difference between the walls is 80mV in 2ms.	$V = IR$ $80(10^{-3}) = I(5(10^9))$ $I = 1.6 \times 10^{-11}A$ $n = \frac{I\Delta t}{e} = \frac{(1.6 \times 10^{-11})(2 \times 10^{-3})}{1.6 \times 10^{-19}}$ $n = 200000$ electrons
4	A typical smartphone powerbank is rated 10000mAh. Determine the total charge in Coulombs that this battery can provide. Calculate the maximum current that the battery can provide for 30minutes.	$\Delta q = (10000 \times 10^{-3})(3600) = 36kC$ $I = \frac{\Delta q}{\Delta t} = \frac{36000}{30 \times 60} = 20A$
5	The drawing shows three situations in which the current takes different paths through a piece of material. Each of the rectangular pieces is made from a material whose resistivity is $1.8 \times 10^{-2} \Omega m$, and the unit of length in the drawing is $L_o = 2.8cm$. Each piece of material is connected to a 6V battery. Find the resistance and the current in each case.  	$R_a = \rho \frac{4L_o}{L_o \times 2L_o} = \rho \frac{2}{L_o} = 1.8(10^{-2})\left(\frac{2}{2.8 \times 10^{-2}}\right)$ $R_a = 1.286\Omega$ $R_b = \rho \frac{L_o}{2L_o \times 4L_o} = \rho \frac{1}{8L_o}$ $R_b = 1.8(10^{-2})\left(\frac{1}{8 \times 2.8 \times 10^{-2}}\right)$ $R_b = 0.0804\Omega$ $R_c = \rho \frac{2L_o}{L_o \times 4L_o} = \rho \frac{1}{2L_o}$ $R_c = 1.8(10^{-2})\left(\frac{1}{2 \times 2.8 \times 10^{-2}}\right)$ $R_c = 0.32143\Omega$
6	A cylindrical wire has a length of 2.8m and a radius of 0.8mm. It carries a current of 1.5A, when a voltage of 4.5V is applied across the ends of the wire. Determine the resistivity of the wire.	$\rho = \frac{RA}{l} = \frac{\left(\frac{V}{I}\right)(\pi r^2)}{l}$ $\rho = \frac{\left(\frac{4.5}{1.5}\right)(\pi)(0.8 \times 10^{-3})^2}{2.8}$ $\rho = 2.15 \times 10^{-6}\Omega m$
7	A piece of wire has a resistance of 30Ω at 20^oC and 50Ω at 60^oC. What is the temperature of coefficient of resistivity?	$\frac{R}{R_o} = 1 + \alpha\Delta T$ $\frac{50}{30} = 1 + \alpha(60 - 20)$ $\alpha = 0.0167^oC^{-1}$
8	A wire spool of has 30m of insulated wire coiled in it. When connected to a DC power source, it is found that 2.2A of current is flowing through it. After some lengths of wire is used, it is found that the current flowing through the wires left reads 3.5A when it is connected to the same DC power source. Determine the length of wire left in the spool.	$\frac{L_f}{L_i} = \frac{VR_fA}{I_f\rho}\left(\frac{I_i\rho}{VR_iA}\right) = \frac{I_i}{I_f}$ $\frac{L_f}{30} = \frac{2.2}{3.5} = 18.86m$
9	What is the fractional change in the resistance $(\frac{\Delta R}{R_o})$ of an iron filament $(\alpha = 5(10^{-3})^oC^{-1})$ when its temperature changes from 25.0°C to 50.0°C?	$R = R_o(1 + \alpha\Delta T)$ $\frac{R - R_o}{R_o} = \alpha\Delta T = (\alpha = 5(10^{-3})^oC^{-1})(50 - 25)$

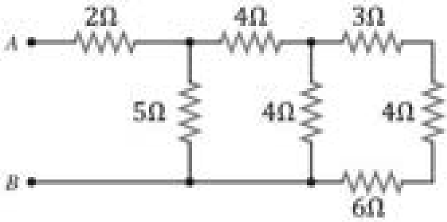
		$$\frac{R-R_o}{R_o}=0.125$$
10	The temperature coefficient of resistivity for the metal A is 0.0028^oC^{-1} , and for metal B it is 0.0048^oC^{-1}.The resistance of a wire of metal increases by 7.0% due to an increase in temperature. For the same increase in temperature, what is the percentage increase in the resistance of a wire of metal B?	Percentages, $$p=\frac{R-R_o}{R_o}\times 100=100\alpha\Delta T$$ $$p_A=7=100\alpha_A\Delta T$$ $$p_B=100\alpha_B\Delta T$$ $$\frac{p_B}{p_A}=\frac{(100\alpha_B\Delta T)}{(100\alpha_A\Delta T)}=\frac{\alpha_B}{\alpha_A}$$ $$p_B=\frac{0.0048}{0.0028}(7)=12\%$$
11	A metal wire of resistance R is cut into three equal pieces that are then connected side by side to form a new wire the length of which is equal to one-third the original length. What is the resistance of this new wire?	$$R_f=\frac{\rho\left(\frac{l}{3}\right)}{3A}=\frac{1}{9}R$$
12	The temperature of a sample of tungsten ($\rho=5.6(10^{-8})\ \Omega m, \alpha=4.5(10^{-3})^oC^{-1}$) is raised while a sample of copper ($\rho=1.7(10^{-8})\Omega\text{m}$) is maintained at 20.0°C. At what temperature will the resistivity of the tungsten be 5 times that of the copper?	$$\rho=\rho_o(1+\alpha\Delta T)$$ $$T_f-T_i=\frac{1}{\alpha}\left(\frac{\rho}{\rho_o}-1\right)$$ $$T_f-20^oC=\frac{1}{4.5(10^{-3})}\left(\frac{3(1.7)(10^{-8})}{5.6(10^{-8})}-1\right)$$ $$T_f=135.08^oC$$

Chapter 3 – Part 2: EMFs & internal resistance

1	Calculate the terminal voltage for a battery with an internal resistance of 1.2Ω and an emf of 12V when the battery is connected in series with a. a 20Ω resistor, b. a 200Ω resistor.	$\varepsilon = V + Ir = I(R+r) \Rightarrow I = \frac{\varepsilon}{R+r}$ $V = \varepsilon - Ir = \varepsilon - \left(\frac{\varepsilon}{R+r}\right)r$ $V(R = 20\Omega) = 12 - \left(\frac{12}{20+1.2}\right)(1.2) = 11.321V$ $V(R = 200\Omega) = 12 - \left(\frac{12}{200+1.2}\right)(1.2)$ $= 11.928V$
2	Three 1.5V cells are connected in series to a 15Ω lightbulb. If the resulting current is 0.25 A, what is the internal resistance of each cell, assuming they are identical and neglecting the resistance of the wires?	For each cell, $V = \varepsilon - Ir$ Total terminal voltage, $V_{total} = 4(\varepsilon - Ir) = IR$ $3(1.5 - (0.25)r) = (0.25)(15)$ $r = 1A$
3	What is the internal resistance of a 15V battery whose terminal voltage drops to 9V when the external resistors draw 30A? What is the resistance of the starter?	$V = \varepsilon - Ir \Rightarrow 9 = 15 - 30r \Rightarrow r = 0.2\Omega$ $V = IR \Rightarrow 9 = 30R \Rightarrow R = 0.3\Omega$
4	A battery has an emf of 15V. The terminal voltage of the battery is 12V when it is delivering 27W of power to an external load resistor R. a. What is the value of R? b. What is the internal resistance of the battery?	$P = IV; V = IR$ $P = \frac{V^2}{R} \Rightarrow 27 = \frac{12^2}{R} \Rightarrow R = 5.3\Omega$ $V = \varepsilon - Ir = \varepsilon - \left(\frac{P}{V}\right)r$ $12 = 15 - \left(\frac{27}{12}\right)r$ $r = 1.33\Omega$
5	What is the current in a 2.5Ω resistor connected to a battery that has a 0.2Ω internal resistance if the terminal voltage of the battery is 10V? What is the emf of the battery?	$V = IR \Rightarrow 10 = I(2.5) \Rightarrow I = 4A$ $V = \varepsilon - Ir \Rightarrow 10 = \varepsilon - (4)(0.2)$ $\varepsilon = 10.8V$
6	Two 1.50-V batteries — with their positive terminals in the same direction — are inserted in series into the barrel of a flashlight. One battery has an internal resistance of 0.255Ω, the other an internal resistance of 0.153Ω. When the switch is closed, a current of 750 mA occurs in the lamp. What is the lamp's resistance?	$R_{total} = \frac{V}{I} = R_{lamp} + r_{batteries}$ $\frac{2(1.5)}{0.75} = R_{lamp} + (0.254 + 0.382)$ $R_{lamp} = 3.364\Omega$
7	Three resistors of resistance (25Ω, 50Ω and 80Ω) are connected in series and a 81mA current passes through them. Determine the equivalent resistance and the potential difference across each resistor.	$V_1 = IR_1 = (0.081)(25) = 2.025V$ $V_2 = IR_2 = (0.081)(50) = 4.05V$ $V_3 = IR_3 = (0.081)(80) = 6.48V$ $V_T = V_1 + V_2 + V_3 = IR_T$ $\Rightarrow 2.025 + 4.05 + 6.48 = (0.081)R_T$ $R_T = 155\Omega$
8	A 15Ω resistor and a 20Ω resistor are connected in series across a 120V source of voltage. A 30Ω resistor is also connected across the 120V source and is in parallel with the series combination. Sketch the circuit and find the total current supplied by the source of voltage.	 $V = IR_{eff} \Rightarrow 120 = I\left(\frac{1}{30} + \frac{1}{15+20}\right)^{-1}$ $I = 7.429A$
9	Find the equivalent resistance between the points A and B in the figures shown. a. Figure 1 	Figure 1: $R_{eff} = R_4 + \left(\frac{1}{R_3} + \frac{1}{R_1 + R_2}\right)^{-1}$ $R_{eff} = 20 + \left(\frac{1}{35} + \frac{1}{18+22}\right)^{-1} = 38.67\Omega$ Figure 2:

<table>
<tr>
<td></td>
<td>

b. Figure 2



</td>
<td>

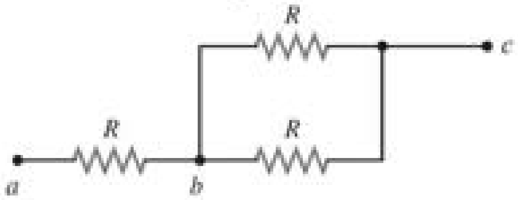
$$R_1 = 3 + 4 + 6 = 13\Omega$$

$$R_2 = 4 + \left(\frac{1}{4} + \frac{1}{13}\right)^{-1} = 7.06\Omega$$

$$R_{eff} = 2 + \left(\frac{1}{5} + \frac{1}{7.06}\right)^{-1} = 4.93\Omega$$

</td>
</tr>
<tr>
<td>10</td>
<td>

The circuit in the drawing contains three identical resistors. Each resistor has a value of 10Ω. Determine the equivalent resistance between the points a and b, b and c, and a and c.



</td>
<td>

$$R_{ab} = 10\Omega$$

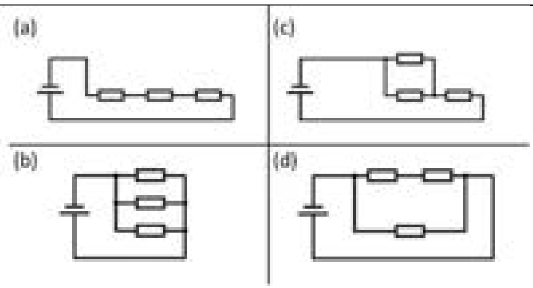
$$R_{bc} = \left(\frac{1}{10} + \frac{1}{10}\right)^{-1} = 5\Omega$$

$$R_{ac} = R_{ab} + R_{bc} = 10 + 5 = 15\Omega$$

</td>
</tr>
<tr>
<td>11</td>
<td>

Three 5Ω resistors can be connected together in four different ways, making combinations of series and/or parallel circuits. What are these four ways, and what is the net resistance in each case?

</td>
<td>



$$R_a = 5 + 5 + 5 = 15\Omega$$

$$R_b = 5 + \left(\frac{1}{5} + \frac{1}{5}\right)^{-1} = 7.5\Omega$$

$$R_c = \left(\frac{1}{5} + \frac{1}{5} + \frac{1}{5}\right)^{-1} = 1.67\Omega$$

$$R_d = \left(\frac{1}{5} + \frac{1}{5 + 5}\right)^{-1} = 3.33\Omega$$

</td>
</tr>
<tr>
<td>12</td>
<td>

A 25Ω and a 37Ω resistor are connected in parallel; this combination is connected in series with a 14Ω resistor. If circuit can only handle 13A, what is the maximum voltage that can be applied across the whole network?

</td>
<td>

$$V = IR = (13)\left(14 + \left(\frac{1}{25} + \frac{1}{37}\right)^{-1}\right)$$

$$V = 375.95V$$

</td>
</tr>
<tr>
<td>13</td>
<td>

Two resistors connected in series have an equivalent resistance of 690Ω. When they are connected in parallel, their equivalent resistance is 150Ω. Find the resistance of each resistor.

</td>
<td>

$$690 = R_1 + R_2$$

$$150^{-1} = R_1^{-1} + R_2^{-1}$$

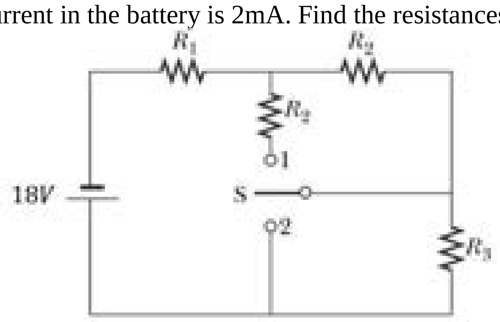
$$\{R_1,\ R_2\} = \{730.505, 19.495\}\Omega$$

OR

$$\{R_1,\ R_2\} = \{250.251, 499.749\}\Omega$$

</td>
</tr>
<tr>
<td>14</td>
<td>

A 18V battery supplies current to the circuit shown in the figure. When the double-throw switch S is open, as shown in the figure, the current in the battery is 1mA. When the switch is closed in position 1, the current in the battery is 1.20mA. When the switch is closed in position 2, the current in the battery is 2mA. Find the resistances.



</td>
<td>

$$V = IR$$

$$18 = (10^{-3})(R_1 + R_2 + R_3)$$

$$18 = (1.2)(10^{-3})\left(R_1 + \left(\frac{1}{R_2} + \frac{1}{R_2}\right)^{-1} + R_3\right)$$

$$18 = 2(10^{-3})(R_1 + R_2)$$

$$\{R_1, R_2, R_3\} = \{3,6,9\}k\Omega$$

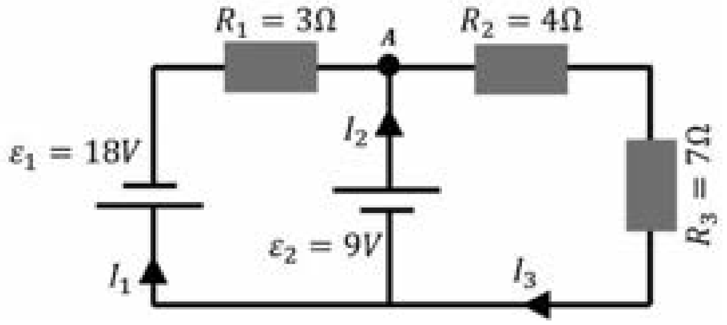
</td>
</tr>
</table>

Chapter 3 – Part 3: Electrical Energy & Power

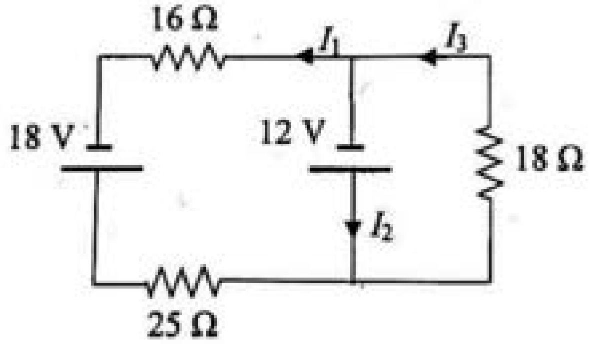
No	Questions	Answers
1	A coffee cup heater and a lamp are connected in parallel to the same 240V outlet. Together, they use a total of 400W of power. The resistance of the heater is 500Ω. Find the resistance of the lamp.	$P_{total} = \frac{V^2}{R_{eff}}$ $P_{total} = V^2\left(\frac{1}{R_{coffee}} + \frac{1}{R_{lamp}}\right)$ $400 = (240)^2\left(\frac{1}{500} + \frac{1}{R_{lamp}}\right)$ $R_{lamp} = 202\Omega$
2	Two resistors, 15Ω and 65Ω, are connected in parallel. The current through the 65Ω resistor is 3A. Determine the current in the other resistor. What is the total power supplied to the two resistors?	$V_{15} = V_{65}$ $I_{65}R_{65} = I_{15}R_{15}$ $(3)(65) = I_{15}(15)$ $I_{15} = 13A$ $P_{total} = I_{65}^2R_{65} + I_{15}^2R_{15}$ $P_{total} = (3)^2(65) + (13)^2(15)$ $P_{total} = 3.12kW$
3	A blow-dryer and a vacuum cleaner each operate with a voltage of 240 V. The current rating of the blow-dryer is 6 A, and that of the vacuum cleaner is 4A. Determine the power consumed by the blow-dryer and the vacuum cleaner. Determine the ratio of the energy used by the blow dryer in 10minutes to the energy used by the vacuum cleaner in half an hour.	$P_{blowdryer} = 6(240) = 1440W$ $P_{vacuum} = 4(240) = 960W$ $\frac{E_{bd}}{E_{vc}} = \frac{(1440)(10)}{(960)(30)} = 0.5$
4	How many 75-W lightbulbs, connected in parallel to 240V source and each other, can be used without blowing a 13A fuse?	$I_{bulb} = \frac{P}{V}$ $I_{total} = N\frac{P}{V}$ $13 = N\left(\frac{75}{240}\right)$ $N = 41.6$ $N = 41$ bulbs
5	What is the total amount of energy stored in a 5V, 1000mAh smartphone power bank when it is fully charged?	$E = QV = (1Ahr)\left(\frac{3600}{1hr}\right)(5)$ $E = 18kJ$
6	A 240V heater is rated at 1200W. Calculate the current through the heater when it is operating, and its resistance.	$P = IV \Rightarrow 1200 = I(240) \Rightarrow I = 5A$ $P = \frac{V^2}{R} \Rightarrow 1200 = \frac{240^2}{R} \Rightarrow R = 48\Omega$
7	In doing a load of clothes, a clothes dryer uses 16A of current at 240V for 30min. A personal computer, in contrast, uses 3A of current at 120V. With the energy used by the clothes dryer, how long (in hours) could you use this computer to "surf" the Internet?	$E = Pt = IVt$ $E = 16(240)\big(30(60)\big) = (3)(120)t$ $t = 19200s \approx 5.33$hrs
8	A piece of Nichrome wire (of resistivity $100 \times 10^{-8}\Omega m$) has a radius of $0.65mm$. It is used in a laboratory to make a heater that uses 1.5kW of power when connected to a voltage source of 240V. Ignoring the effect of temperature on resistance, estimate the necessary length of wire.	$P = IV = \frac{V^2}{R}$ $R = \frac{V^2}{P} = \frac{\rho l}{A} = \frac{\rho l}{\pi r^2}$ $\frac{240^2}{1500} = \frac{(100)(10^{-8})l}{\pi(0.65 \times 10^{-3})^2}$ $l = 50.97m$

Notes on Kirchhoff's Rules

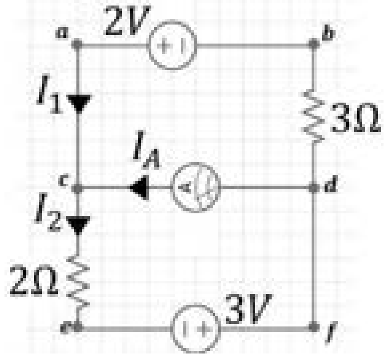
1. What is a junction/node?
2. What is a loop?
3. What does Kirchhoff's 1st Rule say?
4. What does Kirchhoff's 2nd Rule say?
5. [Sample Problem]
   Calculate I_1, I_2 and I_3.



6. Practice
   a. **[PSPM 14/15]** Referring to the diagram below, determine I_1, I_2, I_3 and the voltage across the 18Ω resistor.

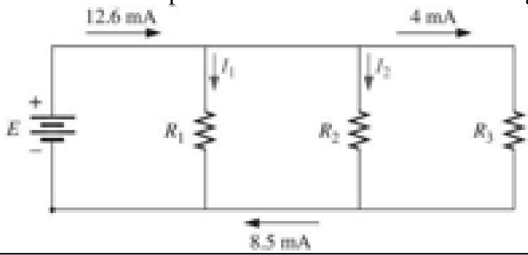
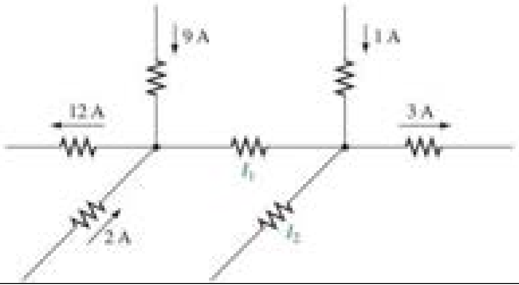
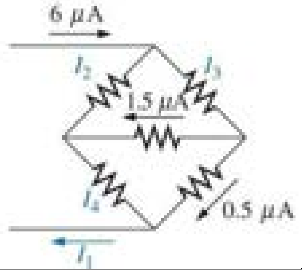
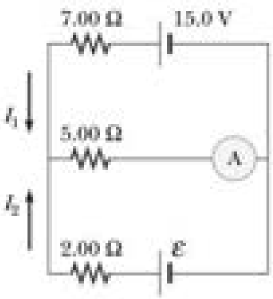
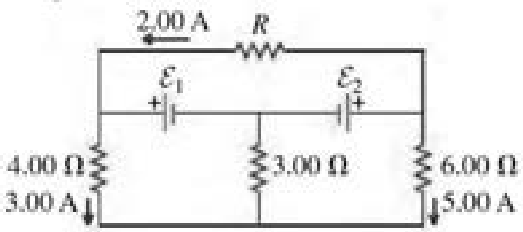
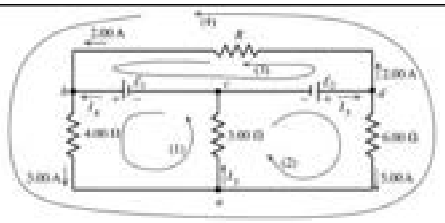


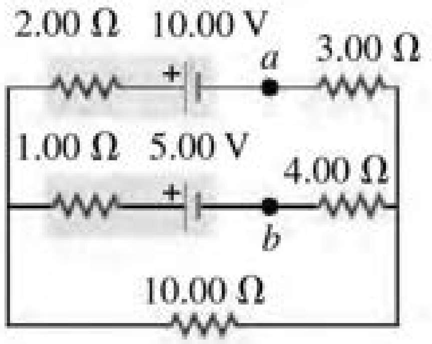
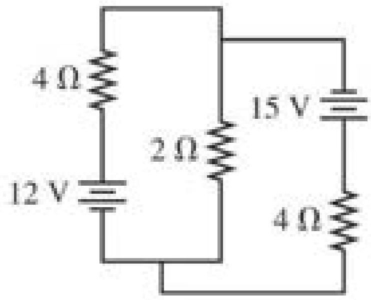
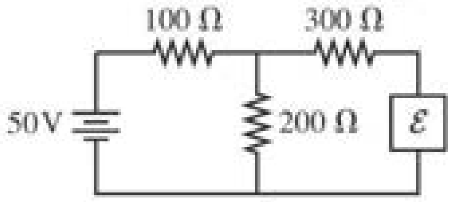
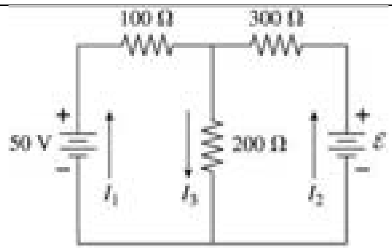
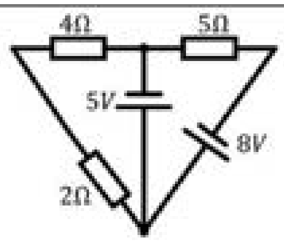
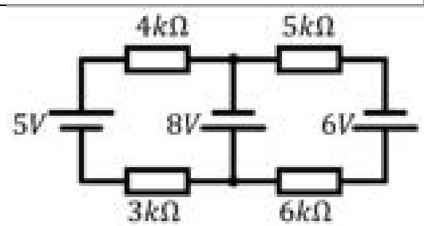
   b. The figure shows a circuit consisting of two batteries, two resistors and an ammeter.

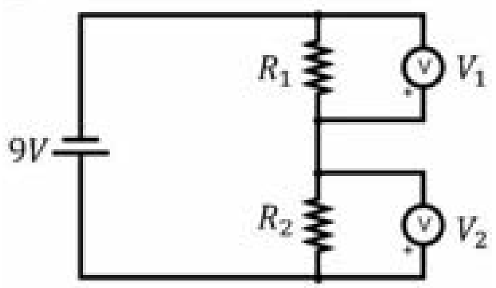
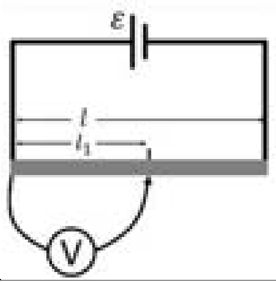
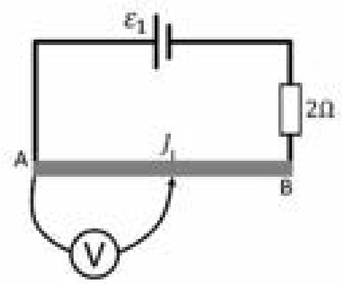
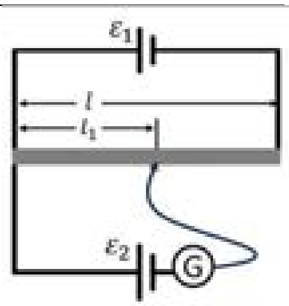
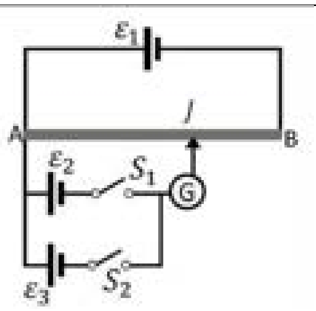


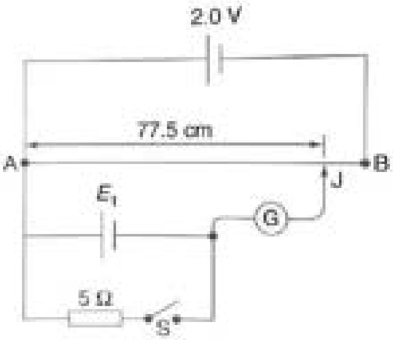
   If the ammeter has internal resistance of 5.0Ω, what is the reading shown by the ammeter?

Chapter 3 – Part 4: Kirchhoff's Rules

No	Questions	Answers
1	Using Kirchhoff's current law, determine the unknown currents for the parallel network shown in the diagram.  	$12.6 = I_1 + 8.5$ $I_1 = 4.1mA$ $4 + I_2 = 8.5$ $I_2 = 4.5mA$
2	Using Kirchoff's current law, find the unknown currents for the complex configurations shown in the diagram below.  	$9 - 12 + 2 + I_1 = 0$ $I_1 = 1A$ $I_2 - 1 + 1 - 3 = 0$ $I_2 = -3A$
3	Using Kirchoff's current law, find the unknown currents for the complex configurations shown in the diagram below.  	$I_3 = 1.5 + 0.5 = 2\mu A$ $6 = I_2 + I_3 \Rightarrow I_2 = 4\mu A$ $I_2 + 1.5 = I_4 \Rightarrow I_4 = 5.5\mu A$ $I_1 = 6\mu A$
4	The ammeter shown in the figure shown reads 1.8A. Find I_1, I_2, and ε.  	$I_1 + I_2 = 1.8$ $15 = 7I_1 + 1.8(5)$ $I_1 = 0.86A$ $0.86 + I_2 = 1.8$ $I_2 = 0.94A$ $\varepsilon = 0.94(2) + 1.8(5) = 10.8V$
5	In the circuit shown below, find a. the current in the 3Ω resistor, b. the unknown emfs ε_1 and ε_2, c. the resistance R. Note that three currents are given.  	 $3 + 5 - I_3 = 0 \Rightarrow I_3 = 8A$ $2 + I_4 - 3 = 0 \Rightarrow I_4 = 1A$ $I_3 + I_4 + I_5 = 0 \Rightarrow I_5 = 7A$ $\varepsilon_1 - 3(4) - I_3(3) = 0 \Rightarrow \varepsilon_1 = 36V$ $\varepsilon_2 - 5(6) - I_3(3) = 0 \Rightarrow \varepsilon_2 = 54V$ $(-2)R - \varepsilon_1 + \varepsilon_2 = 0$ $R = 9\Omega$
6	In the circuit shown, find	$10 - (2 + 3)I_2 - (1 + 4)I_2 - 5 = 0$

	a. the current in each branch b. the potential difference V_{ab} of point a relative to point b 	$I_1 + I_2 = 1A$ $5 + (1+4)I_2 - 10I_3 = 0$ $I_1 - 2I_3 = -1$ $I_1 = I_2 + I_3$ $I_i = \{0.8,\ 0.2,\ 0.6\}A$ $V_{ab} = -2(4) - (8)(3) = -3.2V$
7	Calculate the current through the 2Ω resistor in the circuit shown. 	$12 - 4I_1 - 2I_3 = 0$ $15 - 4I_2 + 2I_3 = 0$ $I_1 = I_2 + I_3$ $I_3 = I_{2\Omega} = -\frac{3}{8}A = -0.375A$
8	Referring to the figure below, determine the value of ε at which the 200Ω resistor dissipate no power. 	 $50 - 100I_1 - 200I_3 = 0$ $\varepsilon - 300I_2 - 200I_3 = 0$ Assume $I_3 = 0$ $I_1 = 0.5A$ $I_2 = -I_1$ $\varepsilon - 300(-0.5) - 200(0) = 0 \Rightarrow \varepsilon = -150V$
9	Referring to the figure shown, determine the current through each resistor. 	$5 = I_{2\Omega}(4+2)$ $I_{2\Omega} = I_{4\Omega} = \frac{5}{6}A \approx 0.833A$ $8 - 5 = I_{5\Omega}(5)$ $I_{5\Omega} = \frac{3}{5}A = 0.6A$
10	Referring to the figure shown, determine the power used by each resistor. 	

No	Questions	Answers
1	The diagram shows a circuit consisting of 2 resistors, one 9V DC power source and 2 voltmeters.  If $R_1 = 2.2k\Omega$ and $R_2 = 6.8k\Omega$, determine the reading of voltmeter V_1 and V_2.	$V_i = \frac{R_i}{R_i+\ldots+R_N}V_T$ $V_1 = \frac{2.2}{2.2+6.8}(9) = 2.2V$ $V_1 = \frac{6.8}{2.2+6.8}(9) = 6.8V$
2	The diagram shows a potentiometer circuit. If $\varepsilon = 12V$ and l_1 is one third of l, determine the reading on the voltmeter. 	$\frac{V}{\varepsilon} = \frac{l_1}{l} = \frac{1}{3}$ $V = \frac{1}{3}(12) = 4V$
3	The diagram shows a potentiometer circuit. The current through the 2Ω resistor is 750mA. If $\varepsilon_1 = 12V$ and length of AJ is one third of length of AB, determine the reading on the voltmeter. 	$\varepsilon_1 = kl_{AB} + IR \Rightarrow \varepsilon_1 - IR = kl_{AB}$ $V = kl_{AJ}$ $\frac{V}{\varepsilon_1 - IR} = \frac{l_{AJ}}{l_{AB}}$ $\frac{V}{12-(0.75)(2)} = \frac{1}{3}$ $V = 3.5V$
4	 The diagram shows a potentiometer circuit involving 2 DC power source. Determine the length l_1 when the galvanometer shows zero reading if $\frac{\varepsilon_1}{\varepsilon_2} = 4$ and $l = 28cm$.	The potentiometer is balanced when $\frac{\varepsilon_1}{\varepsilon_2} = \frac{l}{l_1}$. $4 = \frac{0.28}{l_1}$ $l_1 = 0.07m$
5	The diagram shows a potentiometer circuit involving 3 dry cells of different emf. When switch S_1 is closed and switch S_2 is opened, the length of AJ is 25cm. Conversely, when switch S_1 is opened and switch S_2 is closed, the length of AJ is 50cm. Determine the emf of ε_3 if ε_2 has an emf of 9V. 	$\varepsilon_2 = kl_{AJ-1}; \varepsilon_3 = kl_{AJ-2}$ $\frac{\varepsilon_2}{\varepsilon_3} = \frac{l_{AJ-1}}{l_{AJ-2}} \Rightarrow \frac{9}{\varepsilon_3} = \frac{25}{50}$ $\varepsilon_3 = 18V$

6	The emf E_1 of a cell is measured using a potentiometer as shown in the figure. The driver cell has an emf of 2V and negligible resistance. When the switch S is open, the galvanometer G is balanced when the length AJ is 77.5cm. When the switch *S* is closed, the length AJ is 63.8 cm.  a. Calculate the emf E_1 b. Calculate the internal resistance of the cell.	$\frac{E_1}{2} = \frac{77.5}{100} \Rightarrow E_1 = 1.55V$ Opened Switch: $E_1 = kl_1$ Closed Switch: $V = kl_2 = E_1 - Ir$ By Ohm's Law, $E_1 = I(R+r) \Rightarrow I = \frac{E_1}{R+r}$ $V = E_1 - Ir = E_1 - \left(\frac{E_1}{R+r}\right)r$ $\frac{V}{E_1} = \frac{R}{R+r} \Rightarrow \frac{l_2}{l_1} = \frac{R}{R+r}$ $\frac{63.8}{77.5} = \frac{5}{5+r} \Rightarrow r = 1.07367\Omega$

Mass Defect
&
Binding Energy

Particle	Mass in a.m.u.
Proton	1.007276466
Neutron	1.008664915

The most common isotope of Helium is Helium-4 (^4He), which has 2 proton and 2 neutrons.

Can you estimate the mass of a Helium-4 mass?

Particle	Mass in a.m.u.
Proton	1.007276466
Neutron	1.008664915

The most common isotope of Helium is Helium-4 (^4He), which has 2 proton and 2 neutrons.

Can you estimate the mass of a Helium-4 mass?

$$4.031882762u$$

But measured mass of Helium-4 nucleus is 4.001506179u

A mass difference of $0.0303766u$!

Where did the $0.0303766u$ go?

But measured mass of Helium-4 nucleus is 4.001506179u

A mass difference of $0.0303766u$!

Where did the $0.0303766u$ go?

Answer:

Because of Einstein's $E = mc^2$, some of the mass of the proton and electron was converted to energy.

Energy to do what? To keep the proton and electrons to bind together.

This mass difference is called **mass defect.**

The mass converted to energy is called **binding energy.**

So, can we find an equation for this mass?

So, can we find an equation for this mass?

Yes!

So, can we find an equation for this mass?

Yes!

If the components of the atomic nucleus is

$$N_n(m_n) + N_{p^+}\left(m_{p^+}\right)$$

So, can we find an equation for this mass?

Yes!

If the components of the atomic nucleus is

$$N_n(m_n) + N_{p^+}\left(m_{p^+}\right)$$

and the mass of the atomic nucleus is

$$m_{nucleus}$$

So, can we find an equation for this mass?

Yes!

If the components of the atomic nucleus is

$$N_n(m_n) + N_{p^+}\left(m_{p^+}\right)$$

and the mass of the atomic nucleus is

$$m_{nucleus}$$

then the mass defect is

$$\Delta m = \left(N_n m_n + N_{p^+} m_{p^+}\right) - m_{nucleus}$$

So, can we find an equation for this mass?

Yes!

If the components of the atomic nucleus is

$$N_n(m_n) + N_{p^+}(m_{p^+})$$

and the mass of the atomic nucleus is

$$m_{nucleus}$$

then the mass defect is

$$\Delta m = (N_n m_n + N_{p^+} m_{p^+}) - m_{nucleus}$$

If we want to find how much energy is produced from this mass defect, we can use Einstein's equation

$$E_{binding} = \Delta m c^2$$

Sample Problem

[PSPM 21/22 – Q10(a)]

Calculate the binding energy of a bromine nucleus ($^{81}_{35}Br$) in Joule.

Atomic mass of bromine = 80.916291u.

Chapter 4: Magnetism

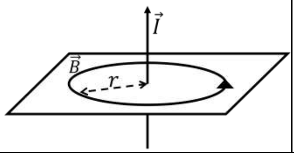
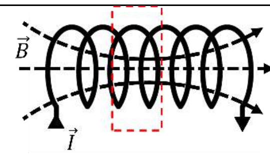
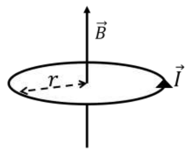
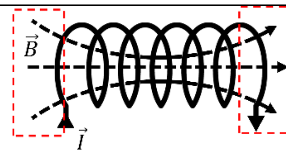
Magnetic Field

A magnetic field is a region of space in which a charged particle will experience magnetic force. They are generated by moving charged particles. Magnetic field lines are always drawn from its north pole to its south pole. When drawn on a 2D plane such as paper, we would generally represent a direction **into** the plane as ⊗, and direction **out** of the plane as ●.

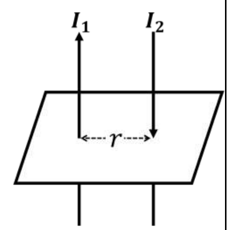
$\vec{B}$ from current-carrying conductor

Direction of magnetic field depends on the direction current flow – Right Hand Rule, where the thumb point to the current direction and curled fingers are the magnetic field lines.

4 cases to considering in calculating the magnitude of magnetic field

Long straight wire $B = \frac{\mu_o I}{2\pi r}$		Centre of solenoid $B = \mu_o I n$ Where n is the number of loops per unit length	
Centre of circular coil $B = \frac{\mu_o I}{2r}$		End of solenoid $B = \frac{1}{2}\mu_o I n$ Where n is the number of loops per unit length	

Magnetic Force

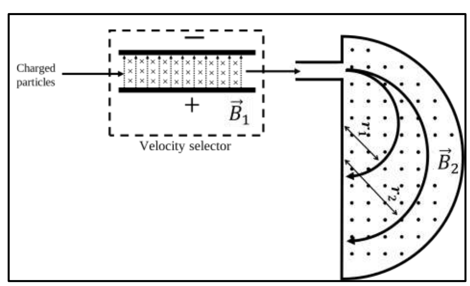
Force on a moving charged particle in uniform $\vec{B}$	**Force on a current carrying conductor in uniform $\vec{B}$**	**Force between two parallel current carrying conductors**
Force on a particle with charge q moving at velocity $\vec{v}$ in a uniform magnetic field $\vec{B}$, the magnetic force acting on it is $\vec{F}_{magnetic} = q(\vec{v} \times \vec{B})$. In the case of a large enough region, the magnetic force will cause the charged particle to travel in a circular motion. In such cases, $\vec{F}_{magnetic} = \vec{F}_{centripetal}$ $\Rightarrow qvB = \frac{mv^2}{r^2}$.	Consider a quantity of charge ΔQ travelling along a conductor of length l in a magnetic field $\vec{B}$ in time t. The magnetic force on the conductor is then $\vec{F}_{magnetic} = I(\vec{l} \times \vec{B})$.	Consider two current carrying conductors of length l in proximity such that their magnetic fields overlap, their resultant magnetic force on each other is then  $\vec{F}_{magnetic} = \frac{\mu_o I_1 I_2}{2\pi r} l$

Bainbridge mass spectrometer

The Bainbridge mass spectrometer is used to accurately determine atomic mass.

The first part of the mass spectrometer is a velocity selector in which both electric field $\vec{E}$ and magnetic field $\vec{B}_1$. For charged particles to exit this velocity selector, their velocity must obey

$$v = \frac{E}{B_1}$$



This part of the mass spectrometer allows only charged particles with a certain velocity to enter the second region of only magnetic field $\vec{B}_2$.

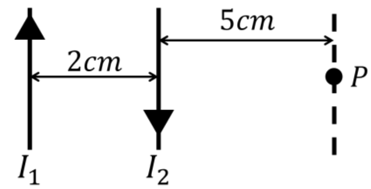
The second part of the instrument takes advantage that charged particles of the same entry velocity but different mass will travel in circular path of different radius.

$$qvB_2 = \frac{mv^2}{r^2} \Rightarrow m = \frac{qB_2 r^2}{v} = \frac{qB_1 B_2 r^2}{E}$$

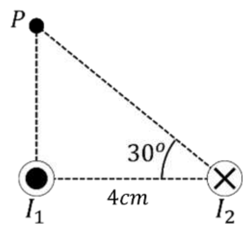
Chapter 4 Questions

Problem 1

The diagram shows 2 wires of currents I_1 (5A) and I_2 (2A).
Determine the magnitude and direction of magnetic field at P.
[$6.2857\mu T$ (out of the page)]



Problem 2



The diagram shows 2 wires of currents I_1 (5A) and I_2 (2A).
Determine the magnitude and direction of magnetic field at P.
[$3.96863(10^{-7})T$ at 10.91^o]

Problem 3

Upon release in a region of magnetic field of 0.3mT, an electron moves in a circular path of radius 20cm. Determine the speed of the electron. **[$1.055 \times 10^7 ms^{-1}$]**

Problem 4

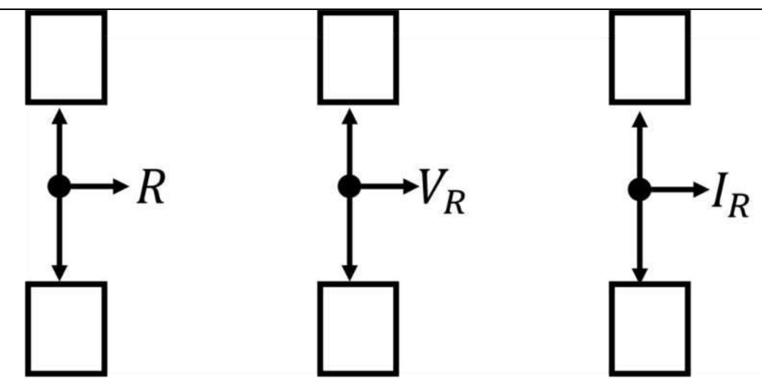
Two 30m long parallel wires has their current flowing in the same direction. One of the wires has a current of 2A and the other has a current of 3A. If they are separated by 30cm, determine the force between them. **[$0.12mN$]**

Problem 5

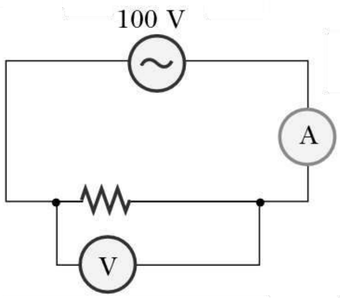
In a Bainbridge mass spectrometer experiment, the velocity selector section has a magnetic field strength of 0.01T and an electric field of $25NC^{-1}$. The second part of the spectrometer has a magnetic field strength of 0.02T. If of particle (of charge 2e) makes a circular path of radius 25cm, determine its mass. **[$6.4 \times 10^{-25}kg$]**

sr

Chapter 6 Notes & Exercises

	Notes	
Alternating Current		
$\boldsymbol{DC \Rightarrow AC}$		
Resistance in AC		
rms values	$I_{rms} =$	$V_{rms} =$
Impedance	$Z =$	
Capacitance Reactance	$X_C =$	
Inductive Reactance	$X_L =$	
Phasor Diagram	 Phasor Diagram for RLC Circuit	
Phase angle between <u>current</u> and <u>voltage</u>	$\theta_{IV} =$	
Resonance Condition	$X_L = X_C \Rightarrow \omega = 2\pi f =$	
Power	Instantaneous power $P =$	Average power $P_{ave} =$
Power Factor	$cos\, \theta_{IV} =$	

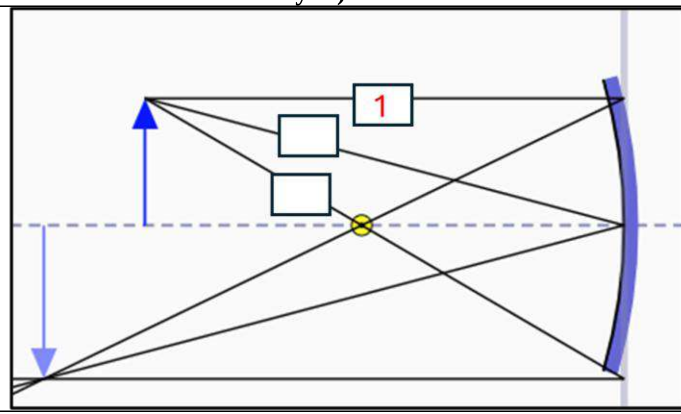
Chapter 6 Exercise

No.	Questions	No	Questions
1	 An AC power supply produces a maximum voltage of 100V and is connected to a 25Ω resistor, as show in the figure. Determine the reading of the ammeter and the voltmeter.	5	An ac series circuit has an impedance of 192Ω, and the phase angle between the current and the voltage of the generator is -75^o. The circuit contains a resistor and either a capacitor or an inductor. Find the resistance and the capacitive reactance or the inductive reactance, whichever is appropriate.
2	A circuit consisting of a resistor and an AC power supply. The current in the circuit equals to 60% of the peak current at $t = 7ms$. What is the smallest frequency of the source that gives this current?	6	A 2700Ω resistor and a 1.1μF capacitor are connected in series across a generator (60Hz, 120V). Determine the power delivered to the circuit.
3	An inductor (400 mH), a capacitor (4.43μF), and a resistor (500Ω) are connected in series. A 50Hz AC source produces a peak current of 250 mA in the circuit. a) Calculate the required peak voltage. b) Determine the phase angle by which the current leads or lags the applied voltage.	7	a) A series RCL circuit has a resonant frequency of 690 kHz. If the value of the capacitance is 2nF, what is the value of the inductance? b) The power dissipated in a series RCL circuit is 65W, and the current is 0.53A. The circuit is at resonance. Determine the voltage of the generator.
4	A circuit consists of a 215Ω resistor and a 0.2H inductor. These two elements are connected in series across a generator that has a frequency of 106Hz and a voltage of 234V. a) What is the current in the circuit? b) Determine the phase angle between the current and the voltage of the generator.	8	In a series RCL circuit the generator is set to a frequency that is not the resonant frequency. This non resonant frequency is such that the ratio of the inductive reactance to the capacitive reactance of the circuit is observed to be 5.36. The resonant frequency is 225Hz. What is the frequency of the generator?

Geometrical Optics Module

Reflection upon Curved Mirror

What is the relationship between the radius of curvature of a curved mirror and its focal length?	$R = \square f$

Label the number of lines! (Line 1 has been labelled for you)	
Line 1: The principal ray line that is parallel to the paraxial line and crosses the focal point after reflecting on the curved mirror. **Line 2:** The principal ray line that goes through the focal point and is reflected parallel to the paraxial line. **Line 3:** The principal ray line that has the same reflection angle and incoming angle relative to the paraxial line.	

Complete the following equations!	
Focal Length, object distance and image distance $\frac{1}{f} = \frac{1}{\square} + \frac{1}{\square}$	Magnification $M = \frac{h_i}{\square} = -\frac{\square}{v}$

Complete the following table of sign conventions!

	Positive when	Negative when
Focal length, f	Focal length is at same side as incoming light (concave)	
Object Distance, u		Object is placed on the opposite side as incoming light ('behind', 'virtual object')
Image Distance, v	Image is placed same side as incoming light ('in front', 'real image')	
Magnification		

PSPM 23/24	PSPM 22/23	PSPM 21/22
A spherical mirror is placed in front of a table lamp and reflecting an inverted image on the wall. The radius of the mirror is 180cm and the size of the image is half the size of the table lamp. Sketch the ray diagram and calculate the object distance.	A student who is standing 1.52m in front of a spherical mirror produces an inverted image 18cm from the mirror. Determine his new position from the mirror to get an upright image that is twice his actual size.	An object is placed 5cm from a curved mirror. An image which is twice the size of the object is formed behind the mirror. Explain if the mirror is convex or concave and determine the radius of the curvature of the mirror.

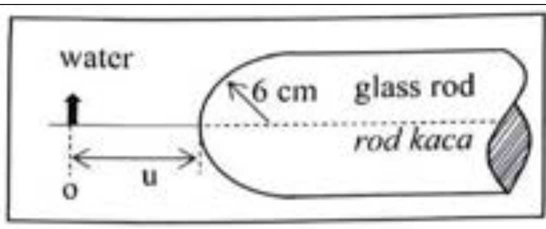
Refraction at a spherical surface

Complete the following equation!	$$\frac{n_1}{\square}+\frac{\square}{v}=\frac{\square-\square}{\square}$$

Complete the following table of sign conventions!

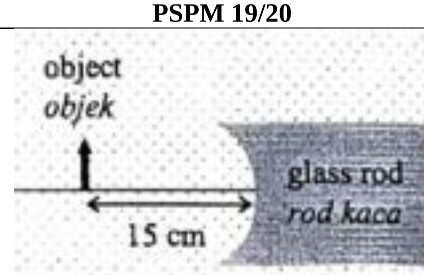
	Positive when	Negative when
Radius, *R*	Radius at opposite side as incoming light ('convex')	
Object Distance, u		Object is placed on the opposite side as incoming light ('behind', 'virtual object')
Image Distance, v	Image is placed on the opposite side as incoming light ('behind', 'real image')	

PSPM 21/22



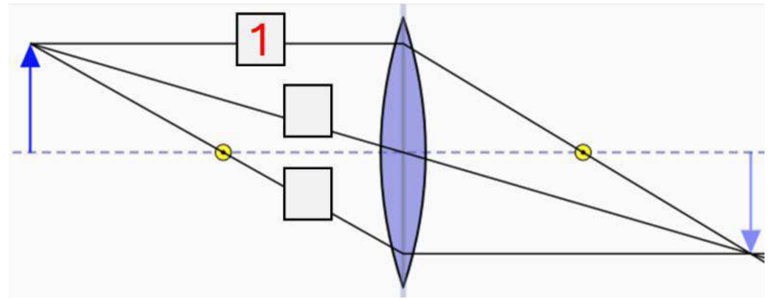
The figure shows a long rod with a convex surface of radius of curvature of 6cm at one end and is made from glass with refractive index of 1.6. The glass rod is placed in water with refractive index of 1.33. An object placed along the rod's axis is to be imaged 53cm inside the rod.
Calculate the object distance.

PSPM 19/20



The figure shows an object and a glass rod immersed in a liquid. The rod has a refractive index of 1.7 and radius of curvature of 8cm. If the object distance is 15cm and the virtual distance is 13cm, determine the refractive index of the liquid.

Thin Lenses

Label the number of lines! (Line 1 has been labelled)	
Line 1: Ray 1 leaves one point on object going parallel to the axis, then refracts through focal point behind the lens. **Line 2:** Ray 2 passes through the focal point in front of the lens; therefore it is parallel to the axis behind the lens. **Line 3:** Ray 3 passes straight through the center of the lens (assumed very thin).	

Complete the following equations!	
$f(u,v)$ $$\frac{1}{f} = \frac{1}{\square} + \frac{1}{\square}$$	Magnification $$M = \frac{h_i}{\square} = -\frac{\square}{v}$$
Lensmaker's Equation: $f(R_1, R_2)$ $$\frac{1}{f} = \left(\frac{\square}{n_{med}}\right)\left(\frac{1}{\square} - \frac{1}{\square}\right)$$	

Complete the following table of sign conventions!

	Positive when	**Negative when**
Focal length, f		Diverging lens
Object Distance, u	Object is placed same side as incoming light ('in front', 'real object')	
Image Distance, v		Image is placed same side as incoming light ('in front', 'opposite image')
Radii of surfaces, R_1 & R_2		Radii is on the opposite side of the incoming light ('behind')

PSPM 23/24	**PSPM 22/23**	**PSPM 21/22**
A biconvex lens of radii 35cm is immersed in chloroform ($n = 1.44$). Its focal length is doubled when it is placed in an unknown liquid. If the refractive index of the glass is 1.57, determine the focal length of the lens in the liquid.	A biconvex lens has surfaces with radii of curvature 18cm and 20cm. When an object is placed in front of the lens, a real image is formed 32cm from the lens. Determine the focal length and refractive index.	A converging meniscus lens is made from a glass of refractive index 1.52 having a radius 7cm and 4cm. An object is placed 24cm in front of the lens. Calculate the position of the image from the lens and justify if the image is magnified or diminished in size.

Worksheet

Part 1: Reflection

No	Questions
1	A concave mirror has a focal length of 30cm. The distance between an object and its image is 45cm. Find the object and image distances, assuming that the object lies a. beyond the center of curvature **[{+90, +30}cm]** b. between the focal point and the mirror. **[{+15,−30}cm]**
	$d_o - d_i = 45.0$ cm. , $1/d_o + 1/d_i = 1/f$. , $\frac{1}{d_o} + \frac{1}{d_o - 45.0\text{ cm}} = \frac{1}{30.0\text{ cm}}$ $d_o^2 - 105\, d_o + 1350 = 0$, $d_o = (105 \pm 75)/2$. a. When the object lies beyond the center of curvature we have $d_{o+} = (1.80 \times 10^2\text{ cm})/2 = \boxed{+9.0\times 10^1\text{ cm}}$ and $d_{i+} = \boxed{+45\text{ cm}}$ b. When the object lies within the focal point $d_{o-} = (3.0 \times 10^1\text{ cm})/2 = \boxed{+15\text{ cm}}$, and $d_{i-} = \boxed{-3.0\times 10^1\text{ cm}}$
2	A spherical mirror is polished on both sides. When the concave side is used as a mirror, the magnification is +2.0. What is the magnification when the convex side is used as a mirror, the object remaining the same distance from the mirror? **[+0.67]**
	$f_{\text{convex}} = -\frac{1}{2}R$ $f_{\text{concave}} = \frac{1}{2}R$ $f_{\text{convex}} = -\frac{1}{2}R = -f_{\text{concave}}$ or $\frac{1}{f_{\text{convex}}} = -\frac{1}{f_{\text{concave}}}$ $m = -\frac{d_i}{d_o}$ or $d_i = -m\, d_o$ $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{d_o} + \frac{1}{(-m\, d_o)} = \frac{1}{d_o}\left(1 - \frac{1}{m}\right)$ $\underbrace{\frac{1}{d_o}\left(1 - \frac{1}{m_{\text{convex}}}\right)}_{1/f_{\text{convex}}} = -\underbrace{\frac{1}{d_o}\left(1 - \frac{1}{m_{\text{concave}}}\right)}_{-1/f_{\text{concave}}}$ or $m_{\text{convex}} = \frac{m_{\text{concave}}}{2m_{\text{concave}} - 1} = \frac{+2.0}{2(+2.0)-1} = \boxed{+0.67}$
3	A tall tree is growing across a river from you. You would like to know the distance between yourself and the tree, as well as its height, but are unable to make the measurements directly. However, by using a mirror to form an image of the tree and then measuring the image distance and the image height, you can calculate the distance to the tree as well as its height. Suppose that this mirror produces an image of the sun, and the image is located 0.90m from the mirror. The same mirror is then used to produce an image of the tree. The image of the tree is 0.91m from the mirror. a) How far away is the tree? **[82m]** b) The image height of the tree has a magnitude of 0.12 m. How tall is the tree? **[11m]**
	a. The distance to the tree is given by the mirror equation as $\frac{1}{d_o} = \frac{1}{f} - \frac{1}{d_i} = \frac{1}{0.9000\text{ m}} - \frac{1}{0.9100\text{ m}}$ so $d_o = \boxed{82\text{ m}}$ b. Since $h_o = h_i/m$ and $m = -d_i/d_o$, we have that $h_o = \frac{h_i}{m} = \frac{h_i}{\left(-\frac{d_i}{d_o}\right)} = h_i\left(-\frac{d_o}{d_i}\right)$ Now $h_i = -0.12$ m, where the minus sign has been used since the image is inverted relative to the tree (see Figure 25.18*b*). Thus, the height of the tree is $h_o = h_i\left(-\frac{d_o}{d_i}\right) = (-0.12\text{ m})\left(-\frac{82\text{ m}}{0.9100\text{ m}}\right) = \boxed{11\text{ m}}$
4	A dentist's mirror is placed 2cm from a tooth. The enlarged image is located 5.6cm behind the mirror. a) What kind of mirror (plane, concave, or convex) is being used? Explain. b) Determine the focal length of the mirror. **[+3.1cm]** c) What is the magnification? **[+2.8]**

	d) How is the image oriented relative to the object? Explain. **[upright]**
	a. Since the image of the tooth is enlarged, it cannot be a plane mirror, for which the object and the image would have the same size. Convex mirrors produce smaller images in all cases. Therefore, the enlarged image means that the mirror must be $\boxed{\text{concave}}$. b. Using the mirror equation (Equation 25.3), we find for the focal length that $\frac{1}{f}=\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{2.0\text{ cm}}+\frac{1}{-5.6\text{ cm}}=0.32\text{ cm}^{-1}$ or $f=\frac{1}{0.32\text{ cm}^{-1}}=\boxed{+3.1\text{ cm}}$ c. Using the magnification equation (Equation 25.4), we find for the magnification that $m=-\frac{d_i}{d_o}=-\frac{-5.6\text{ cm}}{2.0\text{ cm}}=\boxed{+2.8}$ d. Since m is positive, the image is $\boxed{\text{upright}}$ relative to the object.
5	An object is located 14cm in front of a convex mirror, the image being 7cm behind the mirror. A second object, twice as tall as the first one, is placed in front of the mirror, but at a different location. The image of this second object has the same height as the other image. How far in front of the mirror is the second object located? **[+42cm]**
	$\frac{1}{d_{o1}}+\frac{1}{d_{i1}}=\frac{1}{14.0\text{ cm}}+\frac{1}{-7.00\text{ cm}}=\frac{1}{f}$ $f=-14.0\text{ cm}$ $h_i=mh_o=\left(-d_i/d_o\right)h_o$ $h_{i2}=h_{i1}$ $\left(\frac{-d_{i2}}{d_{o2}}\right)h_{o2}=\left(\frac{-d_{i1}}{d_{o1}}\right)h_{o1}$ $d_{i2}=d_{o2}\left(\frac{d_{i1}}{d_{o1}}\right)\left(\frac{h_{o1}}{h_{o2}}\right)$ $h_{o2}=2h_{o1}$ $d_{i2}=d_{o2}\left(\frac{d_{i1}}{d_{o1}}\right)\left(\frac{h_{o1}}{h_{o2}}\right)=d_{o2}\left(\frac{-7.00\text{ cm}}{14.0\text{ cm}}\right)\left(\frac{h_{o1}}{2h_{o1}}\right)=-0.250\,d_{o2}$ $\frac{1}{d_{o2}}+\frac{1}{d_{i2}}=\frac{1}{f}$ $\frac{1}{d_{o2}}+\frac{1}{-0.250\,d_{o2}}=\frac{1}{-14.0\text{ cm}}$ $\boxed{d_{o2}=+42.0\text{ cm}}$
6	A convex mirror has a focal length of 27cm. Find the magnification produced by the mirror when the object distance is 9cm and 18cm. **[0.75, 0.6]**
	$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f}$ or $\frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}=\frac{d_o-f}{fd_o}$ or $d_i=\frac{fd_o}{d_o-f}$ $m=-\frac{d_i}{d_o}=-\frac{fd_o/\left(d_o-f\right)}{d_o}=\frac{f}{f-d_o}$ ***Smaller object distance*** $m=\frac{f}{f-d_o}=\frac{-27.0\text{ cm}}{(-27.0\text{ cm})-(9.0\text{ cm})}=\boxed{0.750}$ ***Greater object distance*** $m=\frac{f}{f-d_o}=\frac{-27.0\text{ cm}}{(-27.0\text{ cm})-(18.0\text{ cm})}=\boxed{0.600}$

Part 2: Refraction

No	Questions
1	One end of a long glass rod ($n = 1.50$) is formed into a convex surface with a radius of curvature of 6.00 cm. An object is located in air along the axis of the rod. Find the image positions corresponding to object distances of a) 20.0 cm, b) 10.0 cm, c) 3.00 cm from the end of the rod.
	$\frac{n_1}{p}+\frac{n_2}{q}=\frac{n_2-n_1}{R}$ becomes $\frac{1.00}{p}+\frac{1.50}{q}=\frac{1.50-1.00}{6.00\text{ cm}}=\frac{1}{12.0\text{ cm}}$ (a) $\frac{1.00}{20.0\text{ cm}}+\frac{1.50}{q}=\frac{1}{12.0\text{ cm}}$ or $q=\frac{1.50}{[(1.00/12.0\text{ cm})-(1.00/20.0\text{ cm})]}=\boxed{45.0\text{ cm}}$ (b) $\frac{1.00}{10.0\text{ cm}}+\frac{1.50}{q}=\frac{1}{12.0\text{ cm}}$ or $q=\frac{1.50}{[(1.00/12.0\text{ cm})-(1.00/10.0\text{ cm})]}=\boxed{-90.0\text{ cm}}$ (c) $\frac{1.00}{3.0\text{ cm}}+\frac{1.50}{q}=\frac{1}{12.0\text{ cm}}$ or $q=\frac{1.50}{[(1.00/12.0\text{ cm})-(1.00/3.0\text{ cm})]}=\boxed{-6.00\text{ cm}}$
2	A glass sphere ($n = 1.50$) with a radius of 15cm has a tiny air bubble 5cm above its center. The sphere is viewed looking down along the extended radius containing the bubble. What is the apparent depth of the bubble below the surface of the sphere?
	$\frac{n_1}{p}+\frac{n_2}{q}=\frac{n_2-n_1}{R}$. $q=\frac{n_2Rp}{p(n_2-n_1)-n_1R}$. $n_1=1.50$, $n_2=1.00$, $R=-15.0\text{ cm}$ $p=10.0\text{ cm}$. $q=\frac{(1.00)(-15.0\text{ cm})(10.0\text{ cm})}{(10.0\text{ cm})(1.00-1.50)-(1.50)(-15.0\text{ cm})}=-8.57\text{ cm}$. $\boxed{\text{apparent depth is 8.57 cm}}$.
3	A simple model of the human eye ignores its lens entirely. Most of what the eye does to light happens at the outer surface of the transparent cornea. Assume that this surface has a radius of curvature of 6mm, and assume that the eyeball contains just one fluid with a refractive index of 1.40. Prove that a very distant object will be imaged on the retina, 21mm behind the cornea. Describe the image.
	$\frac{1.00}{\infty}+\frac{1.40}{21.0\text{ mm}}=\frac{1.40-1.00}{6.00\text{ mm}}$ $0.0667=0.0667$. $\boxed{\text{The image is inverted, real and diminished.}}$
4	A goldfish is swimming at 2cm/s toward the front wall of a rectangular aquarium. What is the apparent speed of the fish measured by an observer looking in from outside the front wall of the tank? The index of refraction of water is 1.33.
	For a plane surface, $\frac{n_1}{p}+\frac{n_2}{q}=\frac{n_2-n_1}{R}$ becomes $q=-\frac{n_2p}{n_1}$. Thus, the magnitudes of the rate of change in the image and object positions are related by $\left\vert\frac{dq}{dt}\right\vert=\frac{n_2}{n_1}\left\vert\frac{dp}{dt}\right\vert$. If the fish swims toward the wall with a speed of 2.00 cm/s, the speed of the image is given by $v_{image}=\left\vert\frac{dq}{dt}\right\vert=\frac{1.00}{1.33}(2.00\text{ cm/s})=\boxed{1.50\text{ cm/s}}$.

Part 3: Thin lenses

<table>
<tr><th>No</th><th>Questions</th></tr>
<tr><td>1</td><td>A camera is supplied with two interchangeable lenses, whose focal lengths are 35mm and 150mm. A woman whose height is 1.6m stands 9m in front of the camera.
a) Show that the height of the image is

$$h_i = \left(\frac{f}{f-u}\right) h_o$$

where h_o is the height of the object, f is the focal length of the lens and u is the object distance from the camera.
b) What is the height of her image on the image sensor, as produced by the 35.0-mm lens and the 150.0-mm lens?</td></tr>
<tr><td></td><td>

$$\frac{h_i}{h_o} = -\frac{d_i}{d_o} \quad \text{or} \quad h_i = h_o\left(-\frac{d_i}{d_o}\right)$$

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \quad \text{or} \quad \frac{1}{d_i}=\frac{1}{f}-\frac{1}{d_o}=\frac{d_o-f}{fd_o} \quad \text{or} \quad d_i=\frac{fd_o}{d_o-f}$$

$$h_i = h_o\left(-\frac{d_i}{d_o}\right) = h_o\left(-\frac{1}{d_o}\right)\left(\frac{fd_o}{d_o-f}\right) = h_o\left(\frac{f}{f-d_o}\right)$$

$$h_i = h_o\left(\frac{f}{f-d_o}\right) = (1.60\text{ m})\left[\frac{35.0\times10^{-3}\text{ m}}{(35.0\times10^{-3}\text{ m})-9.00\text{ m}}\right] = \boxed{-0.00625\text{ m}}$$

$$h_i = h_o\left(\frac{f}{f-d_o}\right) = (1.60\text{ m})\left[\frac{150.0\times10^{-3}\text{ m}}{(150.0\times10^{-3}\text{ m})-9.00\text{ m}}\right] = \boxed{-0.0271\text{ m}}$$

Both heights are negative because the images are inverted with respect to the object.</td></tr>
<tr><td>2</td><td>An object is placed in front of a converging lens in such a position that the lens ($f = 12cm$) creates a real image located 21cm from the lens. Then, with the object remaining in place, the lens is replaced with another converging lens ($f = 16cm$). A new, real image is formed. What is the image distance of this new image?</td></tr>
<tr><td></td><td>The image distance d_{i2} produced by the 2nd lens is related to the object distance d_{o2} and the focal length f_2 by the thin-lens equation:

$$\frac{1}{d_{i2}}=\frac{1}{f_2}-\frac{1}{d_{o2}}$$

Since $d_{o2}=d_{o1}$ (the image distance for the 1st lens), Equation 26.6 can be written as

$$\frac{1}{d_{i2}}=\frac{1}{f_2}-\frac{1}{d_{o1}}$$

$$\frac{1}{d_{o1}}=\frac{1}{f_1}-\frac{1}{d_{i1}}$$

$$\frac{1}{d_{i2}}=\frac{1}{f_2}-\frac{1}{d_{o1}}=\frac{1}{f_2}-\left(\frac{1}{f_1}-\frac{1}{d_{i1}}\right)=\frac{1}{16.0\text{ cm}}-\left(\frac{1}{12.0\text{ cm}}-\frac{1}{21.0\text{ cm}}\right)$$

Solving for d_{i2} gives $d_{i2} = \boxed{37.3\text{ cm}}$.</td></tr>
<tr><td>3</td><td>The distance between an object and its image formed by a diverging lens is 49cm. The focal length of the lens is −233cm. Find the image distance and the object distance.</td></tr>
<tr><td></td><td>

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \quad \text{or} \quad \frac{1}{49.0-d_i}+\frac{1}{d_i}=\frac{1}{-233.0}$$

$$\frac{d_i+49.0-d_i}{d_i(49.0-d_i)}=\frac{49.0}{d_i(49.0-d_i)}=\frac{1}{-233.0}$$

$$d_i(49.0-d_i)=-11\,417$$

$$d_i=\frac{-(-49.0)\pm\sqrt{(-49.0)^2-4(1.00)(-11\,417)}}{2(1.00)}=\boxed{-85.1\text{ cm}}$$

$$d_o=49.0\text{ cm}-d_i=(49.0\text{ cm})-(-85.1\text{ cm})=\boxed{134.1\text{ cm}}$$</td></tr>
<tr><td>4</td><td>An object is placed 96.5 cm from a glass lens with one concave surface of radius 22cm and one convex surface of radius 18.5cm. Where is the final image? What is the magnification?</td></tr>
</table>

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right) \rightarrow$$

$$f=\frac{1}{(n-1)}\left(\frac{R_1R_2}{R_1+R_2}\right)=\frac{1}{(1.52-1)}\left(\frac{(-22.0\text{ cm})(+18.5\text{ cm})}{(-22.0\text{ cm})+(+18.5\text{ cm})}\right)=223.6\text{ cm}$$

$$\frac{1}{d_o}+\frac{1}{d_i}=\frac{1}{f} \rightarrow d_i=\frac{d_o f}{d_o-f}=\frac{(96.5\text{ cm})(223.6\text{ m})}{96.5\text{ cm}-223.6\text{ cm}}=-169.77\text{ cm}=\boxed{-170\text{ cm}}$$

$$m=-\frac{d_i}{d_o}=-\frac{-169.77\text{ cm}}{96.5\text{ cm}}=1.759=\boxed{+1.8}$$

The image is virtual, in front of the lens, and upright.

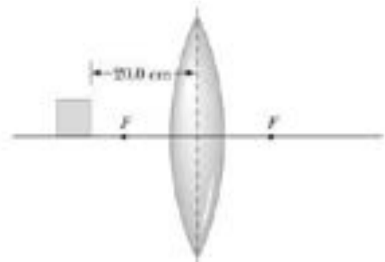
5 A planoconvex lens with $n = 1.55$ is to have a focal length of 16.3 cm. What is the radius of curvature of the convex surface?

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}+\frac{1}{R_2}\right)=\frac{1}{f}=(n-1)\left(\frac{1}{R_1}+\frac{1}{\infty}\right)=\frac{(n-1)}{R_1} \rightarrow$$

$$R_1=(n-1)f=(1.55-1)(16.3\text{ cm})=8.965\text{ cm}=\boxed{9.0\text{ cm}}$$

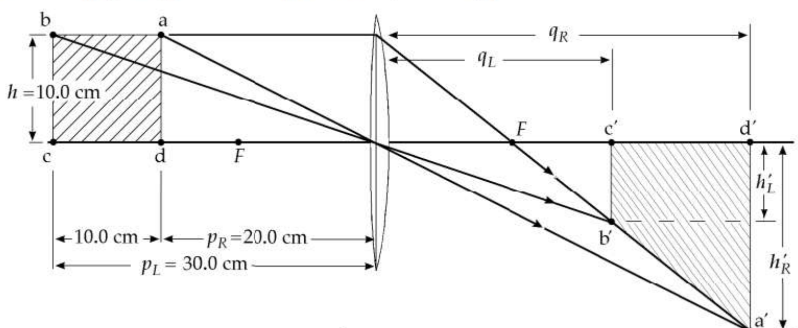
6 The figure shows a thin glass (n=1.5) converging lens for which the radii of curvature are $R_1 = 15cm$ and $R_2 = -12cm$. To the left of the lens is a cube having a face area of $100cm^2$. The base of the cube is on the axis of the lens, and the right face is 20cm to the left of the lens.

a) Determine the focal length of the lens.
b) Draw the image of the square face formed by the lens. What type of geometric figure is this?
c) Determine the area of the image.



(a) $$\frac{1}{f}=(n-1)\left[\frac{1}{R_1}-\frac{1}{R_2}\right]=(1.50-1)\left[\frac{1}{15.0\text{ cm}}-\frac{1}{(-12.0\text{ cm})}\right]$$ $\boxed{f=13.3\text{ cm}}$

(b)



The square is imaged as a trapezoid.

(c) To find the area, first find q_R and q_L, along with the heights h'_R and h'_L, using the thin lens equation.

$\frac{1}{p_R}+\frac{1}{q_R}=\frac{1}{f}$ becomes $\frac{1}{20.0\text{ cm}}+\frac{1}{q_R}=\frac{1}{13.3\text{ cm}}$ or $q_R=40.0\text{ cm}$

$$h'_R=hM_R=h\left(\frac{-q_R}{p_R}\right)=(10.0\text{ cm})(-2.00)=-20.0\text{ cm}$$

$\frac{1}{30.0\text{ cm}}+\frac{1}{q_L}=\frac{1}{13.3\text{ cm}}$ or $q_L=24.0\text{ cm}$

$$h'_L=hM_L=(10.0\text{ cm})(-0.800)=-8.00\text{ cm}$$

Thus, the area of the image is: Area $=|q_R-q_L||h'_L|+\frac{1}{2}|q_R-q_L||h'_R-h'_L|=\boxed{224\text{ cm}^2}$.

Huygen's Principle Statement:

Every $\boxed{1}$ on a wave front can be considered as a source of tiny $\boxed{2}$ that spread out in the $\boxed{3}$ direction at the speed of the $\boxed{4}$ itself. The new $\boxed{5}$ is the $\boxed{6}$ of all the wavelets—that is, the $\boxed{7}$ to all of them.

Match the correct words to their numbers!

1	Wavelets
2	Wavefront
3	Envelope
4	Tangent
5	Point
6	Forward
7	Wave

Fill in the blank!

Conditions for Interference:

Term	Meaning
Coherence	
	Two interacting light waves are of the same wavelength

Types of Interference:

Constructive Interference	
	Phase difference between the two monochromatic interacting wave is $\frac{n\lambda}{2}$, where $n \in N^{+}$

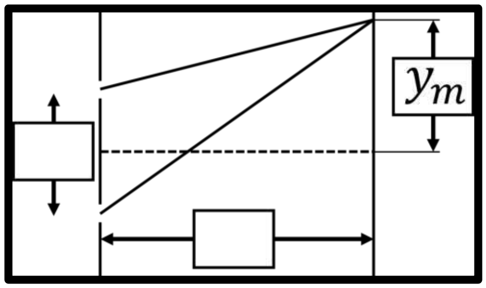
Diffraction?

Double Slit Interference

Complete the table below!

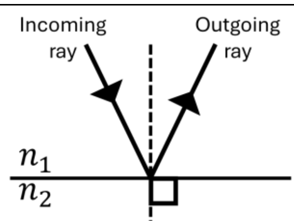
Equations		
Bright Fringes	**Dark Fringes**	**Fringe Separation**
$y_m = \frac{m\lambda D}{d}$	$y_m =$	$\Delta y =$

Write the symbol from your equations into the diagram below.

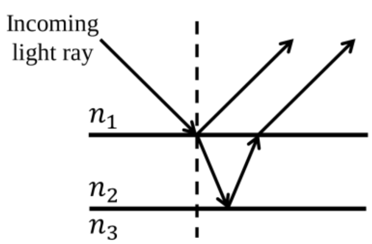
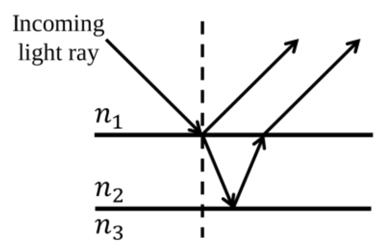


Thin Film Interference

Phase change upon reflection

	If $n_2 > n_1$, π rad phase change occurs upon reflection.	If $n_2 < n_1$,

Situations on Thin Films

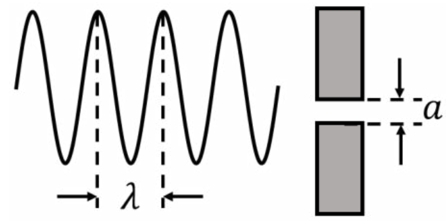
Diagrams		
Conditions	Case 1: $n_3 > n_2 > n_1$	Case 2:
Phase difference	$\Delta\phi =$	$\Delta\phi = 180^o = \pi \text{ rad} = \frac{\lambda}{2}$

Constructive and Destructive Interferences for thin films

	Types	Equation
Case 1: Non-reflective coating	Bright Fringes	$2nt = m\lambda$
	Dark Fringes	
Case 2: Reflective coating	Bright Fringes	
	Dark Fringes	

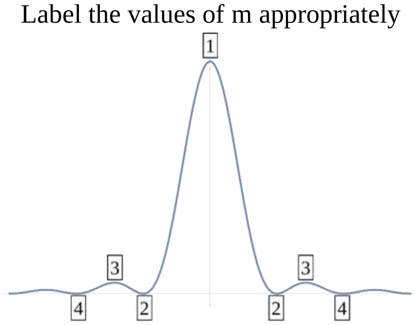
Single Slit Diffraction

Understanding Diffraction

Definition	The bending of waves behind obstacles into the “shadow region” is known as diffraction.
Condition	Diffraction is most prominent when the size of the opening is on the order of the wavelength of the wave.  $a \square \lambda$

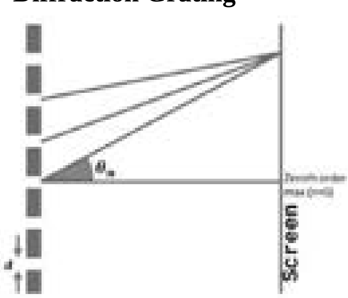
Complete the following table		
Type of Fringe	Equations	Values of *m*
Bright Fringes	$y_m = \dfrac{(m + \square)\square D}{\square}$	
Dark Fringes	$y_m = \dfrac{\square \lambda \square}{a}$	

Label the values of m appropriately



Number in Diagram	Value of m
1	
2	
3	
4	

Diffraction Grating



Complete the following table		
Type of Fringe	**Equations**	**Condition for maximum number of fringes on one side**
Bright Fringes	$d \sin \square = m\square$ $\square = \dfrac{1}{N}$	$\sin \theta \ \square \ 1$

Past Year Questions on Interferences & Diffractions

Double Slit & Thin Films

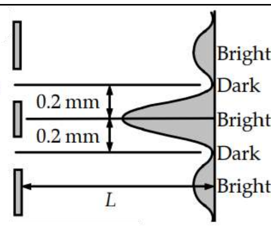
23/24	**Double Slit**	Two narrow slits 0.8mm apart are illuminated by a monochromatic light. The image of evenly distributed dark and bright fringes are displayed on the screen 50cm away. If the distance between two consecutive dark fringes is 0.304mm, determine the wavelength of the light and the distance between the third dark fringe from the central bright fringe.
	Thin Films	A glass of refractive index 1.6 is coated with a thin film to reflect blue light. If the wavelength of blue light is 460nm and the refractive index of film is 1.58, what is the minimum thickness of the film?
22/23	**Double Slit**	A 632nm wavelength light passes through a double slit at normal incident. Interference pattern is formed on the screen at 1.4m away. The distance between second order bright fringes is 23mm. Calculate the slits separation.
	Thin Films	A thin film of soap floating in air has a refractive index 1.33. Calculate the minimum thickness of the film that will reflect yellow light of wavelength 590nm.
21/22	**Double Slit**	A 475nm light passes through two narrow slits. The interference pattern is observed on a screen at a distance 85cm from the slits. The second order bright fringe is seen at $\pm 2.01cm$ from the central bright fringe. Calculate the slit separation and the width of the second order dark fringe.
	Thin Films	A flat glass with index of refraction 1.5 is coated with a transparent material of refractive index 1.25, in order to eliminate reflection of light of wavelength 680nm. Determine the minimum thickness of the coating.
20/21	**Double Slit**	Two narrow slits separated by 2.4mm are illuminated by a light with $\lambda = 512nm$. The screen is placed 6.5m from the slits. Determine the a. Distance between adjacent bright fringes on a screen. b. Distance of the fifth dark fringe from the central bright fringe.
19/20	**Double Slit**	In a double slit experiment, the incident wavelength is 660nm, the slit separation is 0.25mm and the screen is placed 90cm away from the slits. Calculate the distance from the second to the third destructive interference fringe.
	Thin Films	A soap film with refractive index 1.3 and minimum thickness $0.177\mu m$ appears reddish under white light. Calculate the wavelength of light that is missing from the reflection.

Single Slit & Diffraction Grating

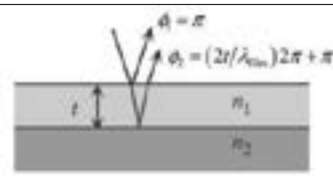
23/24	**Diffraction Grating**	A series of bright fringes is observed on a screen 1m away from a diffraction grating. A monochromatic light of wavelength $5.8 \times 10^{-7}m$ is incident normally on the grating with 200 lines per mm. Calculate the diffraction angle of the second order bright fringe and the maximum order of bright fringe.
22/23	**Single Slit**	For demonstration, a student uses a razor blade to create a slit of width $9.35 \times 10^{-5}m$ on an aluminium foil. When he shines a laser pointer with wavelength 680nm on the slit, a diffraction pattern observed on a screen. The width of the central bright fringe is 8cm. Calculate the distance of the screen from the slit.
21/22	**Diffraction Grating**	A monochromatic light 600nm is incident on a diffraction grating with 400 lines mm^{-1}. Calculate the angle for the first bright order of diffraction and the maximum number of diffraction pattern that be formed.
20/21	**Single Slit**	A monochromatic light of wavelength 620nm is incident on a single slit and forms a diffraction pattern on a screen 1.2m away. The distance of seventh dark fringe from the central maximum is 18mm. Determine the size of the single slit and the distance of the second bright fringe from the central maximum.
19/20	**Diffraction Grating**	In a double slit experiment, the incident wavelength is 660nm, the slit separation is 0.25mm and the screen is placed 90cm away from the slits. The double slit is now replaced with a diffraction grating, if the maximum number of bright fringes is 15, calculate the slit separation of the grating.

Worksheet on Interferences & Diffraction

Young's Double Slit

1	Two narrow, parallel slits separated by 0.250mm are illuminated by green light (λ =546.1nm). The interference pattern is observed on a screen 1.20m away from the plane of the slits. Calculate the distance a. from the central maximum to the first bright region on either side of the central maximum b. between the first and second dark bands.
	For the bright fringe, $y_{\text{bright}} = \frac{m\lambda L}{d}$ where $m=1$ $y = \frac{(546.1\times10^{-9}\text{ m})(1.20\text{ m})}{0.250\times10^{-3}\text{ m}} = 2.62\times10^{-3}\text{ m} = \boxed{2.62\text{ mm}}$. For the dark bands, $y_{\text{dark}} = \frac{\lambda L}{d}\left(m+\frac{1}{2}\right)$; $m = 0, 1, 2, 3, \ldots$ $y_2 - y_1 = \frac{\lambda L}{d}\left[\left(1+\frac{1}{2}\right)-\left(0+\frac{1}{2}\right)\right] = \frac{\lambda L}{d}(1)$ $= \frac{(546.1\times10^{-9}\text{ m})(1.20\text{ m})}{0.250\times10^{-3}\text{ m}}$ $\Delta y = \boxed{2.62\text{ mm}}$.
2	Two slits are separated by 0.32mm. A beam of 500nm light strikes the slits, producing an interference pattern. Determine the number of maxima observed in the angular range $-30° < \theta < 30.0°$.
	At 30.0°, $d\sin\theta = m\lambda$ $(3.20\times10^{-4}\text{ m})\sin 30.0° = m(500\times10^{-9}\text{ m})$ so $m = 320$ There are 320 maxima to the right, 320 to the left, and one for $m=0$ straight ahead. There are $\boxed{641\text{ maxima}}$.
3	Light with wavelength 442nm passes through a double-slit system that has a slit separation $d = 0.4mm$. Determine how far away a screen must be placed in order that a dark fringe appear directly opposite both slits, with just one bright fringe between them.
	$m = 0$, $y = 0.200$ mm $L \approx \frac{2dy}{\lambda} = \frac{2(0.400\times10^{-3}\text{ m})(0.200\times10^{-3}\text{ m})}{442\times10^{-9}\text{ m}} = 0.362\text{ m}$ $L \approx \boxed{36.2\text{ cm}}$ 
4	In Young's experiment a mixture of orange light (611 nm) and blue light (471 nm) shines on the double slit. The centers of the first-order bright blue fringes lie at the outer edges of a screen that is located 0.5m away from the slits. However, the first-order bright orange fringes fall off the screen. By how much and in which direction (toward or away from the slits) should the screen be moved so that the centers of the first-order bright orange fringes will just appear on the screen?
	The first-order orange fringes occur farther out from the center than do the first-order blue fringes. Therefore, the screen must be moved $\boxed{\text{toward the slits}}$ so that the orange fringes will appear on the screen. The distance between the screen and the slits is L, and the amount by which the screen must be moved toward the slits is $L_{\text{blue}} - L_{\text{orange}}$. We know that $L_{\text{blue}} = 0.500$ m, and must, therefore, determine L_{orange}. $\frac{\lambda}{d} \approx \frac{y}{L}$ or $L = \frac{yd}{\lambda}$ $\frac{L_{\text{blue}}}{L_{\text{orange}}} = \frac{yd/\lambda_{\text{blue}}}{yd/\lambda_{\text{orange}}} = \frac{\lambda_{\text{orange}}}{\lambda_{\text{blue}}}$ $L_{\text{blue}} - L_{\text{orange}} = L_{\text{blue}} - \left(\frac{\lambda_{\text{blue}}}{\lambda_{\text{orange}}}\right)L_{\text{blue}} = L_{\text{blue}}\left(1-\frac{\lambda_{\text{blue}}}{\lambda_{\text{orange}}}\right)$ $= (0.500\text{ m})\left[1-\frac{471\text{ nm}}{611\text{ nm}}\right] = \boxed{0.115\text{ m}}$

Thin Film Interference

1	A nonreflective coating of magnesium fluoride (n=1.38) covers the glass (n=1.52) of a camera lens. Assuming that the coating prevents reflection of yellow-green light (wavelength in vacuum= 565 nm), determine the minimum nonzero thickness that the coating can have.
	Thus, in this case, the minimum condition for destructive interference is $2t = \frac{1}{2}\lambda_{\text{film}}$ $\lambda_{\text{film}} = \frac{\lambda_{\text{vacuum}}}{n} = \frac{565\text{ nm}}{1.38} = 409\text{ nm}$ $t = \frac{1}{4}\lambda_{\text{film}} = \frac{1}{4}(409\text{ nm}) = \boxed{102\text{ nm}}$
2	A film of oil lies on wet pavement. The refractive index of the oil exceeds that of the water. The film has the minimum nonzero thickness such that it appears dark due to destructive interference when viewed in red light (wavelength=640nm in vacuum). Assuming that the visible spectrum extends from 380 to 750 nm, for which visible wavelength(s) in vacuum will the film appear bright due to constructive interference?
	the condition for destructive interference becomes $2t = \lambda_{\text{film}} = \frac{640.0\text{ nm}}{n_{\text{film}}}$ The condition for constructive interference is $\underbrace{2t}_{\substack{\text{Extra distance}\\\text{traveled by wave}\\\text{in the film}}} + \underbrace{\tfrac{1}{2}\lambda'_{\text{film}}}_{\substack{\text{Half-wavelength}\\\text{net phase change}\\\text{due to reflection}}} = \underbrace{m\lambda'_{\text{film}}}_{\substack{\text{Condition for}\\\text{constructive}\\\text{interference}}} \quad m = 1, 2, 3, \ldots$ where λ'_{film} is the wavelength that produces constructive interference in the film. $2t = \left(m - \frac{1}{2}\right)\lambda'_{\text{film}} = \left(m - \frac{1}{2}\right)\frac{\lambda'_{\text{vacuum}}}{n_{\text{film}}}$ $\frac{640.0\text{ nm}}{n_{\text{film}}} = \left(m - \frac{1}{2}\right)\frac{\lambda'_{\text{vacuum}}}{n_{\text{film}}} \quad \text{or} \quad \lambda'_{\text{vacuum}} = \frac{640.0\text{ nm}}{m - \frac{1}{2}}$ For m = 1, λ'_{vacuum} =1280 nm; for m = 2, λ'_{vacuum} = 427 nm; for m = 3, λ'_{vacuum} = 256 nm. Values of m greater than 3 lead to values of λ'_{vacuum} that are smaller than 256 nm. Thus, the only wavelength in the visible spectrum (380 to 750 nm) that will give constructive interference is $\boxed{427\text{ nm}}$.
3	A uniform thin film of alcohol ($n = 1.36$) lies on a flat glass plate ($n = 1.56$). When monochromatic light, whose wavelength can be changed, is incident normally, the reflected light is a minimum for $\lambda = 525nm$ and a maximum for $\lambda = 655nm$. What is the minimum thickness of the film?
	For constructive interference, the net phase change must be an even nonzero integer multiple of π. $\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda_{1\text{film}}}\right)2\pi + \pi\right] - \pi = m_1 2\pi \rightarrow t = \frac{1}{2}\lambda_{1\text{film}}m_1 = \frac{1}{2}\frac{\lambda_1}{n_{\text{film}}}m_1, \quad m_1 = 1, 2, 3, \cdots$ For destructive interference, the net phase change must be an odd-integer multiple of π. $\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda_{2\text{film}}}\right)2\pi + \pi\right] - \pi = (2m_2 + 1)\pi \rightarrow t = \frac{1}{4}\frac{\lambda_2}{n_{\text{film}}}(2m_2 + 1), \quad m_2 = 0, 1, 2, \cdots$ $\frac{1}{2}\frac{\lambda_1}{n_{\text{film}}}m_1 = \frac{1}{4}\frac{\lambda_2}{n_{\text{film}}}(2m_2 + 1) \rightarrow \frac{2m_2 + 1}{2m_1} = \frac{\lambda_1}{\lambda_2} = \frac{(655\text{ nm})}{(525\text{ nm})} = 1.2476 \approx 1.25 = \frac{5}{4}$ Thus we see that $m_1 = m_2 = 2$, and the thickness of the film is $t = \frac{1}{2}\frac{\lambda_1}{n_{\text{film}}}m_1 = \frac{1}{2}\left(\frac{655\text{ nm}}{1.36}\right)(2) = 481.6\text{ nm} \text{ or } t = \frac{1}{4}\frac{\lambda_2}{n_{\text{film}}}(2m_2 + 1) = \frac{1}{4}\left(\frac{525\text{ nm}}{1.36}\right)(5) = 482.5\text{ nm}$ The average thickness, with 3 significant figures, is $\boxed{482\text{ nm}}$ 
4	A thin oil slick ($n_o = 1.5$) floats on water ($n_w = 1.33$).When a beam of white light strikes this film at normal incidence from air, the only enhanced reflected colors are red (650 nm) and violet (390 nm). From this information, deduce the (minimum) thickness of the oil slick.
	When illuminated from above, the light ray reflected from the air–oil interface undergoes a phase shift of $\phi_1 = \pi$. A ray reflected at the oil–water interface undergoes no phase shift due to reflection, but has a phase change due to the additional path length of $\phi_2 = \left(\frac{2t}{\lambda_{\text{oil}}}\right)2\pi$. For constructive interference to occur, the net phase change must be a multiple of 2π. $\phi_{\text{net}} = \phi_2 - \phi_1 = \left[\left(\frac{2t}{\lambda_{\text{oil}}}\right)2\pi\right] - \pi = m(2\pi) \rightarrow t = \frac{1}{2}\left(m + \frac{1}{2}\right)\lambda_{\text{oil}} = \frac{1}{2}\left(m + \frac{1}{2}\right)\frac{\lambda}{n_o}$ For $\lambda = 650$ nm, the possible thicknesses are as follows: $t_{650} = \frac{1}{2}\left(m + \frac{1}{2}\right)\frac{650\text{ nm}}{1.50} = 108\text{ nm}, 325\text{ nm}, 542\text{ nm}, \cdots$ For $\lambda = 390$ nm, the possible thicknesses are as follows: $t_{390} = \frac{1}{2}\left(m + \frac{1}{2}\right)\frac{390\text{ nm}}{1.50} = 65\text{ nm}, 195\text{ nm}, 325\text{ nm}, 455\text{ nm}, \cdots$ The minimum thickness of the oil slick must be $\boxed{325\text{ nm}}$.

Single slit & Diffraction grating

1	In a single-slit diffraction pattern, the central fringe is 450 times as wide as the slit. The screen is 18 000 times farther from the slit than the slit is wide. What is the ratio $\frac{\lambda}{W}$, where λ is the wavelength of the light shining through the slit and W is the width of the slit?
	It is given that $2y = 450W$ and $L = 18\ 000W$. We know $\lambda/W = \sin\theta$. Now $\sin\theta \approx \tan\theta = y/L$, so $$\frac{\lambda}{W} = \frac{y}{L} = \frac{225\,W}{18\,000\,W} = \boxed{0.013}$$
2	How many dark fringes will be produced on either side of the central maximum if light (λ =651 nm) is incident on a single slit that is 5.47μm wide?
	The angle θ that specifies the location of the m^{th} dark fringe is given by $\sin\theta = m\lambda/W$, where λ is the wavelength of the light and W is the width of the slit. When θ has its maximum value of 90.0°, the number of dark fringes that can be produced is a maximum. Solving Equation 27.4 for m, and setting $\theta = 90.0°$, we have $$m = \frac{W\sin 90.0°}{\lambda} = \frac{(5.47\times10^{-6}\text{ m})\sin 90.0°}{651\times10^{-9}\text{ m}} = 8.40$$ Therefore, the number of dark fringes is $\boxed{8}$.
3	Light waves with two different wavelengths, 632 nm and 474 nm, pass simultaneously through a single slit whose width is 71.5μm and strike a screen 1.20 m from the slit. Two diffraction patterns are formed on the screen. What is the distance (in cm) between the common center of the diffraction patterns and the first occurrence of a dark fringe from one pattern falling on top of a dark fringe from the other pattern?
	$$\sin\theta = m_1\frac{\lambda_1}{W} \quad \text{and} \quad \sin\theta = m_2\frac{\lambda_2}{W}$$ $$m_1\frac{\lambda_1}{\cancel{W}} = m_2\frac{\lambda_2}{\cancel{W}} \quad \text{or} \quad \frac{m_1}{m_2} = \frac{\lambda_2}{\lambda_1} = \frac{474\text{ nm}}{632\text{ nm}} = 0.75$$ The first dark fringes of the two diffraction patterns do not coincide, because setting $m_1 = m_2 = 1$ yields a ratio of $m_1/m_2 = 1/1 = 1$, which does not satisfy Equation (3). But we can see that other dark fringes do coincide, because Equation (3) is satisfied when $m_1 = 3$ and $m_2 = 4$ ($m_1/m_2 = 3/4 = 0.75$), or when $m_1 = 6$ and $m_2 = 8$ ($m_1/m_2 = 6/8 = 0.75$), and so forth. The first time the dark fringes overlap occurs when $m_1 = 3$ and $m_2 = 4$. Solving the first of Equations (2) for θ, and taking $m_1 = 3$ yields $$\theta = \sin^{-1}\left(m_1\frac{\lambda_1}{W}\right) = \sin^{-1}\left[3\left(\frac{632\times10^{-9}\text{ m}}{7.15\times10^{-5}\text{ m}}\right)\right] = 1.52°$$ $$y = L\tan\theta = (1.20\text{ m})\tan 1.52° = 3.18\times10^{-2}\text{ m} = \boxed{3.18\text{ cm}}$$
4	For a wavelength of 420nm, a diffraction grating produces a bright fringe at an angle of 26 degrees. For an unknown wavelength, the same grating produces a bright fringe at an angle of 41 degrees. In both cases the bright fringes are of the same order m. What is the unknown wavelength?
	$$\sin\theta_1 = \frac{m\lambda_1}{d} \quad \text{and} \quad \sin\theta_2 = \frac{m\lambda_2}{d}$$ $$\frac{\sin\theta_2}{\sin\theta_1} = \frac{m\lambda_2/d}{m\lambda_1/d} = \frac{\lambda_2}{\lambda_1}$$ $$\lambda_2 = \lambda_1\frac{\sin\theta_2}{\sin\theta_1} = (420\text{ nm})\frac{\sin 41°}{\sin 26°} = \boxed{630\text{ nm}}$$
5	The light shining on a diffraction grating has a wavelength of 495 nm (in vacuum). The grating produces a second-order bright fringe whose position is defined by an angle of 9.34 degrees. How many lines per centimeter does the grating have?

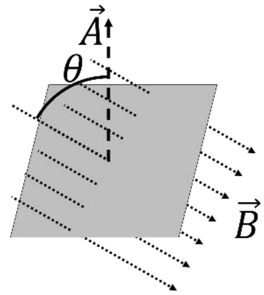
	$$\sin\theta = m\frac{\lambda}{d} \qquad m = 0, 1, 2, 3, \ldots$$ $$d = \frac{m\lambda}{\sin\theta} = \frac{2\left(495\times10^{-9}\text{ m}\right)}{\sin 9.34°} = 6.10\times10^{-6}\text{ m} \quad \text{or} \quad 6.10\times10^{-4}\text{ cm}$$ $$N = \frac{1}{d} = \frac{1}{6.10\times10^{-4}\text{ cm}} = \boxed{1640\text{ lines/cm}}$$
6	Two gratings A and B have slit separations d_A and d_B, respectively. They are used with the same light and the same observation screen. When grating A is replaced with grating B, it is observed that the firstorder maximum of A is exactly replaced by the second-order maximum of B. a. Determine the ratio $\frac{d_B}{d_A}$ of the spacings between the slits of the gratings. b. Find the next two principal maxima of grating A and the principal maxima of B that exactly replace them when the gratings are switched. Identify these maxima by their order numbers.
	a. The angular positions of the specified orders are equal, so $\lambda/d_A = 2\lambda/d_B$, or $$\frac{d_B}{d_A} = \boxed{2}$$ b. Similarly, we have for the m_A order of grating A and the m_B order of grating B that $m_A\lambda/d_A = m_B\lambda/d_B$, so $m_A = m_B/2$. The next highest orders which overlap are $$m_B = \boxed{4},\ m_A = \boxed{2} \qquad \text{and} \qquad m_B = \boxed{6},\ m_A = \boxed{3}$$

===End of Module===

Chapter 5 Notes & Exercises

Magnetic flux (unit: Tm^2 or Wb) is a measure of total magnetic field $\vec{B}$ (unit: T) passing through a given area $\vec{A}$ (unit: m^2), this is calculated with

$$\phi =$$



In the case of N number of area of $\vec{A}$ of which $\vec{B}$ passes through, the total magnetic flux is called the **magnetic flux linkage Φ,** and is determine by

$$\Phi =$$

Induced EMF

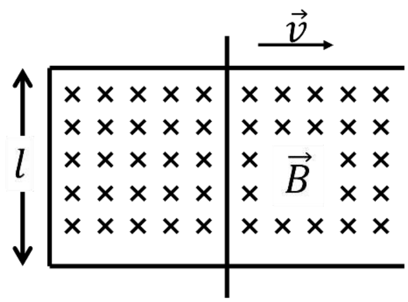
Faraday's Law		$\varepsilon =$
Lenz's Law		

Induced emf in straight conductor

In a straight conductor, the area changes with time which causes the magnetic flux to change with time.

Consider a rectangular coil with one of its side movable and the opposite of the movable side has a length of l, in a region of magnetic field $\vec{B}$. If the movable side is moved at velocity $\vec{v}$, the area of the coil would change. The induced emf would then be

$$\varepsilon =$$



Induced emf in a coil

In a circular coil, the option for inducing emf comes from varying the magnetic field **and** the area of the coil, thus 2 equations can be found,

$$\varepsilon =$$

Induced emf in a rotating coil

For a coil rotating at angular speed of ω, the emf induced is then

$$\varepsilon =$$

Part 1: Magnetic Flux & Induced EMFs

Problem 1:
A 50-turn rectangular coil of dimensions 2.5cm × 10cm is allowed to fall from a position where B=0T to a new position where B=2.5T and the magnetic field is directed perpendicular to the plane of the coil. Calculate the magnitude of the average emf that is induced in the coil if the displacement occurs in 0.5s. [0.625V]

Problem 2:
A 1.2m aluminum bar is held with its length parallel to the east–west direction and dropped from a bridge. Just before the bar hits the river below, its speed is $25ms^{-1}$, and the emf induced across its length is 1.11mV. Assuming the horizontal component of the earth's magnetic field at the location of the bar points directly north,

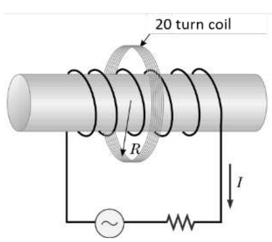
a) determine the magnitude of the horizontal component of the earth's magnetic field, $[37\mu T]$
b) state whether the east end or the west end of the bar is positive

Problem 3:
A circular loop in the plane of the paper lies in a 0.70-T magnetic field pointing into the paper. The loop's diameter changes from 20cm to 4cm in 0.15 s. What is

a) the direction of the induced current,
b) the magnitude of the average induced emf, [141mV]
c) the average induced current if the coil resistance is 2.5Ω? [56.4mA]

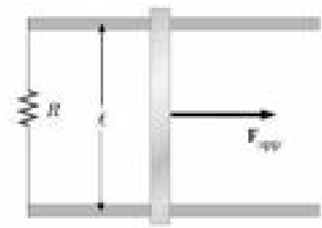
Problem 4:
A 416-loop circular armature coil with an 8cm diameter rotates at $120\,rev\,s^{-1}$ in a uniform magnetic field of strength 0.64T. Determine the peak induced emf. [1.009kV]

Problem 5:
A coil of 20 turns and radius 10cm surrounds a long solenoid of radius 2cm and 1000 turns/meter, as shown in the figure. The current in the solenoid changes from 120A to 0A in 3ms. Find the induced emf in the 20-turn coil.
$[-1.00531V]$



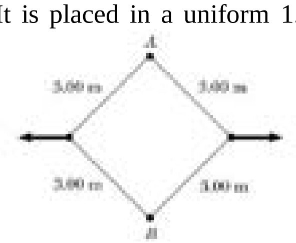
Problem 6:
A 700-turn solenoid, 20cm long, has a diameter of 2.5cm. A 14turn coil is wound tightly around the centre of the solenoid. If the current in the solenoid increases uniformly from 0 to 25A in 8ms, what will be the induced current in the short coil during this time if the short coil has a resistance of 0.3Ω? [315mA]

Problem 7:
Consider the arrangement shown in the figure. Assume that $R = 5\Omega$, $l = 1.5m$, and a uniform 4T magnetic field is directed into the page.



a) At what speed should the bar be moved to produce a current of 0.5A in the resistor? $[0.417ms^{-1}]$
b) Calculate the applied force required to move the bar to the right at a constant speed of 3m/s. [21.6N]

Problem 8:
The square loop in the figure shown is made of wires with total series resistance 10Ω. It is placed in a uniform 1.2T magnetic field directed perpendicularly into the plane of the paper. The loop, which is hinged at each corner, is pulled as shown until the separation between points A and B is 3m. If this process takes 90ms, what is the average current generated in the loop? What is the direction of the current? [1.6A]



Inductance

Self-induction

The idea of self-inductance is this – a magnetic field induces emf in a conductor, which in turns induces another magnetic field that opposes the initial induced emf. The conductor 'self induces' a magnetic field. The ability of a conductor to do this is quantified by ***self-inductance L*** (unit: Henry, *H*),

$$\mathrm{L} =$$

Generally, this means that

$$\mathrm{LI} =$$

For a coil of N turns with a cross-sectional area of *A* and radius of *r*,

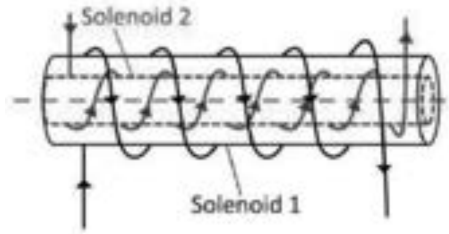
$$\mathrm{L} =$$

For a solenoid of N turns with a cross-sectional area of *A* and length *l*,

$$\mathrm{L} =$$

Mutual induction

Mutual inductance happens between 2 conductors, when the magnetic field induced by one conductor induces current in the other conductor.



Consider two coaxial solenoids, a magnetic field is generated by solenoid 1 and thus solenoid 2 respond by an induced emf, if solenoid 2 has a cross sectional area of A_2, then the mutual inductance between solenoid 1 and 2 is

$$M_{21} =$$

where *l* is the length of the solenoid.

Energy Stored in Inductor

The energy stored (unit: Joule, *J*) in an inductor of inductance *L* and with current *I* running through it, is simply

$$\mathrm{U} =$$

Part 2: Inductance & Energy Stored in Inductor

Problem 1:

a) An air-filled cylindrical inductor has 2600turns, and it is 2.5cm in diameter and 28.2cm long. What is its inductance? [15mH]

b) An air-filled cylindrical inductor has 4000turns, and it is 30cm in diameter and 2cm long. What is its inductance? [1.51H]

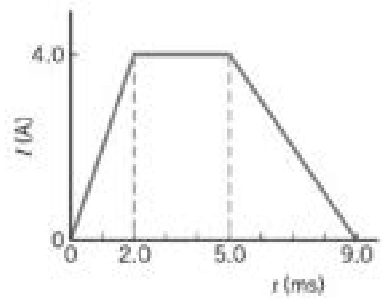
c) A coil has 200-mH inductance. If the current is 3.00 A and is increasing at a rate of $3.8As^{-1}$, what is the potential difference across the coil at this moment? [0.6V]

Problem 2:

A long thin solenoid of length 20cm and cross-sectional area $20cm^{-2}$ contains 200 closely packed turns of wire. Wrapped tightly around it is an insulated coil 650 of turns. Assume all the flux from coil 1 (the solenoid) passes through coil 2, and calculate the mutual inductance. [1.6336mH]

Problem 3:

The current through a 3.2-mH inductor varies with time according to the graph shown in the drawing.



What is the average induced emf during the time intervals

a) 0-2ms [-6.4V]

b) 2-5ms [0V]

c) 5-9ms [+3.2V]

Problem 4:

Two coils of wire are placed close together. Initially, a current of 2.5A exists in one of the coils, but there is no current in the other. The current is then switched off in a time of $3.7 \times 10^{-2}s$. During this time, the average emf induced in the other coil is 1.7 V. What is the mutual inductance of the two-coil system? [25mH]

Problem 5:

Two coils of wire are placed close together. Initially, a current of 2.5A exists in one of the coils, but there is no current in the other. The current is then switched off in a time of $3.7 \times 10^{-2}s$. During this time, the average emf induced in the other coil is 1.7 V. What is the mutual inductance of the two-coil system? [25mH]

Problem 6:

A constant current 15A of exists in a solenoid whose inductance is 3.1H. The current is then reduced to zero in a certain amount of time.

i. If the current goes from 15 to0 A in a time of 75ms, what is the emf induced in the solenoid? [620V]

ii. How much electrical energy is stored in the solenoid? [350J]

iii. At what rate must the electrical energy be removed from the solenoid when the current is reduced to 0A in a time of 75ms? [4700W]

Problem 7:

Suppose you wish to make a solenoid whose self-inductance is 1.4mH. The inductor is to have a cross-sectional area of $1.2 \times 10^{-3}m^2$ and a length of 5.2cm. How many turns of wire are needed? [220 turns]

Problem 8:

A $54\mu H$ solenoid is constructed by wrapping 65 turns of wire around a cylinder with a cross-sectional area of $9cm^2$. When the solenoid is shortened by squeezing the turns closer together, the inductance increases to $86\mu H$. Determine the change in the length of the solenoid. [33mm]

Chapter 3 – Part 2: EMFs & internal resistance

1	Calculate the terminal voltage for a battery with an internal resistance of 1.2Ω and an emf of 12V when the battery is connected in series with a. a 20Ω resistor, **[11.321V]** b. a 200Ω resistor. **[11.93V]**

$$V = IR = \varepsilon - Ir$$
$$\varepsilon = IR + Ir$$
$$12 = I(20 + 1.2)$$
$$I = 0.566A$$
$$V = (0.566)(20) = 11.321V$$
$$V = IR = \varepsilon - Ir$$
$$\varepsilon = IR + Ir$$
$$12 = I(200 + 1.2)$$
$$I = 0.0596A$$
$$V = (0.0596)(20) = 11.93V$$

13	Two resistors connected in series have an equivalent resistance of 690Ω. When they are connected in parallel, their equivalent resistance is 150Ω. Find the resistance of each resistor. **[$\{730.51, 19.5\}$Ω or $\{250.25, 499.8\}$Ω]**

$$R_1 + R_2 = 690$$
$$R_1 = 690 - R_2$$
$$\left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = 150$$
$$\left(\frac{1}{690 - R_2} + \frac{1}{R_2}\right)^{-1} = 150$$
$$R = \{469,\ 220\}\Omega$$

9	The temperature of a sample of tungsten ($\rho = 5.6(10^{-8})\ \Omega m, \alpha = 4.5(10^{-3})^{o}C^{-1}$) is raised while a sample of copper ($\rho = 1.7(10^{-8})\Omega m$) is maintained at 20.0°C. At what temperature will the resistivity of the tungsten be 5 times that of the copper? **[$135.08^{o}C$]**

$$R = \frac{\rho l}{A}$$

$$\frac{R_f}{R_o} = \frac{\rho_f}{\rho_o} = 1 + \alpha \Delta T$$

$$\frac{\rho_f}{\rho_o} = 1 + \alpha\left(T_f - T_o\right)$$

$$\frac{5(1.7 \times 10^{-8})}{(5.6 \times 10^{-8})} = 1 + (4.5 \times 10^{-3})\left(T_f - 20\right)$$

$$T_f = 135.08^{o}C$$

Minggu Anjal Session 1

<table>
<tr><td>No</td><td>Questions</td></tr>
<tr><td>1a</td><td>An AC source of peak voltage 120 V and frequency 50 Hz is connected to a 300 Ω resistor, 4 μF capacitor and 4.2 H inductor in series. Calculate the

(i) impedance of the circuit.
(ii) power factor of the circuit.

[6 marks]</td></tr>
<tr><td></td><td>

$X_L = 2\pi fL$	
$= 2\pi(50)(4.2)$	G1
$X_L = 1319.46\,\Omega$	
$X_C = \frac{1}{2\pi fC}$	
$= \frac{1}{2\pi(50)(4\times10^{-6})}$	G1
$X_C = 795.77\,\Omega$	
$Z = \sqrt{R^2 + (X_L - X_C)^2}$	
$= \sqrt{(300)^2 + (1319.46 - 795.77)^2}$	G1
$Z = 603.53\,\Omega$	JU1

</td></tr>
<tr><td>1b</td><td>An AC generator with a frequency of 20 Hz and a voltage of 110 V is connected to an RLC series circuit with a 25 Ω resistor, a 0.4 H inductor, and a 0.1 mF capacitor. Calculate the
(i) impedance in the circuit.
(ii) average power dissipated.
(iii) value of current when the circuit is at resonance.

[7 marks]</td></tr>
<tr><td></td><td>

$Z = \sqrt{R^2 + (X_c{}^2 - X_L{}^2)}$	
Where;	
$X_c = \frac{1}{2\pi fC} = \frac{1}{2\pi(20)(0.1\times10^{-3})} = 79.58\,\Omega$	**G1**
$X_L = 2\pi fL = 2\pi(20)(0.4) = 50.27\Omega$	**G1**
$Z = \sqrt{25^2 + (79.58 - 50.27)^2}$	
$= 38.52\,\Omega$	**JU1**

</td></tr>
</table>

	$P_{av} = I_{rms}{}^2 R$ Where; $I_{rms} = \frac{V_{rms}}{Z} = \frac{110}{38.52} = 2.86$ A *(ecf for Z)* $P_{av} = (2.86)^2 \times (25) = 204.49$ W	**G1** **JU1**
	At resonance , Z_{min}=R= 25 Ω $I_{rms} = \frac{V_{rms}}{Z} = \frac{110}{25} = 4.4\ A$	**K1** **GJU1**
2a	A cat of 32 cm height is standing 1.2 m in front of a spherical mirror produces an upright image 4.8 m from the mirror. (i) Calculate the focal length of the mirror. (ii) If the image formed is inverted and half of its original height, determine the distance between the cat and mirror. **[4 marks]**	
	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $= \frac{1}{1.2} + \frac{1}{(-4.8)}$ $f = 1.6$ m	**G1** **JU1**
	$M = -\frac{v}{u} = \frac{h_i}{h_o} = \frac{16}{32}$ $-0.5 = -\frac{v}{u} \rightarrow v = 0.5u$ $\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\frac{1}{1.6} = \frac{1}{u} + \frac{1}{0.5u}$ $u = 4.8$ m	**G1** **GJU1**

2b

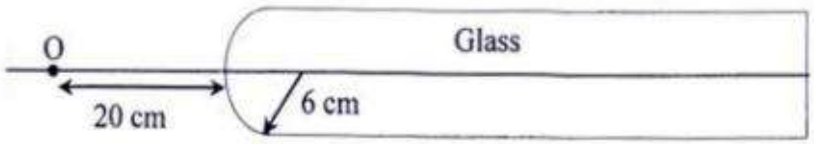


FIGURE 7

FIGURE 7 shows a glass rod with a convex surface of radius of curvature 6 cm at one end. The refractive index of the glass is 1.5. A point object, O is located at 20 cm from the curved end.

i) Determine the location of the image.

ii) If the glass rod is immersed in water with a refractive index of 1.33, determine the location of the image. State **ONE** characteristic of the image.

[*5 marks*]

(i) $\frac{n_1}{u}+\frac{n_2}{v}=\frac{n_{2}-n_1}{R}$	
$\frac{1}{(20)}+\frac{1.5}{v}=\frac{(1.5-1)}{6}$	G1
v = 0.45 m / 45 cm (**opposite side as the object**)	JU1
(ii) $\frac{n_1}{u}+\frac{n_2}{v}=\frac{n_{2}-n_1}{R}$	
$\frac{1.33}{(20)}+\frac{1.5}{v}=\frac{(1.5-1.33)}{6}$	G1
v = -39.3 cm / - 0.393 m The negative sign indicates the image is at the **same side as the object** or at the **front** of convex surface.	J1
The characteristics of the image are ○ **Virtual** ○ **upright**	J1

2c

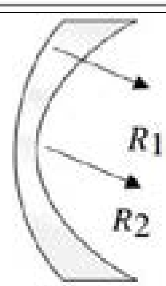


FIGURE 6

FIGURE 6 shows a lens made from glass with refractive index of 1.57. The radius of curvature R_1 and R_2 are 15.0 cm and 13.0 cm respectively.

i) Calculate the focal length.

ii) If the lens immersed in water with refractive index of 1.33, calculate its new focal length.

[*4 marks*]

	i) $\frac{1}{f} = \left(\frac{n_{material}}{n_{medium}} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ $R_1 = 15cm$ $R_2 = 13cm$ $\frac{1}{f} = (1.57 - 1)(\frac{1}{15} - \frac{1}{(13)})$ $\therefore f = -171.05\ cm$	K1 GJU1
	ii) $\frac{1}{f} = (\frac{1.57}{1.33} - 1)(\frac{1}{15} - \frac{1}{(+13)})$ $\therefore f = -540\ cm$	G1 JU1
2d	Two thin convex lens with focal length 6 cm and 13 cm are placed on a common axis, 10 cm between each other. If an object is placed 4 cm in front of first lens, calculate the final position of the image formed from second lens. [3 *marks*]	
	$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$ $\frac{1}{6} = \frac{1}{4} + \frac{1}{v}$ $v = -12$ cm $u = 12 + 10$ $= 12$ cm $\frac{1}{13} = \frac{1}{22} + \frac{1}{v}$ $v = +31.8$ cm (behind lens 2)	J1 K1 J1
2e	A film of soap is view in reflected light. The film has index of reflection $n = 1.36$. The light reflected perpendicular to the film at a certain point is missing the wavelength 504 nm and 630 nm. No other wavelengths between these two are missing. Calculate the thickness of the film. [4 *marks*]	

Missing wavelengths means destructive interference has occured. Therefore;

$$2nt = m\lambda$$

$$if\ \lambda = 630\ nm\ , order\ is\ m^{th}$$

$$if\ \lambda = 504\ nm\ , order\ is\ (m+1)^{th}$$

K1

$$2nt = m\lambda_{630} = (m+1)\lambda_{504}$$

$$m(630 \times 10^{-9}) = (m+1)(504 \times 10^{-9})$$

$$m = 4.0$$

G1

Therefore, $2nt = m\lambda$

$$t = \frac{m\lambda}{2n} = \frac{(4)(630 \times 10^{-9})}{2(1.36)}$$

G1

$$t = 926.5 \text{ nm}$$

JU1

3a Semiconductors such as silicon are used to fabricate solar cells, devices that generate electric energy when exposed to sunlight. A silicon solar cell(n=3.50) is coated with a transparent thin film, such as silicon monoxide (Sio; n=1.45). Determine the minimum thickness of the film that will produce no reflection at a wavelength of 552 nm

[*3 marks*]

Both rays undergo 180° phase changes on reflection.
The condition for a reflection minimum is when **m = 0**, K1

$$2nt = (m + \frac{1}{2})\lambda$$

$$2(1.45)t = (0 + \frac{1}{2})(552 \text{ n})$$ G1

$$t = 95.2 \text{ nm}$$ JU1

3b A double slit experiment is perform using light of wavelength 589 nm. The distance between the slits and the screen is 2 m. The tenth dark fringe is observed 7.26 mm from the center maximum.

(i) Calculate the distance of the fifth bright fringe from the center maximum.

(ii) What will happen to the interference pattern if the distance between the slits increase? Justify your answer.

[*6 marks*]

	(i)	$m = 9$ $Y = \dfrac{\left(9+\frac{1}{2}\right)(589\times10^{-9})(2)}{(d)} = 7.26\times10^{-3}$ $d = 1.54\times10^{-3}$ m $Y_5 = \dfrac{5\lambda D}{d}$ $Y_5 = \dfrac{5(589\times10^{-9})(2)}{1.54\times10^{-3}}$ $= 3.82\times10^{-3}$ m	K1 G1 G1 JU1	
	(ii)	$\Delta y \; \alpha \; \dfrac{1}{d}$ $d\uparrow \Delta y\downarrow$ The fringes become narrow	K1 J1	
3c	Light of wavelength 580 nm is incident on a slit of width 0.3 mm. The observing screen is placed 2.0 m from the slit. i) Find the position of the first dark fringe. ii) Calculate the width of the central bright fringe. *[4 marks]*			
	i) $y_m = \dfrac{m\lambda D}{a}$ $= \dfrac{1(5.8x10^{-7})(2)}{0.3x10^{-3}}$ $= 3.87\ x10^{-3}$ m ii) $W = \dfrac{2\lambda D}{a}$ $= \dfrac{2(5.8x10^{-7})(2)}{0.3x10^{-3}}$ $= 7.73x10^{-3}$ m		G1 JU1 G1 JU1	
3d	The violet light with a wavelength of 430 nm is incident onto a diffraction grating with 9500 lines per 2 cm length. (i) Calculate the angle for the second order maximum. (ii) Does the fifth-order maximum exist in the diffraction pattern? Justify your answer. **[5 marks]**			

	(i)	$d = \frac{1}{N} = \frac{1}{4750\ \text{cm}^{-1}} = 2.11 \times 10^{-4}\text{cm}$ $d \sin\theta = m\lambda$ $(2.11 \times 10^{-6}) \sin\theta = (2)(430 \times 10^{-9})$ $\theta = 24.1°$	**G1** **GJU1**
	(ii)	No, fifth-order maximum didn't exist. $d \sin\theta = m\lambda$ $(2.11 \times 10^{-6}) \sin 90° = m(430 \times 10^{-9})$ $m = 4.91 \approx m_{max} = 4$	**J1** **K1(** $\theta = 90°$**)** **GJ1**
4a	An electron and a proton are accelerated through the same voltage. If the de Broglie wavelength of the electron is 0.12nm, what is the de Broglie wavelength of the proton? [*3 marks*]		
		$\lambda = \frac{h}{\sqrt{2meV}}$, $\lambda\ \alpha\ \frac{1}{\sqrt{m}}$ $\frac{\lambda_p}{\lambda_e} = \sqrt{\frac{m_e}{m_p}} \frac{\lambda_p}{0.12 \times 10^{-9}} = \sqrt{\frac{9.11\ x\ 10^{-31}}{1.66\ x\ 10^{-27}}}$ $\lambda_p = 2.81\ x\ 10^{-12}\ m$	K1 G1 JU1
4b	An electron is accelerated in vacuum through a potential difference of 1500 V. If the potential difference is quadrupled, calculate (a) the ratio of the electron's new speed to its original speed. (b) the new wavelength of the electron. [3 *marks*]		
	(i)	$\lambda = \frac{h}{mv}$ $= \frac{6.63 \times 10^{-34}}{7.5 \times 10^{-3}(400)}$ $= 2.21 \times 10^{-34}$ m	G1 JU1
	(ii)	$\lambda = \frac{h}{mv}$ $= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31}(3 \times 10^{5})}$ $= 2.43 \times 10^{-9}$ m	GJU1
5a	Given the mass of $^{11}_{5}B$ nucleus is 11.008757 u, calculate the binding energy per nucleon in MeV/nucleon. [3 marks]		

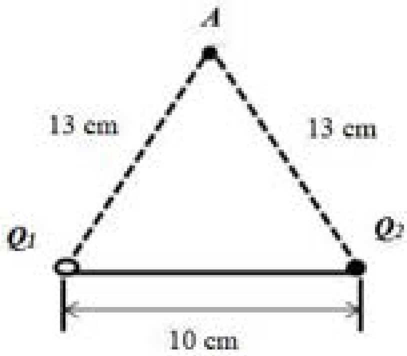
	(a)	$\Delta m = [Zm_p + Nm_n] - m_{nuclues}$ $\Delta m = [5(1.007277u) + 6(1.008665u)] - 11.008757u$ $\Delta m = 0.079618u$ $\dfrac{E_B}{A} = \dfrac{\Delta mc^2}{A} = \dfrac{0.079618(931.5MeV)}{11}$ $\dfrac{E_B}{A} = 6.74MeV/nucleon$	G1 G1 JU1	
5b	The half- life of ${}^{60}_{27}Co$ is 5.26 years. Calculate the decay constant of this atom **AND** the activity of 1.00 g of ${}^{60}_{27}Co$. [4 *marks*]			
	Decay constant, $\lambda = \dfrac{\ln 2}{T_{\frac{1}{2}}}$ $\lambda = \dfrac{\ln 2}{(5.26)}$ $\lambda = 0.13\ year^{-1}$ 60 g of ${}^{60}_{27}Co$ contains 6.02×10^{23}atoms 1.00 g of ${}^{60}_{27}Co$ contains $\dfrac{6.02\times10^{23}}{60} = 1.003\times10^{22}$ atoms Activity $= \dfrac{dN}{dt} = \lambda N$ $= (0.13)(1.003\times10^{22})$ $= 1.304\times10^{21}\ year^{-1}$			
5c	A 2 g sample of a radioactive element has a half-life of 78 hours. The molar mass element is 67 g/mol. Calculate the (i) decay constant (ii) number of atoms remained in the sample after 30 hours. [4 *marks*]			

	(b)(i)	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ $= \frac{\ln 2}{78} = 8.89 \times 10^{-3}\ hours^{-1}$	GJU1
	(b)(ii)	Initial number of atoms, N_o $N_o = \frac{2\ g}{67\ g} \times 6.02 \times 10^{23}$ $= 1.797 \times 10^{22}\ nuclei$ Number of atoms after 30 hours $N = N_o\, e^{-\lambda t}$ $= (1.797 \times 10^{22})\, e^{-8.89\times10^{-3}(30)}$ $= 1.376 \times 10^{22}\ nuclei$	G1 G1 JU1
5d	A sample of uranium-238 contains 2.5×10^{23} atoms. Given that the half-life of uranium-238 is $1.42\times10^{19}\,s$. Calculate i) the initial activity of the sample in Becquerel. ii) the number of uranium-238 atoms remaining after $3 \times 10^{18}\ s$. [*5 marks*]		
	i) $\lambda = \frac{\ln 2}{T_{\frac{1}{2}}}$ $= \frac{\ln 2}{1.42\times10^{19}}$ $= 4.88\times10^{-20}\ s^{-1}$ $A_O = \lambda N_O$ $= (4.88\times10^{-20})2.5\times10^{23}$ $= 12200\,Bq$ ii) $N = N_0 e^{-\lambda t}$ $N = 2.5\times10^{23} e^{-4.88\times10^{-20}(3\times10^{18})}$ $= 2.16\times10^{23}$ nuclei	GJU1 G1 JU1 G1 JU1	
6a	A 250 turns coil is rotating at 5π rad s^{-1} in a uniform magnetic field of 0.40 T. The cross-sectional area of the coil is 3.5 cm^2. Calculate the maximum induced emf in the coil. **[3 marks]**		

	$\varepsilon_{ind} = NBA\omega sin\omega t$ $\varepsilon_{ind(max)}$ when $sin\omega t = 1$ $\varepsilon_{ind} = 250\,(0.40)(3.5 \times 10^{-4})(5\pi)$ $\varepsilon_{ind} = 0.55$ V	K1 G1 JU1
6b	X and Y are two adjacent coaxial solenoids. The number of turns of solenoids X and Y are 150 and 100, respectively. (i) Each turn of solenoid X produces a flux of 5.50×10^{-3} Wb when a current of 5.0 mA flows through it. Calculate the self-inductance of solenoid X. (ii) Calculate the mutual inductance of the solenoids X and Y if the cross-sectional area of solenoid X is 16.0 cm^2 and its length is 7.5 cm. **[4 marks]**	
	(i) $L = \frac{N\emptyset}{I}$ $L = \frac{150(5.50 \times 10^{-3})}{5.0 \times 10^{-3}}$ $L = 165$ H	G1 JUI
	(ii) $M = \frac{\mu_o N_X N_Y A}{l}$ $M = \frac{4\pi \times 10^{-7}(150)(100)(16.0 \times 10^{-4})}{7.5 \times 10^{-2}}$ $M = 4.02 \times 10^{-4}$ H	G1 JUI

Total Marks: 80

Minggu Anjal Session 2

No	Question
1a	 **FIGURE 1** **FIGURE 1** shows two point charges Q_1= +12 nC and Q_2= −12 nC, placed 10 cm apart. Calculate the (a) electric force on charge Q_1 **and** state its direction. (b) electric field strength at point **A and** state its direction. (c) electric force acting on another charge of magnitude +2 μC placed at point **A**. [10 *marks*]

NO.	ANSWER SCHEME	MARK(S)
1(a)	$F = \frac{kQq}{r^2}$	
	$= \frac{(9\times10^9)(12\times10^{-9})(12\times10^{-9})}{(10\times10^{-2})^2}$	G1
	$F = 1.3\times10^{-4}$N	JU1
	Direction to the **RIGHT** or **towards Q_2**	J1
1(b)	$E_1 = \frac{kQ}{r^2}$	
	$E_1 = \frac{9\times10^9(12\times10^{-9})}{(13\times10^{-2})^2} = 6.39\times10^3\ NC^{-1}$	G1
	$E_2 = \frac{9\times10^9(12\times10^{-9})}{(13\times10^{-2})^2} = 6.39\times10^3\ NC^{-1}$	G1
	Vector / x-axis / y-axis: E_1: $6.39\times10^3\cos 67.4°$ / $6.39\times10^3\sin 67.4°$ E_2: $6.39\times10^3\cos 67.4°$ / $-6.39\times10^3\sin 67.4°$ Total: $4.92\times10^3\ NC^{-1}$ / $0\ NC^{-1}$	
	$E_{nett} = \sqrt{(4.92\times10^3)^2+0^2}$	G1
	$E_{nett} = 4.92\times10^3\ NC^{-1}$	JU1
	Direction: To the **RIGHT**	J1
1(c)	$F = q_oE$	
	$F = (2\times10^{-6})(4.92\times10^3)$	G1
	$F = 9.84\times10^{-3}$N	JU1
	JUMLAH	**10**

<table>
<tr><td>1b</td><td>

(a)

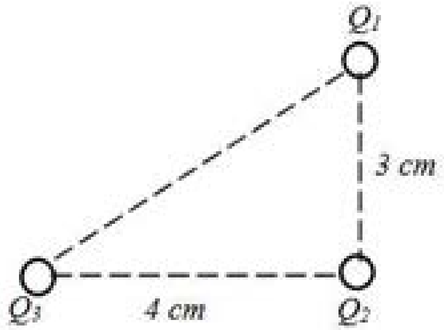


FIGURE 1

Three point charges, Q_1= +15 μC, Q_2 = −25 μC and Q_3 = −35 μC are arranged as in **FIGURE 1**.

(i) Copy **FIGURE 1** and draw the direction of the electrostatic forces on Q_2.

(ii) Calculate the magnitude and direction of the resultant force on Q_2.

[6 *marks*]

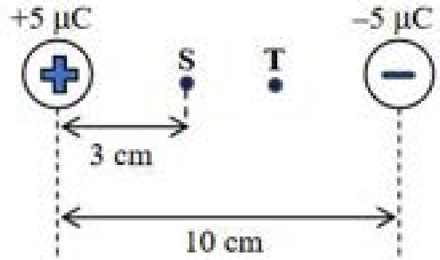


FIGURE 2

FIGURE 2 shows two point charges, + 5 μC and –5 μC separated by 10 cm. If the work done to bring a charge + 3 μC from point **S** to point **T** is 2 J, calculate the electric potential at point **T.**

[4 *marks*]

</td></tr>
<tr><td></td><td>

(a)(ii) $F = 6.19 \times 10^3\ N, \theta = 37.31° \text{ above } x - axis$

(b) $V_T = 1.52 \times 10^6\ V$

</td></tr>
<tr><td>2</td><td>

(a) A certain parallel plate capacitor consists of two plates, each with area 500 cm^2, separated by a 1.0 cm air gap. If the capacitor is connected across a voltage of 900 V, calculate

(i) the capacitance of the capacitor.

(ii) the charge stored in the capacitor.

[4 *marks*]

</td></tr>
</table>

(b)

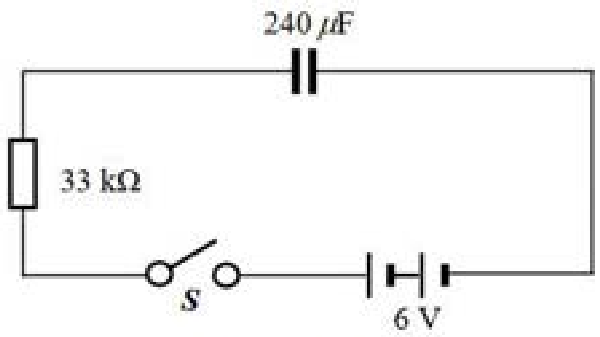


FIGURE 3

A 240 μF capacitor is charged through a 33 kΩ resistor using a 6 V battery as shown in **FIGURE 3**. Calculate

(i) the time constant of the circuit.

(ii) the energy stored in the charged capacitor.

[3 *marks*]

$(a)(i)\ C_o = 4.43 \times 10^{-11}\ F$ (ii) $Q = 3.98 \times 10^{-8} C$

(b)(i) $\tau = 7.92\ s$ (ii) $U = 4.32 \times 10^{3}\ J$

3a (a) A current of 3.0 A flows in a constantan wire of length 120 cm and cross sectional area of 0.45 mm^2. The resistivity of constantan is 4.9×10^{-7} Ω m. Calculate potential difference between the two ends of the wire.

[2 *marks*]

(b) A resistor of 100 Ω is connected across a battery of e.m.f 15.0 V and internal resistance 1.5 Ω. Determine the

(i) terminal potential difference.

(ii) power consumed in the internal resistance, r of the battery.

(iii) energy dissipated by 100 Ω resistor in one minute.

[5 *marks*]

(c)

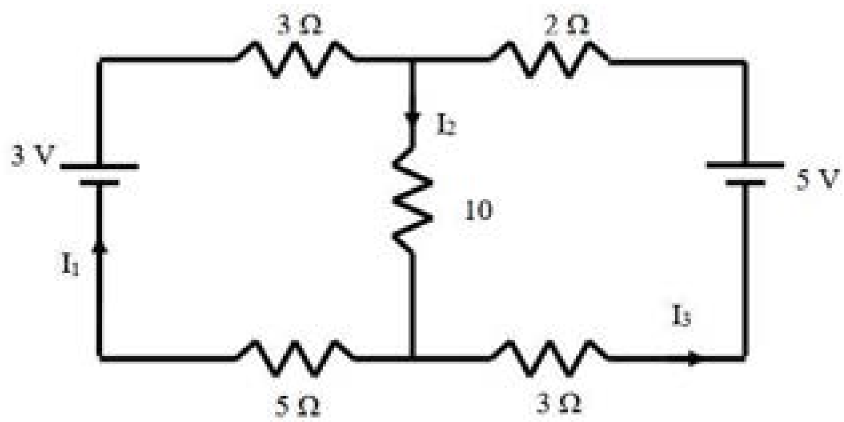
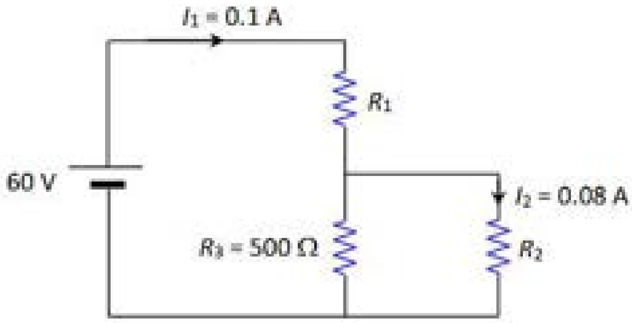


FIGURE 3

FIGURE 3 shows a circuit containing two batteries and five resistors. Calculate I_1, I_2 and I_3.

[6 *marks*]

	(a) 3.93 V (b) (i) 14.8 V (ii) 0.0329W (iii) 131.42J (c) - 0.0294 A, 0.3235 A 0.3529 A
3b	(a) Two circuits, P and Q each has a voltmeter connected across a 6 V battery. If the voltmeter in circuit P shows 6 V and that in circuit Q shows 5.3 V, calculate if there is internal resistance in any of the batteries given that the current in the circuit is 2 A. [2 *marks*] (b) A copper wire is initially at 25.0°C. What is the final temperature of the wire if its resistance is increased by 20%? Temperature coefficient of resistivity for copper, $\alpha = 6.8 \times 10^{-3}$ °C^{-1}. [3 *marks*] (c)  **FIGURE 3** **FIGURE 3** shows an arrangement of resistors connected to a 60 V battery. Determine the (i) resistance of R_1 **and** R_2. (ii) effective resistance. [5 *marks*]
	(a) $r_P = 0\ \Omega$, $r_Q = 0.35\ \Omega$ (b) $T = 54.41$ °C (c) (i) $R_1 = 500\ \Omega$, $R_2 = 125\ \Omega$ (ii) $R_{eff} = 600\ \Omega$

4a	(a) A 300 turn solenoid of length 10 cm has a cross sectional area of 20 cm^2 and a current of 5 A flows through the solenoid. Calculate the (i) magnetic field at the axis of the solenoid. (ii) total flux linkage passing through solenoid. (iii) self-inductance of the solenoid. [6 *marks*] (b) A 1000 turn solenoid has across sectional area of 2.0 cm^2 and length of 50 cm carrying a current 3.8 A. Calculate the (i) energy stored in the solenoid. (ii) induced emf in the solenoid if the current drops uniformly to zero in 1 minute. [4 *marks*]
	(a)(i) $B = 0.0188\ T$ (ii) $\Phi = 1.128 \times 10^{-2}\ Wb$ (iii) $L = 2.26 \times 10^{-3} H$ (b)(i) $U = 3.63 \times 10^{-3} J$ (ii) $\varepsilon = 3.18 \times 10^{-5}\ V$
4b	(a) A solenoid P has length 0.5 m and cross-sectional area 8×10^{-4} m^2 has 2000 turns and carries 5 A current. A solenoid Q with 600 turns is placed in the center of solenoid P. Calculate the (i) magnetic flux through solenoid P. (ii) mutual inductance between solenoids P and Q. (iii) induced emf in solenoid Q when the current in solenoid P is increasing at a rate of 12 A s^{-1}. [5 *marks*]

(b)

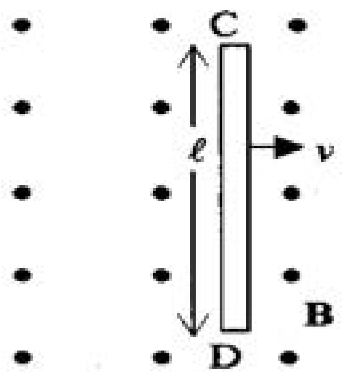


FIGURE 5

FIGURE 5 shows a conducting rod with length l = 0.065 m moves perpendicularly in a uniform magnetic field with magnitude, B = 1.20 T. The e.m.f induced in the moving rod is 0.32 V.If the total circuit resistance is 0.80 Ω, determine the:

(i) speed of the rod.

(ii) magnitude and direction of the induced current flowing through the rod.

[5 *marks*]

(a)(i) $\Phi = 2.01 \times 10^{-5}\ Wb$ (ii) $M = 2.41 \times 10^{-3}\ H$ (iii) $\varepsilon = 0.029\ V$

(b)(i) $v = 42.03\ m\ s^{-1}$ (ii) $I = 0.4\ A\ \ direction\ of\ current\ downward$

5a

a. A circular coil of 100 turns with a plane area 8.0×10^{-3} m^2 is placed in a magnetic field of 0.2 T.

i. Calculate the magnetic flux linkage through the coil when the plane of the coil makes an angle of 30° to the magnetic field.

ii. The coil is rotated about an axis of rotation perpendicular to the uniform magnetic field at a constant speed of 10.0 revolution per second. Calculate the maximum value of the emf induced.

[6 marks]

b. X and Y are two adjacent coaxial coils. The number of turns of coils X and Y are 1000 and 5000 respectively. Each turn of coil X produces a flux of 8.5×10^{-5} Wb when a current of 3.0 A flows through it. Calculate the

i. self-inductance

ii. energy stored in coil X

[2 marks]

4 (a) (i)	$\theta = 90 - 30 = 60°$ $\phi = NBA\cos\theta$ $\phi = 100(0.2)(8.0 \times 10^{-3})\cos 60$ $\theta = 0.08\ Wb$	K1 G1 JU1
(ii)	$\omega = 10\ rev \times 2\pi = 20\pi\ rad\ s^{-1}$ $\varepsilon_{max} = NBA\omega$ $\varepsilon_{max} = 100(0.2)(8.0 \times 10^{-3})20\pi = 10.05\ V$	K1 K1 GJU1
(b) (i)	$L_X = \frac{N_X \phi_X}{l}$ $L_X = \frac{1000(8.5 \times 10^{-5})}{3} = 0.0283\ H$	GJU1
(ii)	$U = \frac{1}{2}LI^2$ $U = \frac{1}{2}(0.0283)(3)^2 = 0.127\ J$	GJU1

5b

Three capacitors with capacitance of 23 μF, 35 μF and 40 μF are connected as shown in **FIGURE 2.**

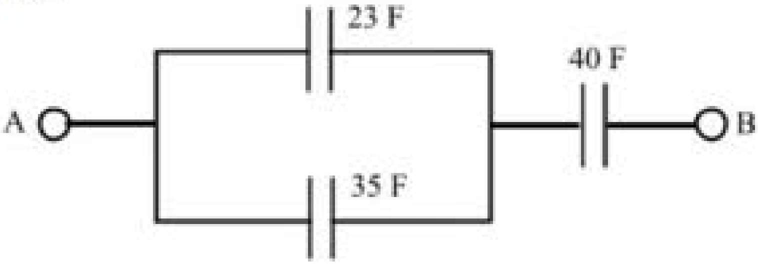


FIGURE 2

a) Calculate the effective capacitance between points A and B.

b) Calculate the charge in the capacitor 40 μF if the potential difference between points A and B is 20 V.

[5 marks]

2) a) $C_{ef} = \frac{1}{\frac{1}{23\mu + 35\mu} + \frac{1}{40\mu}} = 23.67\ \mu F$

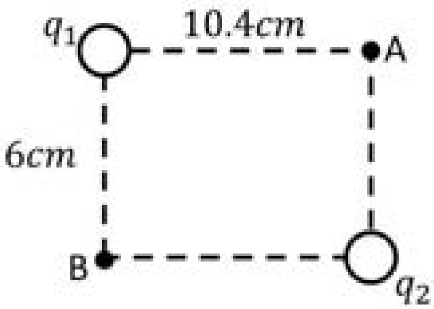
b) $Q = CV = 23.4\mu(20) = 4.734 \times 10^{-4}\ C$

or $473.4\ \mu C$

Total: 83marks

Post Holiday Quiz

Problem 1

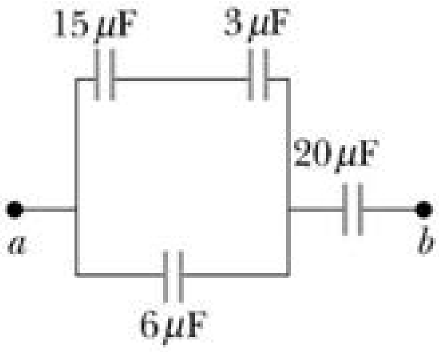


The figure shows two point charges $q_1 = -6\mu C$ and $q_2 = 8\mu C$ arranged at two opposite corners of a rectangle in vacuum. Determine the

a) Electric field strength at point A
b) Potential difference between point A and B.
c) Amount of energy needed to moves a $+2nC$ from A to B.

[8 marks]

Problem 3



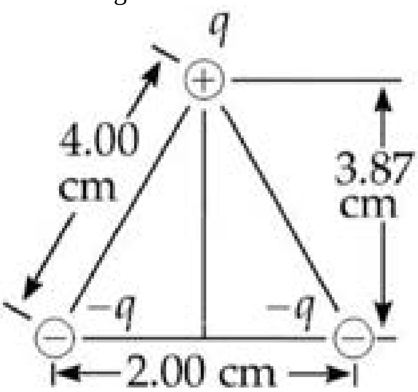
Four capacitors are connected as shown in the figure.

a. Find the equivalent capacitance between points a and b.
b. Calculate the charge on the $20\mu F$ capacitor if $\Delta V_{ab} = 12V$.

[2 marks]

Problem 2

The three charges in the figure below are at the vertices of an isosceles triangle.

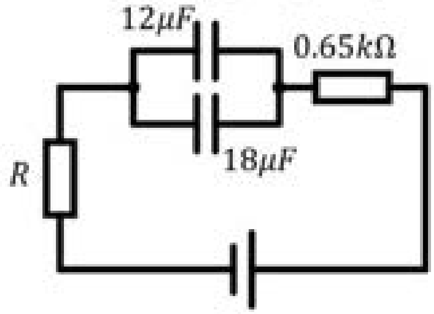


Calculate the electric potential at the midpoint of the base, taking $q = 7\mu C$.

[2 marks]

Problem 4

The circuit shows a charging set up for capacitors.

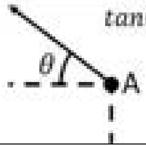


If the capacitors takes 500ms to charge up to 60% of its maximum capacity, determine the resistance R.

[3 marks]

Solutions

Problem 1

$E_1 = (9 \times 10^9)\left(\frac{6\times10^{-6}}{0.104^2}\right)$	G1
$E_1 = 4.993 \times 10^6 NC^{-1}$	
$E_2 = (9 \times 10^9)\left(\frac{8\times10^{-6}}{0.06^2}\right)$	G1
$E_2 = 2 \times 10^6 NC^{-1}$	
$E_{net} = \sqrt{4.993^2 + 2^2}(10^6) = 4.38 \times 10^6 NC^{-1}$	GJU1
 $tan(\theta) = \frac{E_2}{E_1} = \frac{2}{4.993} \Rightarrow \theta = 21.83^o$	GJU1
$\Delta V = V_A - V_B = k\left(\frac{q_1}{r_1} + \frac{q_2}{r_2}\right) - k\left(\frac{q_1}{r_2} + \frac{q_2}{r_1}\right)$	
$\Delta V = (9 \times 10^9)\left(\frac{-6\mu}{0.104} + \frac{8\mu}{0.06} - \frac{-6\mu}{0.06} - \frac{8\mu}{0.104}\right)$	G1
$V = 888.462kV$	JU1
$W = q\Delta V = (2 \times 10^{-9})(888462)$	G1
$W = 1.777mJ$	JU1

Problem 2

$V = k\left(\frac{q}{r_1} + \frac{-q}{r_2} + \frac{-q}{r_3}\right) = kq\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3}\right)$	
$V = (9)(7)(10^{9-6})\left(\frac{1}{0.0387} - \frac{1}{0.01} - \frac{1}{0.01}\right)$	G1
$V = -10.97MV$	JU1

Problem 3

$C_1 = \left(\frac{1}{15\mu} + \frac{1}{3\mu}\right)^{-1} = 2.5\mu F$ $C_2 = 2.5\mu + 6\mu = 8.5\mu F$ $C_{eff} = \left(\frac{1}{8.5\mu} + \frac{1}{20\mu}\right)^{-1} = 5.96\mu F$	G1
$V_2 + V_{20\mu F} = 12 = Q\left(\frac{1}{8.5\mu} + \frac{1}{20\mu}\right)$	
$V_{20\mu F} = \frac{Q}{C} = \frac{71.58\mu}{20\mu} = 3.58V$	GJU1

Problem 4

$Q = Q_o\left(1 - e^{-\frac{t}{\tau}}\right)$ $0.6 = 1 - e^{-\frac{0.5}{\tau}}$	G1
$\tau = 0.54568 = (650 + R)(12 + 18)(10^{-3})$	G1
$R = 1168.93\Omega$	GJU1

SP025 Physics

Tutorial Book

Student's name: ______________________

Tutorial Class: ______________________

Lecturer's Name: ______________________

Contributors: Shafiq R, Mary Yusus, John Liew, Ahmad SYuhud

Table of Contents

1 Three point charges, q_1 = +3.0 µC, q_2 = −4.0 µC and q_3 = −7.0 µC are placed 20 cm and 15 cm apart on a straight line in air as shown in **FIGURE 1.1**.

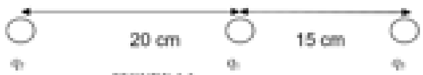


FIGURE 1.1

a) Sketch the electric force diagram on charge q_1 due to the other two charges.

b) What is the magnitude **and** direction of the net electrostatic force acting on charge q_1?

(LO: 1.1)

2 A –3 µC charge lies on the straight line between a 2 µC charge and a 4 µC charge. The separation between the 2 µC and 4 µC is 0.06 m. By sketching the electric force diagram, calculate the distance of the 2 µC charge from –3 µC charge where net force acting on –3µC charge is zero.

(LO: 1.2)

3 Two equal positive point charges $q_1 = q_2$ = 2.0 µC are located at x = 0, y = 0.3 m and x = 0, y = −0.3 m respectively. What is the magnitude **and** direction of the total electric force that these charges exert on a third positive point charge Q = 4.0 µC at x = 0.4 m, y = 0?

(LO: 1.2)

4 (a) When a test charge q = 2 nC is placed at the origin, it experiences a force of 8.0 10^{-4} N. Calculate the magnitude of electric field strength at the origin.

(b) Two point charges of +2 µC and -5.0 µC are separated by a distance of 6.0 cm. Find the electric field strength at the midpoint between the charges.

(LO: 1.2)

5 **FIGURE 1.2** shows four charges, q_1, q_2, q_3, and q_4, each of magnitude 4 µC are placed at the respective corners of a square with sides 20 cm.

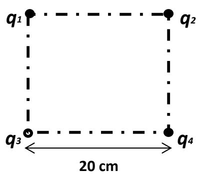


FIGURE 1.2

(a) Sketch the electric field strength diagram at the center of the square.

(b) Find the magnitude of electric field strength at the center of the square

(c) Calculate the electric force acting on another charge of magnitude – 4 µC placed at the center of the square

(LO: 1.2)

6 Sketch the equipotential lines and surfaces of

(a) an isolated positive charge.

(b) a uniform electric field.

State the shape of the surfaces.

(LO: 1.2)

7 **FIGURE 1.3** shows two points A and B at a distance of 0.4 m and 0.3 m respectively from a point charge Q of 5.0 µC. Determine the

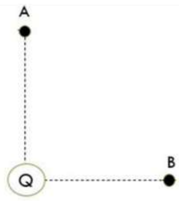


FIGURE 1.3

a) electric potential at point A and B

b) the potential difference between point B and A.

c) the work done to bring a proton from point A to B.

(LO: 1.3)

8 Two point charges each of 2 µC are located at coordinates (0.1,0) m and (-0.1, 0) m respectively. Calculate the

a) electric potential at coordinate (0, 0.5) m

b) change in electric potential energy of the system if a third charge of magnitude 3 µC is brought from infinity to coordinate (0, 0.5) m

(LO: 1.3)

9 Three point charges of $+q$, $+2q$ and $-3q$ are arranged as shown in **FIGURE 1.4.** Calculate the electric potential energy of the system of three charges if q = 3 µC and a = 4 cm.

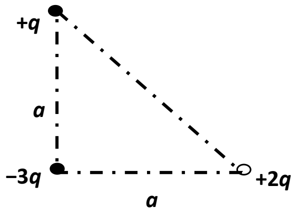


FIGURE 1.4

(LO: 1.3)

10 a) A small ball with mass 25 g has a total charge of +20 µC is placed between two parallel charged plates.

i. In static equilibrium, determine the magnitude of the electric field in the plates.

ii. Calculate the acceleration of the ball if it moves horizontally parallel with electric field.

b) **FIGURE 1.5** shows a section of the deflection system of a cathode ray oscilloscope. An electron travelling at a certain speed enters the space between two parallel metal plates with distance 20 mm. The electric field between the plates is 4.0×10^{3} V m^{-1}.

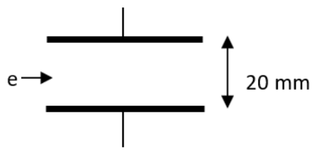


FIGURE 1.5

i. Copy the **FIGURE 1.5** and sketch the path of the electron in between the plates and after emerging from the space between the plates.

ii. Calculate the acceleration of the electron.

iii. Find the electric potential difference between the plates.

c) **FIGURE 1.6** shows a uniform electric field 395 V m^{-1} exists in a region between two oppositely charged plates. An electron is released from rest at the surface of the negatively charged plate and strikes the surface of the opposite plate, 2.0 cm away. Calculate the

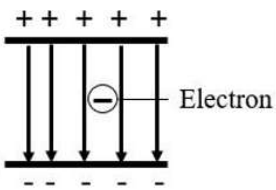


FIGURE 1.6

(i) acceleration of the electron.
(ii) potential difference between the plates.
(iii) work done by the electric field.

(LO: 1.4)

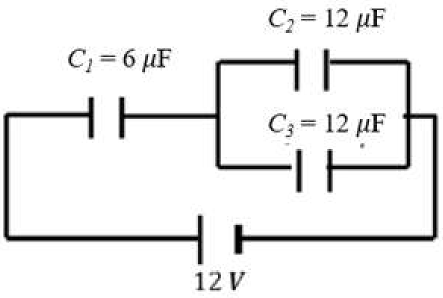
<u>Answer</u>

1	(a) Refer to lecturer (b) 5.7 N to the right
2	0.025 m
3	0.46 N to the right
4	(a) 4.0 x 10^5 N C^{-1} (b) 7.0 x 10^7 N C^{-1}
5	(a) Refer to lecturer (b) 0 N C^{-1} (c) 0 N
6	Refer to lecturer
7	(a) 1.125 x 10^5 V, 1.5 x 10^5 V (b) 3.75 x 10^4 V (c) 6 x 10^{-15} J
8	(a) 7.06 x 10^4 V (b) 0.212 J
9	15.37 J
10	(a) (i) $1.23\times10^4 NC^{-1}$ (ii) $9.8 ms^{-2}$ (b) (i) You Think? (ii) 7.03 x 10^{14} m s^{-2} (iii) 80 V (c) (i) $6.94\times10^{13} ms^{-2}$ (ii) 7.9V (iii) 1.264×10^{-18}J

Chapter 2: Capacitors (jl)

LO: 2.1abc

1



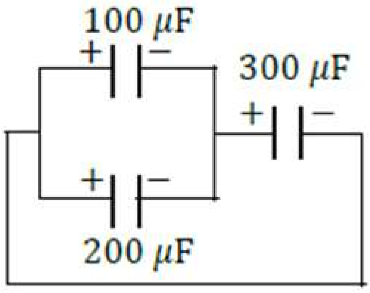
The figure shows an arrangement of three capacitors, C_1, C_2, and C_3. Calculate

a. total charge of these capacitors.

b. potential difference across capacitor C_1, C_2, and C_3.

2

Three isolated capacitors 100 μF, 200 μF and 300 μF have potential differences between plates 4.0 V, 6.0 V and 8.0 V respectively. Initially, the terminals of capacitors are connected as shown in the diagram below.



(a) Determine the total capacitance across the capacitors.

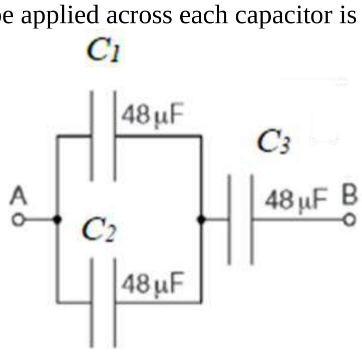
(b) Calculate the total energy stored by the three capacitors after being connected.

3

Two capacitors C_1 and C_2 of capacitance 2.0 μF and 3. μF are connected in series to a 100 V source. What is the ratio of the energy stored in C_1 to that in C_2?

4

Three capacitors, each of capacitance 48 μF, are connected as shown in figure 9. The maximum safe potential difference that can be applied across each capacitor is 6.0 V.



i. Calculate the effective capacitance across AB.

ii. Calculate the maximum voltage across AB.

iii. Determine the charges in each capacitor at maximum voltage.

LO: 2.2ac

5

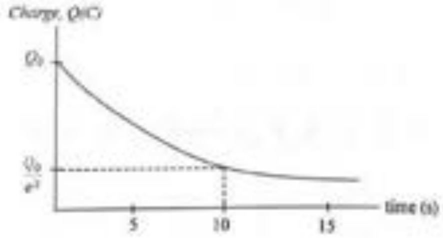


FIGURE shows the variation of current in a circuit with the time during discharging process of a capacitor through a resistor of 2 MΩ. Determine

i. the capacitance of the capacitor

ii. the time constant

iii. the time taken for the current to decrease to half of its maximum value.

6

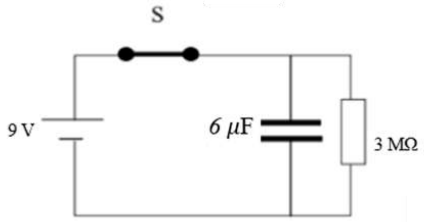


FIGURE 3 shows a circuit consisting of a switch S, 3MΩ resistor, 9V battery and a fully charged 6μF capacitor. If the switch is opened, calculate the remaining charge in the capacitor after 6s.

7

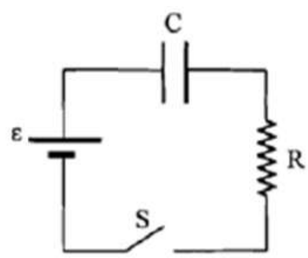


FIGURE 3

FIGURE 3 shows an RC circuit with an emf source ε and a switch S. If the capacitance and resistance is 150 μF and 25 kΩ respectively, calculate the time taken for the charge to reach 60% of its maximum value.

8

A 150 μF capacitor is fully charged by a 12 V battery and is then discharged. What is the charge stored in the capacitor after two time constants of the circuit have passed since discharging began?

9

A 2V battery is connected to a 2 μF capacitor and a 40 Ω resistor. Calculate the charge in the capacitor at time t = 90 μs.

LO: 2.3acd

10

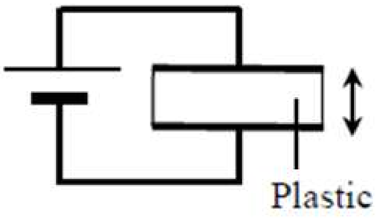


FIGURE 2

A parallel-plate capacitor filled with plastic is charged by 6.0 V battery as shown in FIGURE 2. The area of one plate is 150 cm^2. The thickness and dielectric constant of the plastic layer is 0.8 mm and 3.2 respectively. Calculate the energy stored in the capacitor.

11

A dielectric is inserted into an air-filled parallel plate capacitor of capacitance 1500 pF so that $\frac{1}{3}$ of the space between the plates is filled as shown in Figure 1.

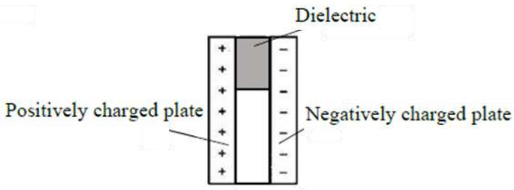


Figure 1

If the dielectric constant is 7.0, what is the new capacitance of the capacitor?

12

A parallel plate air-filled capacitor whose capacitance, C is 400 pF is charged by a battery to a potential difference of 12 V between the two plates. Then the fully charged capacitor is disconnected and a porcelain slab with dielectric constant 3.2 is inserted between the plates. Calculate

i) the capacitance of the capacitor after the slab is inserted.
ii) the energy stored in the capacitor after the slab is inserted.
iii) What happens to the potential difference if after the dielectric is inserted between the plates

13

An empty capacitor has an area of 6.00 cm^2 plates that is separated by 4.00 mm. Dielectric material insert in between the parallel plate and the capacitance increase to 5.31 pF. What is the dielectric constant?

14

Calculate the capacitance of a capacitor consisting of two parallel plates separated by a layer of paraffin wax 1.5 cm thick, the area of each plate being 60 cm^2. The dielectric constant for the wax is 2.

Answer:

1	(i) 57.6 μC (ii) V_1=9.6 V, V_2=2.4 V, V_3=2.4 V
2	(a) 150 μF (b) 2.13 x 10^{-3} J
3	3:2
4	(i) 32 μF (ii) 9 V (iii) Q_1= Q_2=140 μC, Q_3=290 μC
5	(i) 2.5 μF (ii) 5 s (iii) 3.4657 s
6	38.69 μC
7	3.436 s
8	2.44 x 10^{-4} C
9	3.24 x 10^{-5} C
10	9.558 x 10^{-9} J
11	4500 pF
12	(i) 1280 pF ii) 2.88 x 10^{-8} J (iii)decrease
13	4
14	7.08 x 10^{-12} F

Chapter 3: Electric Current and Direct Current Circuits (jl)

LO: 3.1b, 3.1c		LO: 3.2a, 3.2b	
1	A bulb drawn 0.5 A current from a 3 V battery in 7.5 minutes. Calculate the charge that flows in the circuit.	3	A potential difference of 3.0 V is applied across a tungsten wire of length 1.5 m with cross sectional area of 0.05 mm^2 . Calculate the current flow in the wire. *(Given the resistivity of tungsten is* 5.7×10^{-8} Ω m*)*
2	In 4500 ms, a charge of 6000 μC passes each point of a wire. Calculate i the current. ii the number of electrons flow through the point.	4	Two wires made of the same material have the same length but different diameters. The first wire has twice the diameter of the second wire. Compare the resistances of the two wires.
		5	A copper wire has a length of 5.0 m and a cross-sectional area of 1.0×10^{-6} m^2. The resistivity of copper is 1.68×10^{-8} Ω m (a) Calculate the resistance of the wire. (b) If the wire is connected to a 12 V battery, determine the current flowing through it.

LO: 3.3b

6	The resistance of the tungsten filament of a bulb at 30 ℃ is 2.5 Ω. Given the temperature coefficient of resistance of tungsten is 4.6×10^{-3} K^{-1}, what is the operating temperature of the bulb if the current in the filament is 1.6 A and the voltage is 6V?	8	A 12 V emf battery with a internal resistance of 2.0 Ω is connected to a 8 Ω resistor. Calculate the voltage across the battery terminal.
7	A wire of cross-sectional area 0.4 mm^2 is connected to a variable voltage, ***V*** and the current, ***I*** in the wire is measured. At 27 ºC, the resistance of the wire is 0.25 Ω and the resistivity is 4.5 x 10^{-8} Ω m. Calculate the (i) length of the wire. (ii) **change in the resistance** of the wire when it is heated to 80 ºC. The temperature coefficient of resistivity of the wire is 3.9 × 10^{-3} $ºC^{-1}$.	9	A battery of internal resistance 0.5 Ω has a terminal voltage of 9.0 V **when no current flows**. A 15.0 Ω resistor is connected across the battery terminals. Calculate the i) emf of the battery ii) current through the 10.0 Ω resistor iii) new terminal voltage

LO: 3.4d

10

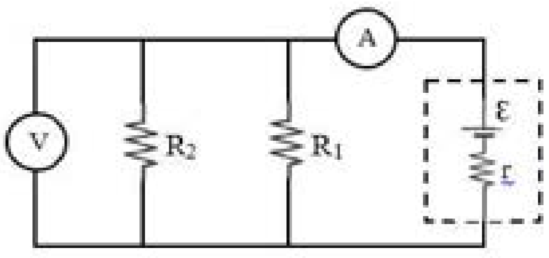


FIGURE 2

The circuit in **FIGURE 2** shows a battery emf,= 10 V with unknown internal resistance, *r* that is connected to a circuit includes resistor R_1 = 10 Ω and R_2 = 15 Ω. The reading on the ideal voltmeter is 9 V.

i What is the terminal voltage?
ii What is the reading of ammeter?
iii Determine the internal resistance, r.

LO: 3.5a

11 **Series Combination**

Three resistors of 5 Ω, 10 Ω, and 15 Ω are connected in series.

a) Calculate the total resistance of the combination.

b) If a 12 V battery is connected across this series combination, calculate the total current.

12 **Parallel Combination**

Two resistors, 6 Ω and 12 Ω, are connected in parallel.

a) Determine the effective resistance of the combination.

b) If the total current from the power supply is 4 A, find the current through each resistor.

13 **Combination of Series and Parallel**

A 12 Ω resistor is connected in series with a combination of two parallel resistors, 8 Ω and 16 Ω.

a) Calculate the equivalent resistance of the entire circuit.

b) If the circuit is connected to a 24 V battery, find the total current supplied by the battery.

14 **Circuit with a Switch**

Three resistors of 2 Ω, 4 Ω, and 6 Ω are connected in a circuit. The 2 Ω and 4 Ω resistors are in parallel, and their combination is in series with the 6 Ω resistor.

a) Calculate the total resistance of the circuit.

b) If a switch is added to bypass the 6 Ω resistor, what will be the new total resistance when the switch is closed?

15

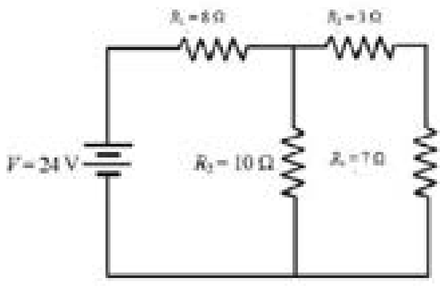


FIGURE 3.1

FIGURE 3.1 shows a circuit with a 24 V battery connected to four resistors of resistance, R_1 = 8 Ω, R_2 =10 Ω, R_3 = 3 Ω and R_4 = 7 Ω. Calculate the

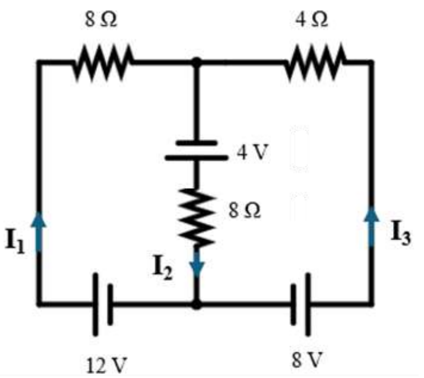
(i) effective resistance.

(ii) potential difference across the resistor R_1.

(iii) power dissipated in the resistor R_1.

LO: 3.6a

16



The circuit diagram shows a circuit containing batteries and resistors. You may assume that the batteries have negligible internal resistance. Calculate the current I_1, I_2, and I_3

17

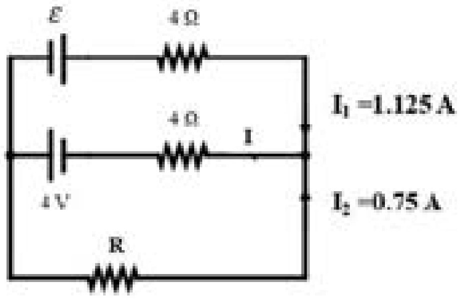


FIGURE shows an electrical circuit of three resistors and two batteries. Calculate

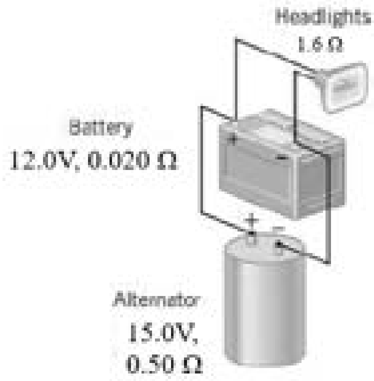
(i) Current, *I*

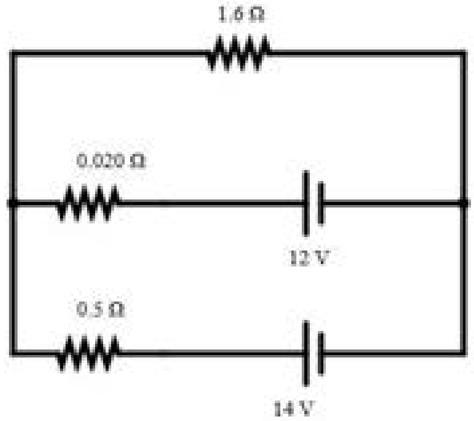
(ii) emf, *ε*

(iii) resistance, *R*

LO: 3.6a

18 In a car, the headlights are connected to the battery and would discharge the battery if it were not for the alternator, which is run by the engine. Diagram below indicates how the car battery, headlights and alternator are connected.





The circuit includes an internal resistance of 0.020 Ω for the car battery and a resistance of 1.60 Ω for the headlights. For the sake of simplicity, the alternator is approximated as an additional 14.00 V battery with an internal resistance of 0.500 Ω. Determine the currents through the car battery, I_B, the headlights, I_H, and the alternator, I_A.

LO: 3.7ab

No.	Question
19	A kettle with a power rating of 1500 W is used for 15 minutes to boil water. How much electrical energy is consumed by the kettle?
20	An electric motor uses a current of 10 A when connected to a 240 V supply. What is the power used by the motor?
21	A toaster uses 1000 W of power. How much time will it take to consume 1.8 kWh of electrical energy?

LO: 3.8b

22

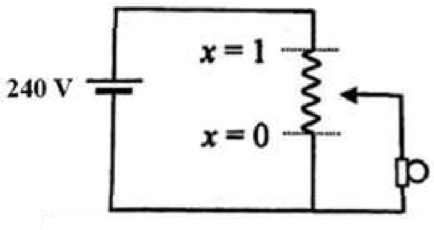


FIGURE 5

FIGURE 5 shows a light bulb dimmer consisting of a 150 Ω variable resistor, 240 V voltage source and a light bulb. The slider moves between x = 0 to x = 1.2. If it is at x = 0.4, calculate the voltage of the bulb.

23

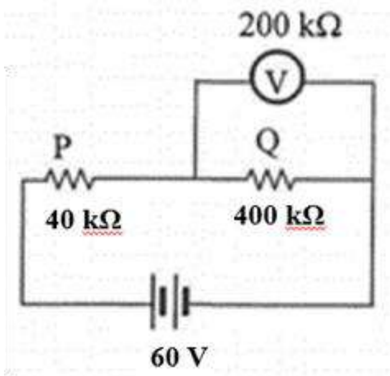
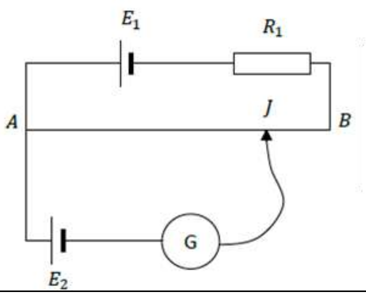


FIGURE shows a voltmeter with resistance 200 kΩ connected across a resistor Q. Determine the voltmeter reading.

LO: 3.9b

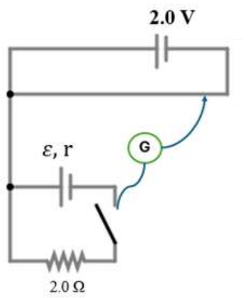
24



A battery with unknown e.m.f E_2 is connected to a potentiometer as shown in the diagram below.
The driver cell E_1 has an e.m.f of 6.0 V and negligible internal resistance. The length of sliding wire *AB* is 100.0 cm with a resistance of 10.0 Ω. The resistor R_1 has a resistance of 20.0 Ω. The reading of galvanometer is zero when the length of *AJ* is 68.0 cm. Determine the e.m.f E_2.

25

Diagram below shows a 2.0 V potentiometer with a slide wire AB of length 100 cm is used for the determination of e.m.f and internal resistance of a cell. When the switch *S* is opened, the balance length of the cell is 60.0 cm. When the switch is closed, the balance length shifts to 40.0 cm of the potentiometer. Determine the e.m.f and internal resistance of the cell.



26

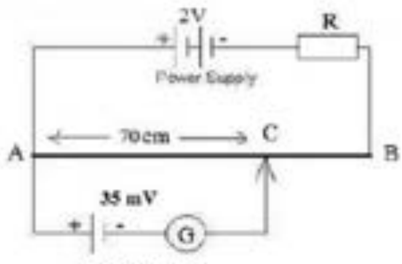


FIGURE 3

FIGURE 3 shows a potentiometer used to determine the emf of a cell. The sliding wire is 100 cm long and has resistance of 10 Ω. The internal resistance for power supply and the cell is negligible. AC is 70 cm long at equilibrium.
Calculate
i the voltage in sliding wire AB.
ii the value of current across resistor R.
iii the value of R

27

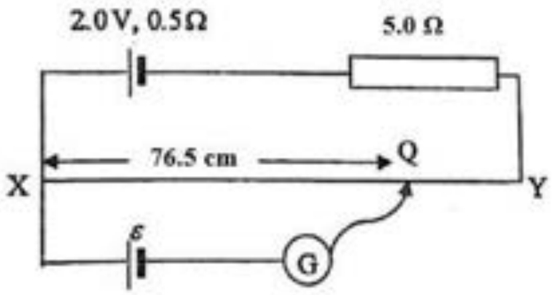
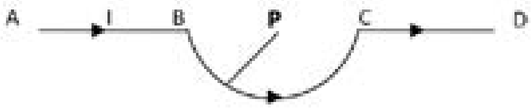
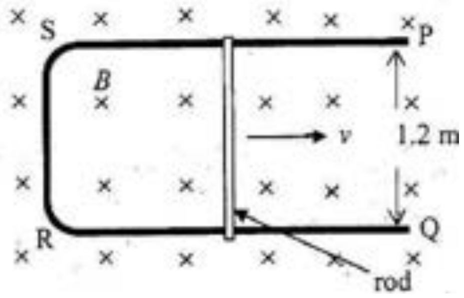
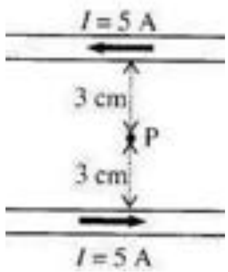


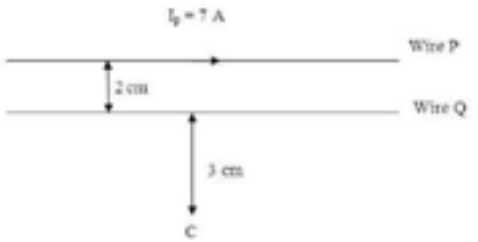
FIGURE shows a potential divider consisting of a wire XY of length 1.0 m and resistance 4.5 Ω. A cell of emf 2.0 V with internal resistance 0.5 Ω is connected in series with a 5.0 Ω resistor. When another cell with emf ε is connected to potential divider the balance length XQ is 76.2 cm. Calculate ε.
[2marks]

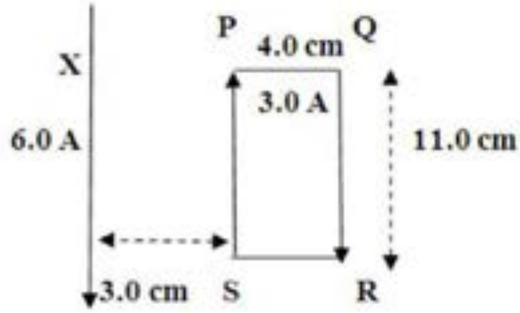
Answer:

1	225 C	15	(i) 13 Ω (ii) 14.77 V (iii) 27.27 W
2	(i) 1.33×10^{-3} A (ii) 3.75×10^{16} electrons	16	I_1 = 0.750 A , I_2= 1.25 A, and I_3= 0.500 A
3	1.754 A	17	(i) 1.875 A (ii) 3 V (iii) 2 Ω
4	$R_2 = 4R_1$	18	I_B =3.325 A I_H =7.458 A and I_A=4.133 A
5	(a) 0.084Ω (b) I≈142.9A	19	1.35MJ
6	138.7 °C	20	2.4kW
7	(i) 2.22 m (ii) 0.051675 Ω	21	1.8hours
8	9.6 V	22	80 V
9	(i) 9.0 V (ii) 0.45 A (iii) 6.75 V	23	46.16 V
10	(i) 9 V (ii) 1.5 A (iii) 0.667 Ω	24	1.36 V
11	(a) 30Ω (b) 0.4A	25	1.2 V, 1 Ω
12	(a) 4Ω (b) 2.67A	26	(i) 50 mV (ii) 5 mA (iii) 390 Ω
13	(a) 17.33Ω (b) 1.38A	27	0.6885 V
14	(a) 7.33Ω (b) 1.33Ω		

Chapter 4: Magnetic Field (as)

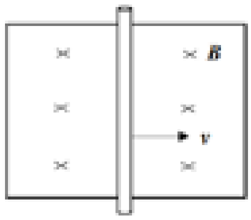
No	Question
1	 Determine the magnitude and direction of the magnetic field at point P due to current, 1.0A flowing in a semi-circle wire with radius, R = 2 cm as shown in **FIGURE** above. **(LO:4.2)**
2	(a) Explain why a charged particle is moving in a circular path in a uniform magnetic field. (b) A particle of charge 3.2×10^{-19} C and velocity of 2×10^{5} ms^{-1} enters a uniform magnetic field of magnetic field strength, 0.2 T. If the particle moves in a circular path of radius 4.0 cm, calculate the mass of the charged particle. **(LO:4.3)**
3	a) Write the expression for the force acting on an electron carrying a charge ***e*** moving with velocity *v* when it enters perpendicularly into i. an electric field of intensity ***E*** ii. a magnetic field of intensity ***B***. b) Sketch two separate diagrams of the direction of field, velocity and path of the electron and the force acting on it for the motion in part (a) (i) and (ii). c) With reference to your diagrams, state two differences between the electric field and magnetic field. d) A helium ion of charge +2e and mass 6.6×10^{-27} kg is accelerated by a voltage of 2400V. The accelerated ion then moves into a perpendicular uniform magnetic field of magnitude 0.24 T. Determine i. the radius of the circular path of the helium ion. ii. the period of revolution of the helium ion. [Given charge of electron = 1.60×10^{-19} C] **(LO:4.3)**
4	 A 1.2 m conducting rod rests on metal rails SP and RQ as shown in FIGURE 8. The rod is placed in a uniform magnetic field B=2.5 T perpendicular to the plane of the paper. The rod is pulled to the right at a uniform velocity v=2 m s^{-1}. If the resistance of the circuit PQRS is 6 Ω, determine a) the induced current in the rod. b) the magnitude and direction of the force required to keep the rod moving to the right at constant velocity 2 m s^{-1}. **(LO: 4.4)**
5	 A copper rod of mass 0.08 kg and length 0.20 m is attached to two thin current carrying wires, as shown in **the figure**. The rod is perpendicular to a uniform magnetic field of 0.60T. Determine the magnitude and direction of the electric current to keep the copper rod fixed and stay horizontal. **(LO: 4.4)**
6	 The figure shows two long parallel wires, each carrying a 5 A current in opposite direction. Determine the magnetic field, at point P, 3 cm from both wires. **(LO: 4.5)**

7	 **FIGURE** above shows two parallel wires 2 cm apart. Wire P carries a current 7 A to the right. Point C is 3 cm from wire Q and in the same plane as wire P and Q. Determine the magnitude and direction of current in wire Q so that the magnetic field at C is zero. **(LO: 4.5)**
	(a) Write an expression for the force between two parallel conductors. Explain the physical quantities that you have used. (b) State two differences between the force due to an electric field and the force due to a magnetic field on a charged particle.

	 (c) The **FIGURE** above shows a long straight conductor, X, carrying a current of 6.0A. A rectangular metal frame PQRS is suspended with PS 3.0 cm from X. The sides of PQ and QR are 4.0 cm and 11.0 cm respectively, and a current of 3.0 A flows in the rectangular coil as indicated. The conductor X and the metal frame PQRS are in the same plane. Calculate (i) the force on the wire PS, (ii) the force on the wire QR. Hence, calculate the resultant force on PQRS and determine its direction. **(LO: 4.5)**

Answer:

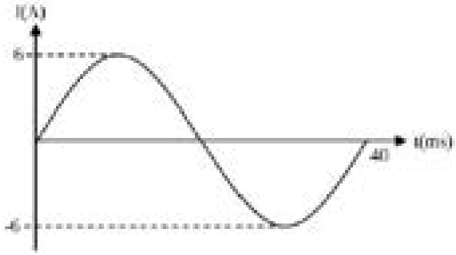
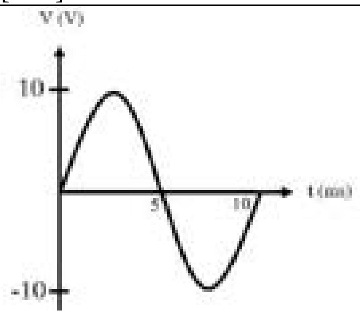
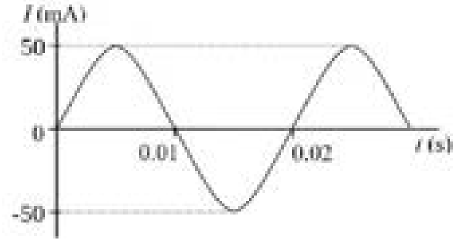
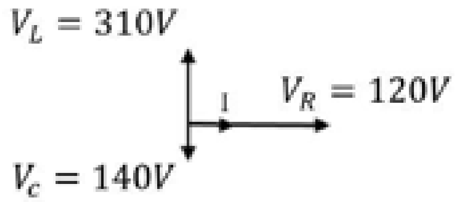
No	Answer:
1	$\mathbf{1.5 \times 10^{-5}\ T}$, out of the plane paper
2	(b) $1.28\text{x}10^{-26}$ kg
3	(d) $4.14\text{x}10^{-2}$ m, $5.39\text{x}10^{-7}$ s
4	(a) I= 1A, (b) F = 3 N (to the right)
5	$\mathbf{6.54}\boldsymbol{A}$ to the right
6	6.66 x 10^{-5} T (out of page)
7	$\mathbf{4.2}\ \boldsymbol{A}$ to the left
8	(c) 1.32×10^{-5} N, 0.5657×10^{-5} N, 7.54×10^{-6} N to the right

1	A circular coil of 80 turns with a plane area of $8 \times 10^{-3} m^2$ is placed in a region of 0.2T magnetic field. Calculate the magnetic flux linkage through the coil when the plane of the coil makes an angle of 30^o to the magnetic field. [LO 5.1]	5	A coil of 200 turns is placed perpendicularly in a magnetic field region of 5T. The cross-sectional area of the coil if $0.4cm^2$.The magnetic field is the reduced to 3.5T after 3s. Determine the induced emf in the coil and the induced current if resistance is 20Ω. [LO 5.2d]
2	Find the maximum induced emf if a 50-turn circular coil of plane $8 \times 10^{-3} m^2$ is rotated about an axis of rotation perpendicular to the uniform magnetic field at $10 revs^{-1}$. [LO 5.2d]	6	 A wire of 0.4m length moves to the right with a uniform velocity of 0.25m/s, as shown in the figure. If the resistance of the wire is 5Ω and the magnetic field strength is 4T, calculate the induced emf and current in the wire. [LO 5.2d]
3	A and B are two adjacent coaxial coils and has 1000 and 5000 turns respectively. If each turn in coil B has a flux of 0.035mWb due to a 2A current in coil A, determine the mutual inductance of the coils. [LO 5.5b]	7	A solenoid has a length of 8cm and cross sectional area of $6 \times 10^{-2} m^2$. The solenoid has a turn density of 1300 per meter. Determine the self inductance of the solenoid. [LO 5.3b]
4	Each turn of a coil produces a magnetic flux of 0.045mWb when a current of 3A flows through it. Determine the self-inductance of this coil and the energy stored in it. [5.3b]	8	An inductor coil of 4 turns and 15mm in diameter, carries a 6A current. Calculate the inductance of the coil, the energy stored in the inductor and the induced emf if current drops to 3A in $15\mu s$. [LO 5.9d, 5.3b, 5.4a]

Answers:

1	0.064Wb	5	4mV; 0.2mA
2	5.03V	6	0.4V; 0.08A upwards
3	0.087H	7	0.496H
4	0.015H; 0.0675J	8	$2.63\times 10^{-8} H$, $4.67\times 10^{-6} J$, 5.26mV

Chapter 6: AC Circuits (sr)

1	An AC circuit contains 12Ω resistor, a $3mF$ capacitor, and a $0.33H$ inductor connected in series to an AC power supply with 75V and frequency 2.2Hz. Calculate the rms current, rms voltage across the capacitor and power factor with phase angle. Sketch a labelled phasor diagram for the supply voltage and current. [6.2b, 6.3a, 6.4aiii)]
2	An AC generator with a frequency of 40Hz and a voltage of 120V is connected to an RLC series circuit with a 20 Ω resistor, a 0.45H inductor, and a 1.4 mF capacitor. Calculate the impedance in the circuit, average power dissipated and value of current when the circuit is at resonance. [6.3c, 6.3d, 6.4ai]
3	An unknown resistor and an inductor are connected in series to an AC generator with rms voltage of 12V. The inductive reactance and impedance in the circuit are 36 Ω and 95 Ω, respectively. Determine the resistance of the unknown resistor. Calculate the phase angle. [6.3c]
4	 The figure shows a graph of current against time of an AC generator. Calculate the rms current value and frequency of the source. [25Hz] [6.3b]
5	A series RLC circuit is connected to an AC supply of 220V, 50 Hz. If given R = 360Ω, L = 1.8H and C = 3.2μF, calculate the inductive and capacitive reactance, impedance, phase angle and the power factor. [6.3c]
6	 The figure shows a graph of voltage against time of an AC circuit. Determine the frequency and the root mean square voltage. [6.2b]
7	 FIGURE 5 shows a graph of current against time of an AC generator. Determine the peak current, the frequency and the alternating current equation. [6.2b]
8	An AC source of peak voltage 120 V and frequency 60.0 Hz is connected in series to an 880Ω resistor, 2.36H inductor and 15μF capacitor. Calculate the impedance of the circuit, the phase angle of the circuit, the power factor of the circuit [0.777] [6c; 6d]
9	 The figure shows the values of root means square voltage across the resistor R, inductor, L and capacitor, C. Calculate the source voltage and phase angle of the source voltage with respect to the current. Does the source voltage lag or lead the current? Determine power factor of the circuit. [6c; 6d]
10	A sinusoidal voltage $V(t)$ = 20 sin($55\pi t$) is applied to a series RLC circuit with R = 670Ω, L = 245 mH and C = 50μF. Calculate the impedance of the circuit and phase angle of the circuit [-6.2^o] [6c; 6d]

Chapter 7: Optics (mgy)

1 The radius of curvature of a convex mirror is 20 cm. A virtual image formed 6 cm away from the mirror.

i) Calculate the focal length of the mirror.
ii) Calculate the object distance.
iii) Calculate the height of the image if the height of the object is 10 cm.
iv) State three characteristics of the image formed.

(LO: 7.1)

2 An object is placed at -18 cm in front of a mirror, an upright image is twice the size of the object is formed. Calculate the radius of curvature of the mirror.

(LO: 7.1)

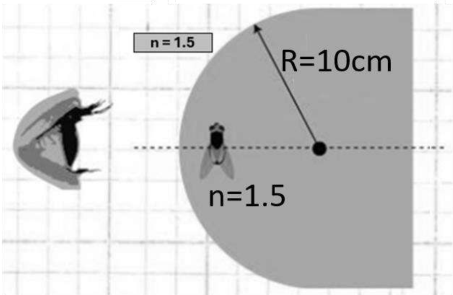
3 A spherical mirror has a focal length of 6.0 cm. Determine the distance at which you hold the mirror from your face in order to see your upright image with a magnification of 5.

4 A convex mirror of focal length 9.0 cm produces a virtual image, 4.0 cm from the mirror.

i) Sketch a labelled ray diagram to show the formation of the image.
ii) Calculate the object distance

(LO: 7.1)

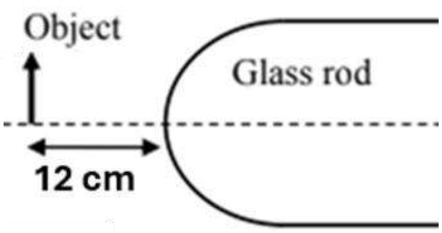
5



Refer to **FIGURE 1**, a fly is in a ball of amber with a radius of curvature of 10 cm. The amber has an index of refraction of n = 1.5. To an observer outside the amber, the fly appears to be located 3 cm from the surface. Where is fly actually located?

(LO: 7.2)

6 An object is placed 5 cm from a glass rod with hemispherical tip as shown in **FIGURE 2**. If the radius of curvature and refractive index of glass rod is 12 cm and 1.49 respectively, calculate the image distance.

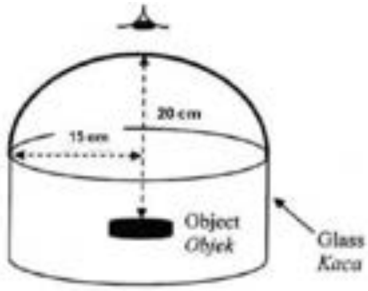


(LO: 7.2)

7 A point object is placed at the centre of a glass sphere of radius 2 cm and refractive index of 1.5. Calculate the image distance of the point object.

(LO: 7.2)

8 **FIGURE 3** shows an object embedded in a solid glass with a hemispherical end of radius 15 cm and refractive index 1.49. The object is 20 cm inside the glass. Calculate the image distance. Refractive index of air is 1.0.



(LO: 7.2)

9 A toy is placed 25.0 cm in front of a converging (convex) lens with a focal length of 16.0 cm.

i) Sketch a ray diagram to show the formation of an image
ii) Determine the image distance
iii) Determine the magnification of the image
iv) State two characteristics of the image

(LO: 7.2)

10 A biconvex lens made from glass with refractive index 1.47 has a focal length of 9 cm in air. Given the refractive index of air is 1.00. Calculate the focal length of the lens when it is submerged in a liquid with refractive index 1.35.

(LO: 7.3)

11 An object is placed at 11.0 cm from a thin biconcave lens with radius of curvature 35.0 cm. The refractive index of the lens is 1.89. Determine the focal length of the lens.

(LO: 7.3)

12 The convex meniscus lens has a 12.5 cm radius for convex surface and 20.0 cm for the concave surface. The lens is made of glass with a refractive index, n=1.42 in air. Refractive index of air is 1.0. Determine the focal length of the lens.

(LO: 7.3)

13 An apple is placed in front of a thin lens. The distance between the apple and the lens is 15 cm. The index of refraction of the lens, n =1.40, radius of the nearer lens surface is -20 cm, and the radius of the farther lens surface is +16 cm. Determine

i) the focal length of the lens.
ii) the image distance.
iii) the magnification of the apple.

(LO: 7.3)

14

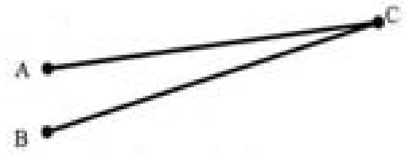


FIGURE 4 shows two paths of in phase coherent lights from points A and B that produce an interference pattern at point C. Determine whether it is a constructive or destructive interference if AC and BC are 4.2λ and 6.7λ.
(LO: 7.3)

15 In a Young's Double slit experiment, the slit separation is 0.05 cm and the distance of the double slit from the screen is 200 cm. When a green light is used, the distance of the first bright fringe from the central maximum is 0.4 cm.

i) Calculate the wavelength of the green light.
ii) Calculate the distance of the third dark fringes from the central maximum.
iii) Explain the changes to the interference pattern if the screen is moved further from the slits.

(LO: 7.6)

16 In a Young's Double Slit experiment, the distance measured between the central bright maximum and the fifth dark fringe is 5.0 cm. The slits are separated by a distance of 0.175 mm. The distance between the slits and the screen is 3.5 m. Calculate

i) the wavelength of light.
ii) the fringe separation.

(LO: 7.6)

17 A 550 nm monochromatic light is incident on a thin film (n=1.40).Calculate the minimum thickness of the film which produce destructive interference of the reflected light in the following condition:

i) the film in air.
ii) the film is a coating on a glass of reflective index 1.60.

(LO: 7.7)

18 An gasoline film (n=1.40) floats on the water puddle (n=1.33) You notice that green light with wavelength 623 nm is absent in the reflection. What is the minimum thickness of the gasoline film.
(LO: 7.7)

19 A monochromatic light of wavelength 520 nm is incident on a slit 0.3 mm wide. A diffraction pattern is produced on a screen placed at a distance of 3.5 m from the slit. What is the distance between consecutive dark fringes on both sides of the central bright fringe?
(LO: 7.8)

20 A single-slit diffraction pattern is obtained on a screen placed at a distance of 15 cm from the slit of width 7 μm. The wavelength of the monochromatic light used is $6.6 \times 10^{-7}\ m$

i) Calculate the angular separation between the first and second minima.
ii) What is the width of the central bright fringe?
iii) How many dark fringes are found on the screen?

(LO: 7.8)

21 A monochromatic green light is diffracted by a slit of width 0.65 mm. The diffraction pattern forms on a screen 2.5 m away from the slit. The width of central bright fringe is 3.7 mm. Calculate the distance between the central bright fringe and the 3rd dark fringe.
(LO: 7.8)

22 A diffraction grating has 6000 $lines\ cm^{-1}$. A monochromatic light with wavelength of 769 nm is incident on the grating. A screen is placed 2.00 m away from the grating. Determine the number of bright fringes can be observed on a screen.
(LO: 7.9)

Answer

1	10m, 15 cm, 4cm, Virtual, Upright, Diminished	12	65.19 cm
2	-72 cm	13	22.22 m, -8.95 cm, 0.597
3	4.8 cm	14	Destructive interference
4	7.2 cm	15	$1 \times 10^{-6}\ m$; 0.01 m Fringe separation Δy increases and the maximum intensity of the bright fringes decreases.
5	5.29 cm	16	$5.56 \times 10^{-7}\ m$; $1.11 \times 10^{-2}\ m$
6	-9.36 cm	17	196 nm; 98.21 nm
7	-2 cm	18	$2.23 \times 10^{-7}\ m$
8	-23.9 cm	19	$1.21 \times 10^{-2}\ m$
9	44.44 m; -1.78	20	5.47°; $2.83 \times 10^{-2}\ m$; 20
10	47.59 cm	21	$5.55 \times 10^{-3}\ m$
11	-19.66 cm	22	5

Chapter 8: Matter Waves (sr)

1	A beam of electrons is accelerated through a potential difference of 6500 V in an electron microscope. Calculate the speed of the electrons and their de Broglie wavelength.	6	What is the wavelength of a photon that has the same momentum as an electron moving with a speed of $1500ms^{-1}$?
2	The speed of an electron is $2.8(10^{6})ms^{-1}$. Calculate the momentum and the de Broglie wavelength of the electron.	7	An electron has energy of $400eV$. Calculate the de Broglie wavelength associated with the electron.
3	Given that the de Broglie wavelength of a photon is 900nm, determine the momentum of the photon.	8	An electron and a proton are accelerated through the same voltage. If the de Broglie wavelength of the electron is 0.15nm, what is the de Broglie wavelength of the proton?
4	Calculate the de Broglie wavelength for a 7.5g bullet moving at a speed of $400ms^{-1}$.	9	The de Broglie wavelength of an electron is 1nm, determine its kinetic energy.
5	An electron is accelerated in vacuum through a potential difference of 1kV. If the potential difference is tripled, calculate the ratio of the electron's new speed to its original speed and the new wavelength of the electron.		

Chapter 9: Mass defect, Binding Energy & Radioactivity (sr)

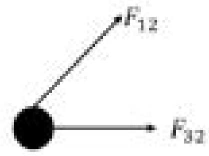
Binding Energy		Radioactivity	
1	Determine the mass defect and the binding energy of Bromine nucleus, ${}^{81}_{35}Br$ in Joule (J), given that the mass of bromine nucleus is 80.916291u.	1	A 2.5g sample of radioactive element has a half-life of 82hours and has a molar mass of $65gmol^{-1}$. Calculate the decay constant and the number of atoms remained in the sample after 30hours.
2	The binding energy of an aluminium nucleus (${}^{27}_{13}Al$) is 224.93MeV. Calculate the mass of its nucleus in atomic mass unit.	2	The half-life of an isotope is 90minutes, determine how long it will take for 75% of the nuclei of the isotope to decay from its initial activity.
3	The mass of ${}^{56}_{26}Fe$ nucleus is 55.9349u. Calculate the binding energy per nucleon in MeV per nucleon.	3	Suppose a ${}^{51}_{24}Cr$ sample has an activity of 6.74×10^{9} decay per days. If the sample has a half-life of 28 days, determine the number of nuclei the sample initially contains and the sample activity in Bq after 1 year.
4	Given that the mass of $B - 11$ nucleus is 11.009305u and has 5 protons, calculate the binding energy per nucleon in MeV per nucleon.	4	${}^{199}_{78}Pt$ has a half-life of 30.8 min and an activity of $9 \times 10^{15}Bq$. Calculate the mass of the sample.
5	The nuclear mass of Radon (${}^{226}_{88}Rn$) is 226.025403u. Determine the mass defect in kilograms for Radon.	5	A sample of a radioactive source has 3×10^{23} atoms. If the half-life of the sample nuclei is $1.5 \times 10^{19}s$, determine the initial activity of the sample in Bq and the number of the sample atoms remaining after $3.2 \times 10^{17}s$.
		6	A 10^{-6}g radioactive sample has a nucleon number of 239 and an activity of 3000 particles per second, determine the decay constant and the time required for the activity of the source to decay to 20decay per second.

Answer:

Chapter 8		Chapter 9: Binding Energy		Chapter 9 - Radioactivity	
1	$4.78 \times 10^{7}ms^{-1}$, $1.523 \times 10^{-11}m$	1	$0.736994u$, $1.1 \times 10^{10}J$	1	$8.453 \times 10^{-3}hours^{-1}$, 1.79676×10^{22} nuclei
2	$2.55(10^{-24})ms^{-1}$; $2.6 \times 10^{-10}m$	2	26.97u	2	180 minutes
3	$7.37 \times 10^{-28}Ns$	3	8.55MeV per nucleon	3	$2.7 \times 10^{11}atoms$, 8.49Bq
4	$2.21 \times 10^{-34}m$	4	6.696MeV per nucleon	4	7.9g
5	1.73; $2.23 \times 10^{-11}m$	5	$3 \times 10^{-27}kg$	5	$13862Bq$; 2.95596×10^{23} atoms
6	485nm			6	$1.49 \times 10^{-12}s^{-1}$; $4.2 \times 10^{12}s$
7	0.0619nm				
8	3.5×10^{-12}m				
9	$1.314 \times 10^{-22}J$				

This page was intentionally left blank.

Pra-PSPM SP025 KMSw Answer Scheme

<table>
<tr><th>No</th><th>Answer Scheme</th><th>Marks</th></tr>
<tr><td>1a)</td><td></td><td>D2
(Correct Label and Direction)</td></tr>
<tr><td>1b)</td><td>$$F_{12} = \frac{(9.0 \times 10^9)(55.0\mu)(14.0\mu)}{3^2}$$
$F_{12} = 0.77\ N$
$$F_{32} = \frac{(9.0 \times 10^9)(19.0\mu)(14.0\mu)}{3^2}$$
$F_{32} = 0.266\ N$</td><td>G1</td></tr>
<tr><td></td><td><table>
<tr><td>Forces</td><td>F_x</td><td>F_y</td></tr>
<tr><td>F_{12}</td><td>$= 0.77\ cos\ 60°$
$= 0.385\ N$</td><td>$= 0.77\ sin\ 60°$
$= 0.67\ N$</td></tr>
<tr><td>F_{32}</td><td>$= 0.266\ N$</td><td>=0</td></tr>
<tr><td>F_2</td><td>$= 0.651\ N$</td><td>$= 0.67\ N$</td></tr>
</table></td><td>G1</td></tr>
<tr><td></td><td>$F_2 = \sqrt{(0.651)^2 + (0.67)^2}$</td><td>G1</td></tr>
<tr><td></td><td>$F_2 = 0.934\ N$</td><td>JU1</td></tr>
<tr><td></td><td>$\theta = tan^{-1}(\frac{0.67}{0.651}) = 45.82°$</td><td>GJU1</td></tr>
<tr><td>1c)</td><td>Distance of charge from the centre = r
$r\ cos\ 30° = 1.5$
$r = 1.73\ m$</td><td>K1</td></tr>
<tr><td></td><td>$$V_x = \frac{(9.0 \times 10^9)(55.0\mu)}{1.73} + \frac{(9.0 \times 10^9)(-14.0\mu)}{1.73} + \frac{(9.0 \times 10^9)(19.0\mu)}{1.73}$$</td><td>G1</td></tr>
<tr><td></td><td>$V_x = 3.85 \times 10^5\ V$</td><td>JU1</td></tr>
<tr><td colspan="2">Total</td><td>10 marks</td></tr>
</table>

No	Answer Scheme	Marks
2a)	$C = \frac{\varepsilon_r A}{d}$ $\varepsilon_r = \varepsilon\varepsilon_0 = (5.4)(8.85 \times 10^{-12}) = 4.779 \times 10^{-11}$	K1
	$C = \frac{\varepsilon_r A}{d}$ $C = \frac{(4.779 \times 10^{-11})(150 \times 10^{-4})}{9.5 \times 10^{-3}}$	G1
	$C = 7.55 \times 10^{-11}\ F$	JU1
2b)	$E = \frac{V}{d}$	
	$E = \frac{6.0}{9.5 \times 10^{-3}}$	G1
	$E = 631.578\ Vm^{-1}$	JU1
2c)	$U = \frac{1}{2}CV^2$ $U = \frac{1}{2}(7.55 \times 10^{-11})(6^2)$	G1
	$U = 1.359 \times 10^{-9}\ J$	JU1
Total		**7 marks**

No	Answer Scheme	Marks
3a)	$\varepsilon = V + Ir = I(R_{eff} + r) \Rightarrow I = \frac{\varepsilon}{R_{eff} + r}$	
	$I = \frac{12}{(2+4)+0.2}$	G1
	$I = 1.9355A$	JU1
	$\frac{V_1}{V_2} = \frac{I(R_2 + R_4)}{I(R_4)}$	
	$\frac{V_1}{V_2} = \frac{2+4}{4}$	G1
	$\frac{V_1}{V_2} = 1.5$	JU1
3b)	$I_{2k\Omega} + I_{1k\Omega} = I_{3k\Omega}$	K1
	$\varepsilon_{5V} = I_{3k\Omega}(R_{3k\Omega}) + I_{2k\Omega}(R_{2k\Omega})$ $\varepsilon_{2V} + \varepsilon_{3V} = I_{1k\Omega}(R_{1k\Omega}) + I_{3k\Omega}(R_{3k\Omega})$	K1
	$5 = I_{3k\Omega}(3000) + I_{2k\Omega}(2000)$	G1
	$2 + 3 = I_{1k\Omega}(1000) + I_{3k\Omega}(3000)$	G1
	$I_{1k\Omega} = 909.1\mu A; I_{2k\Omega} = 454.5\mu A; I_{3k\Omega} = 1.364mA$	JU1
3c)	$\varepsilon_{source} = I(R_{wire} + R_2 + r)$	K1
	$5 = I(5 + 3 + 0.5)$	G1
	$I = 0.588A$	
	$\frac{\varepsilon}{V_{wire}} = \frac{l_{XQ}}{l_{XY}}$	K1
	$\frac{\varepsilon}{IR_{wire}} = \frac{l_{XQ}}{l_{XY}}$	
	$\frac{\varepsilon}{(0.588)(5)} = \frac{75}{100}$	G1
	$\varepsilon = 2.21V$	JU1
Total		**14 marks**

No	Answer Scheme	Marks
4a) i)	$\varepsilon = -NA \times \frac{dB}{dt}$ $\frac{dB}{dt} = \frac{0 - 0.04}{1.5} = -0.027\ Ts^{-1}$	K1
	$\varepsilon = -(500)(\pi)\left(\frac{0.35}{2}\right)^2 \times (-0.027)$	G1
	$\varepsilon = 1.30\ A$	JU1
4a) ii)	$I = \frac{\varepsilon}{R} = \frac{1.30}{0.5}$	G1
	$I = 2.6\ A$	JU1
	Direction: Clockwise direction	J1
4b) i)	$L = \mu_0 \left(\frac{N}{l}\right)^2 Al$ $L = (4\pi \times 10^{-7})(3000)^2 \pi(0.04)^2(0.075)$	G1
	$L = 4.264 \times 10^{-3}\ H$	JU1
4b) ii)	$\varepsilon = -L\frac{dI}{dt} = -(4.264 \times 10^{-3})(\frac{1.4}{1.5})$	G1
	$\varepsilon = 3.98\ \times 10^{-3}\ V$	JU1
Total		**10 marks**

No	Answer Scheme	Marks
5a)	Given $L = 0.2\ H$ and $R = 10\ \Omega$, $V = 120\ V$, $f = 20\ Hz$	
	$X_L = 2\pi fL = 2\pi(20)(0.2) = 25.12\ \Omega$	G1
	$Z = \sqrt{R^2 + (X_L)^2}$ $Z = \sqrt{10 + (25.12)^2} = 27.04\ \Omega$	G1
	V=IZ	
	I = 4.44 A	GJU1
5b)	$cos\emptyset = \frac{R}{Z}$	K1
	$cos\emptyset = \frac{10}{27.04}$	G1
	$\emptyset = 68.4°$	JU1
5c)	$cos\emptyset = \frac{10}{27.04}$	
	$cos\emptyset = 0.37$	GJU1
5d)	$P=I^2R=(4.44)^2(10)$	G1
	P = 197.3 W	JU1
Total		**9 marks**

No	Answer Scheme	Marks
6a)	$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}; M=-\frac{v}{u}$	
	$3=\frac{-v}{9}$	G1
	$v=-27cm$	
	$\frac{1}{f}=\frac{1}{9}+\frac{1}{-27}$	G1
	$f=13.5cm$	JU1
	Since $f>0$, mirror is concave.	JU1
6b)	Convex → R>0	K1
	$\frac{n_1}{u}+\frac{n_2}{v}=\frac{n_2-n_1}{R}$	
	$\frac{1.33}{2.00}+\frac{1}{v}=\frac{1-1.33}{+0.60}$	G1
	$v=-0.823m$	
	Distance from bottom tank, $s=2-0.823=1.177m$	JU1
6c) i)	$\frac{1}{f}=\left(\frac{n_2}{n_1}-1\right)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$	
	$\frac{1}{f}=\left(\frac{1.52}{1}-1\right)\left(\frac{1}{30}-\frac{1}{-30}\right)$	G1
	$f=28.85cm$	JU1
6 c) ii)	$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$	
	$\frac{1}{28.85}=\frac{1}{10}+\frac{1}{v}$	G1
	$v=-15.31cm$	JU1
6 d)	$2nt=m\lambda$	
	$2(1.47)t=1(589.6nm)$	G1
	$t=200.54nm$	JU1
	$2nt=(m+0.5)\lambda$	
	$2(1.47)t=(0.5)(589.6nm)$	G1
	$t=100.27nm$	JU1
6 e) i)	$d\sin\theta_m=m\lambda \Rightarrow \sin\theta_m=Nm\lambda$	
	$\sin\theta_2=(570000)(2)(650\times10^{-9})$	G1
	$\theta_2=47.82^o$	JU1
6 e) ii)	$m\le\frac{1}{N\lambda}$	
	$m\le\frac{1}{(570000)(650\times10^{-9})}$	G1
	$m\le 2.699$	
	Number of bright fringes, $n=2m+1=2(2)+1$	G1
	$n=5$	JU1
Total		**20 marks**

No	Answer Scheme	Marks
7	$K_x = 16K_p$; $\frac{\lambda_p}{\lambda_x} = 3.2\ x\ 10^{-3}$ m_p= 1.67 x 10^{-27}kg	K1
	$\lambda = \frac{h}{\sqrt{2mK}}, \lambda^2 \propto \frac{1}{mK}$	
	$m_c = (3.2 \text{ x } 10^{-3})^2 \text{ x } 1.67 \text{ x } 10^{-27} / 16$	G1
	$m_c = 6.68 \text{ x } 10^{-35}$ kg	JU1
Total		**3 marks**

No	Answer Scheme	Marks
8a)	${}^{232}_{90}Th \Rightarrow N = 232 - 90 = 142$	
	$\Delta m = \left(Zm_p + Nm_n\right) - m_{nucleus}$	
	$\Delta m = [90(1.007277u) + 142(1.008665u) - 232.038\ u$	G1
	$\Delta m = 1.84736u$ or $\Delta m = 3{,}00492 \times 10^{-27} kg$	JU1
8b)	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{ln2}{12} = 0.05776$ min^{-1}	
	$N = N_o e^{-\lambda t}$ $20000 = N_o e^{-0.05776(15)}$ N_0 = 47566 nuclei	K1
	$N = 47566\ e^{-0.05776(20)}$	G1
	N=34713 nuclei	J1
8c)	$\lambda = \frac{\ln 2}{T_{\frac{1}{2}}} = \frac{ln2}{5760} = 1.2034 \times 10^{-4} yr^{-1}$	
	$A = A_o e^{-\lambda t}$	
	$A = 1300 e^{-1.2034\times10^{-4}(2500)}$	G1
	$A = 962 decay\ min^{-1}$	JU1
Total		**7 marks**

SP025 Physics 2 Semester II Session 2024/2025 2 hours	SP025 Fizik 2 Semester II Sesi 2024/2025 2 jam

KEMENTERIAN PENDIDIKAN

KOLEJ MATRIKULASI SARAWAK
SARAWAK MATRICULATION COLLEGE

PRA-PEPERIKSAAN SEMESTER PROGRAM MATRIKULASI
PRE-MATRICULATION PROGRAMME EXAMINATION

JANGAN BUKA KERTAS SOALAN INI SEHINGGA DIBERITAHU
DO NOT OPEN THIS QUESTION PAPER UNTIL YOU ARE TOLD TO DO SO.

Kertas soalan ini mengandungi **12** halaman bercetak.
*This question paper consists of **12** printed pages.*

LIST OF SELECTED CONSTANT VALUES
SENARAI NILAI PEMALAR TERPILIH

Speed of light in vacuum *Laju cahaya dalam vakum*	c	$= 3.00 \times 10^{8}\ \text{m s}^{-1}$
Permeability of free space *Ketelapan ruang bebas*	μ_o	$= 4\pi \times 10^{-7}\ \text{H m}^{-1}$
Permittivity of free space *Ketelusan ruang bebas*	ε_o	$= 8.85 \times 10^{-12}\ \text{F m}^{-1}$
Electron charge magnitude *Magnitud cas elektron*	e	$= 1.60 \times 10^{-19}\ \text{C}$
Planck constant *Pemalar Planck*	h	$= 6.63 \times 10^{-34}\ \text{J s}$
Electron mass *Jisim elektron*	m_e	$= 9.11 \times 10^{-31}\ \text{kg}$ $= 5.49 \times 10^{-4}\ \text{u}$
Neutron mass *Jisim neutron*	m_n	$= 1.674 \times 10^{-27}\ \text{kg}$ $= 1.008665\ \text{u}$
Proton mass *Jisim proton*	m_p	$= 1.672 \times 10^{-27}\ \text{kg}$ $= 1.007277\ \text{u}$
Hydrogen mass *Jisim hidrogen*	m_H	$= 1.673 \times 10^{-27}\ \text{kg}$ $= 1.007825\ \text{u}$
Deuteron mass *Jisim deuteron*	m_d	$= 3.34 \times 10^{-27}\ \text{kg}$ $= 2.014102\ \text{u}$
Molar gas constant *Pemalar gas molar*	R	$= 8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
Avogadro constant *Pemalar Avogadro*	N_A	$= 6.02 \times 10^{23}\ \text{mol}^{-1}$
Boltzmann constant *Pemalar Boltzmann*	k	$= 1.38 \times 10^{-23}\ \text{J K}^{-1}$

LIST OF SELECTED CONSTANT VALUES
SENARAI NILAI PEMALAR TERPILIH

Free-fall acceleration *Pecutan jatuh bebas*	g	$= 9.81 \text{ m s}^{-2}$
Atomic mass unit *Unit jisim atom*	1 u	$= 1.66 \times 10^{-27}$ kg $= 931.5 \frac{MeV}{c^2}$
Electron volt *Elektron volt*	1 eV	$= 1.6 \times 10^{-19}$ J
Constant of proportionality for Coulomb's law *Pemalar hukum Coulomb*	$k = \frac{1}{4\pi\varepsilon_o}$	$= 9.0 \times 10^{9} \text{ N m}^2 \text{ C}^{-2}$
Atmospheric pressure *Tekanan atmosfera*	1 atm	$= 1.013 \times 10^{5}$ Pa
Density of water *Ketumpatan air*	ρ_w	$= 1000 \text{ kg m}^{-3}$

LIST OF SELECTED FORMULAE
SENARAI RUMUS TERPILIH

1. $F = \frac{Qq}{4\pi\varepsilon_0 r^2} = k\frac{Qq}{r^2}$

2. $E = \frac{F}{q_o}$

3. $E = \frac{kQ}{r^2}$

4. $V = \frac{W}{q_o}$

5. $V = \frac{kQ}{r}$

6. $\Delta U = q\Delta V$

7. $U = k\left(\frac{q_1 q_2}{r_{12}}\right)$

8. $U = k\left(\frac{q_1 q_2}{r_{12}} + \frac{q_1 q_3}{r_{13}} + \frac{q_2 q_3}{r_{23}}\right)$

9. $E = \frac{\Delta V}{d}$

10. $C = \frac{Q}{V}$

11. $\frac{1}{C_{effective}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots + \frac{1}{C_n}$

12. $C_{effective} = C_1 + C_2 + \ldots + C_n$

13. $U = \frac{1}{2}CV^2 = \frac{1}{2}QV = \frac{1}{2}\frac{Q^2}{C}$

14. $\tau = RC$

15. $Q = Q_o e^{\frac{-t}{RC}}$

16. $Q = Q_o\left(1 - e^{\frac{-t}{RC}}\right)$

17. $\varepsilon_r = \frac{\varepsilon}{\varepsilon_o}$

18. $C_o = \frac{\varepsilon_o A}{d}$

19. $C = \varepsilon_r C_o$

20. $I = \frac{dQ}{dt}$

21. $Q = ne$

22. $V = IR$

23. $\rho = \frac{RA}{l}$

24. $R = R_o\left[1 + \alpha(T - T_o)\right]$

25. $V = \varepsilon - Ir$

26. $R_{effective} = R_1 + R_2 + \ldots + R_n$

27. $\frac{1}{R_{effective}} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots + \frac{1}{R_n}$

LIST OF SELECTED FORMULAE
SENARAI RUMUS TERPILIH

28. $P = IV = I^2 R = \dfrac{V^2}{R}$

29. $W = IVt$

30. $V_1 = \left(\dfrac{R_1}{R_1 + R_2 + \ldots R_n}\right)V$

31. $\dfrac{\varepsilon_1}{\varepsilon_2} = \dfrac{l_1}{l_2}$

32. $B = \dfrac{\mu_o I}{2\pi r}$

33. $B = \dfrac{\mu_o I}{2r}$

34. $B = \mu_o n I$

35. $B = \dfrac{1}{2}\mu_o n I$

36. $F = qvB\sin\theta$

37. $F = IlB\sin\theta$

38. $\dfrac{F}{l} = \dfrac{\mu_o I_1 I_2}{2\pi d}$

39. $v = \dfrac{E}{B}$

40. $\phi = BA\cos\theta$

41. $\Phi = N\phi$

42. $\varepsilon = -\dfrac{d\phi}{dt}$

43. $\varepsilon = Blv\sin\theta$

44. $\varepsilon = -NA\dfrac{dB}{dt}$

45. $\varepsilon = -NB\dfrac{dA}{dt}$

46. $\varepsilon = NAB\omega\sin\omega t$

47. $L = -\dfrac{\varepsilon}{\left(\dfrac{dI}{dt}\right)}$

48. $L = \dfrac{N\phi}{I}$

49. $L_{coil} = \dfrac{\mu_o N^2 A}{2r}$

50. $L_{solenoid} = \dfrac{\mu_o N^2 A}{l}$

51. $U = \dfrac{1}{2}LI^2$

52. $M = \dfrac{\mu_o N_1 N_2 A}{l}$

53. $V = V_o\sin\omega t$

LIST OF SELECTED FORMULAE
SENARAI RUMUS TERPILIH

54. $I = I_o \sin \omega t$

55. $I_{rms} = \dfrac{I_o}{\sqrt{2}}$

56. $V_{rms} = \dfrac{V_o}{\sqrt{2}}$

57. $X_C = \dfrac{1}{2\pi fC}$

58. $X_L = 2\pi fL$

59. $Z = \sqrt{R^2 + \left(X_L - X_C\right)^2}$

60. $\phi = \tan^{-1} \dfrac{\left(X_L - X_C\right)}{R}$

61. $\cos\phi = \dfrac{R}{Z}$

62. $P_{av} = I_{rms} V_{rms} \cos\phi$

63. $P_{inst} = IV$

64. $\cos\phi = \dfrac{P_r}{P_a} = \dfrac{P_{av}}{I_{rms} V_{rms}}$

65. $R = 2f$

66. $\dfrac{1}{f} = \dfrac{1}{u} + \dfrac{1}{v}$

67. $M = \dfrac{h_i}{h_o} = -\dfrac{v}{u}$

68. $\dfrac{n_1}{u} + \dfrac{n_2}{v} = \dfrac{n_2 - n_1}{R}$

69. $\dfrac{1}{f} = \left(\dfrac{n_{material}}{n_{medium}} - 1\right)\left(\dfrac{1}{R_1} - \dfrac{1}{R_2}\right)$

70. $y_m = \dfrac{m\lambda D}{d}$

71. $y_m = \dfrac{\left(m + \frac{1}{2}\right)\lambda D}{d}$

72. $\Delta y = \dfrac{\lambda D}{d}$

73. $2nt = m\lambda$

74. $2nt = \left(m + \frac{1}{2}\right)\lambda$

75. $y_m = \dfrac{m\lambda D}{a}$

76. $y_m = \dfrac{\left(m + \frac{1}{2}\right)\lambda D}{a}$

77. $d \sin\theta = m\lambda$

78. $d = \dfrac{1}{N}$

LIST OF SELECTED FORMULAE
SENARAI RUMUS TERPILIH

79. $\lambda = \dfrac{h}{p} = \dfrac{h}{mv}$

80. $\lambda = \dfrac{h}{\sqrt{2meV}}$

81. $\lambda = \dfrac{h}{\sqrt{2mK}}$

82. $A = Z + N$

83. $\Delta m = \left(Zm_{\mathrm{p}} + Nm_{\mathrm{n}} \right) - m_{\mathrm{nucleus}}$

84. $m_{\mathrm{nucleus}} = m_{atom} - Zm_{e}$

85. $\Delta m = \left(Zm_{H} + Nm_{n} \right) - m_{atom}$

86. $E_{\mathrm{B}} = \Delta mc^{2}$

87. $\dfrac{dN}{dt} = -\lambda N$

88. $N = N_{\mathrm{o}} e^{-\lambda t}$

89. $A = A_{\mathrm{o}} e^{-\lambda t}$

90. $A = \lambda N$

91. $T_{\frac{1}{2}} = \dfrac{\ln 2}{\lambda}$

1 Point charges Q_1, Q_2 and Q_3 are located at the vertices of an equilateral triangle as shown in FIGURE 1.

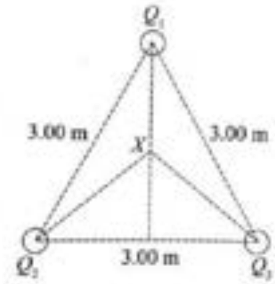


FIGURE 1

Given that $Q_1 = 55.0\ \mu C, Q_2 = -14.0\ \mu C$ and $Q_3 = 19.0\ \mu C$. Determine the magnitude and direction of the

a) Sketch the force on Q_2

[2 marks]

b) Calculate the electrostatic force on Q_2

[5 marks]

c) Calculate the electric potential at the center point X of the triangle

[3 marks]

2 A parallel plate capacitor of area $150\ cm^2$ is charged by a battery of $6.0\ V$. The separation between the plates is $9.5\ mm$ and the space between the plates is filled by mica of dielectric constant 5.4.

a) Determine the capacitance of the capacitor

[3 marks]

b) Calculate the electric fields between the plates.

[2 marks]

a) Calculate the energy stored in the capacitor.

[2 marks]

3 a) A battery of 12V e.m.f. and internal resistance of 0.2Ω is connected to a resistors of resistances 4Ω and 2Ω, as shown in FIGURE 2.

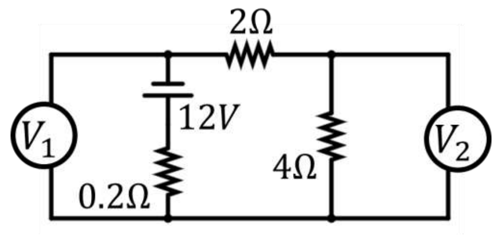


FIGURE 2

Calculate the

a) current through the 2Ω resistor

[2 marks]

b) ratio of voltmeter readings, $\frac{V_1}{V_2}$.

[2 marks]

b) FIGURE 3 shows a circuit consisting of 3 batteries and 3 resistors.

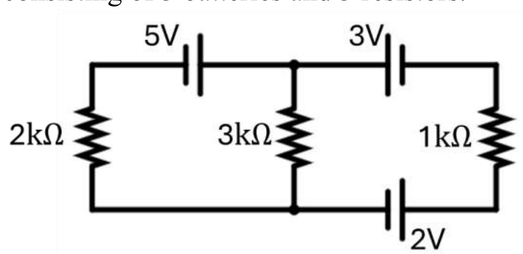


FIGURE 3

Determine the current through each resistor.

[5 marks]

c) FIGURE 4 shows a potential divider consisting of wire XY of length 1m and resistance of 5Ω.

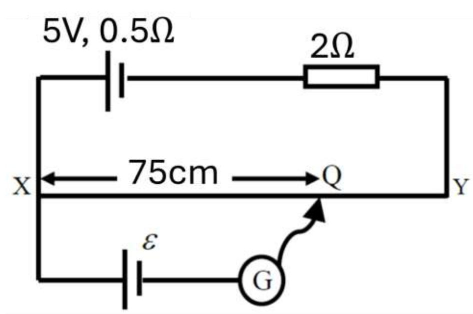


FIGURE 4

A cell of 5V with internal resistance of 0.5Ω is connected in series with a 2Ω resistor. When another cell with emf ε is connected to the potential divider, the balance length XQ is 75cm. Calculate ε.

[5 marks]

4 a) A thin circular coil of diameter $35\ cm$ and 500 turns is located in a magnetic field such that the plane of the coil is perpendicular to the magnetic field of $40\ mT$. The magnetic field is then reduced to zero in $1.5\ s$. Determine

i. the induced e.m.f in the coil.

[3 marks]

ii. the magnitude and direction of induced current in the coil if the total resistance of the coil is $0.5\ \Omega$ and the magnetic field is directed into the page.

[3 marks]

b) An air cored long solenoid of length $7.5\ cm$ and a diameter $8.0\ cm$ is made of $30.0\ turns$ per cm. A current is flowed and increased to 1.4 A in 1.5 s.

i. Determine the self-inductance of the solenoid.

[2 marks]

ii. Determine the induced e.m.f in the solenoid.

[2 marks]

5 A coil having an inductance of 0.2 H and resistance of 10 Ω is connected across a 120 V and 20 Hz line. Calculate

a) the current in the coil

[3 marks]

b) the phase angle between the current and the supply voltage

[3 marks]

c) the power factor

[1 mark]

d) the power loss in the coil

[2 marks]

6 a) A mirror has a focal length of f. If the mirror produces a magnification of 3 when someone looking at the mirror from 9cm away, determine the focal length of the mirror and the type of mirror.

[4 marks]

b) A thin hemispherical clear plastic bowl of radius $R = 60cm$ is placed in a tank filled with water ($n_{water} = 1.33$). The bottom of the bowl sinks to a depth of $d = 8cm$ and the water level rises to a height of $h = 208cm$ as shown in FIGURE 5.

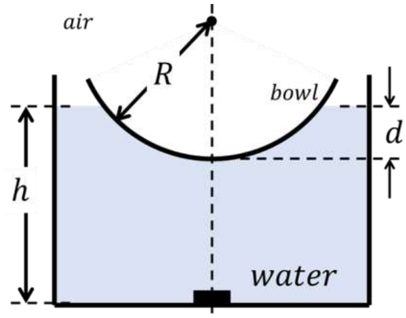


FIGURE 5

An object at the bottom of the tank is viewed vertically from above the bowl. If the refractive index of the air is 1.0. Calculate the image distance from the bottom of the tank.

[3 marks]

c) An object is placed 10cm from a thin biconcave lens of refractive index of 1.52 and a radii of surface curvature of 30cm. Calculate the

i. focal length of the lens
ii. the image distance of the image from the lens.

[4 marks]

d) What is the minimum thickness of oily film on a glass surface which will appear bright when viewed with a sodium light source of wavelength 589.6nm reflecting perpendicular to the film? The refractive index of the oily film is 1.45 and the refractive index of the glass is 1.50. If the oily film is placed on water of refractive index of 1.33 instead, determine the minimum thickness for the light source to be strongly reflected.

[4 marks]

e) A grating with 5700 lines per cm is illuminated with a light of 650 nm. Determine the

i. angle of the second order maximum
ii. the maximum number of bright fringes observed.

[5 marks]

7 A particle's kinetic energy is sixteen times bigger than a proton's kinetic energy. If the ratio of the de Broglie wavelength of the proton to the particle is 3.2 × 10-3, calculate the mass of the particle.

[3 marks]

8 a) the mass defect for the nucleus of Thorium, ${}^{232}_{90}Th$.
(Nucleus mass of Thorium is 232.038 u)

[2 marks]

b) A radioactive sample has a half-life of 12 minutes. 20000 nuclei are present at t = 15 minutes. How many nuclei were there at t = 20 minutes?

[3 marks]

c) The initial activity of C-14 from an ancient fossil is 1300 decay per minute. Given the half-life of C-14 is 5760 years, calculate the activity 2500 years ago.

[2 marks]

END OF QUESTION PAPER

<u>KMSw: Numeracy Practice</u>

An electrical engineer is designing a DC electric motor.
The DC electric motor required a circular coil with the range of diameter between **9.0 cm to 11.0 cm.**
TABLE 1 and **TABLE 2** show a set of data for two circular coils, coil A and coil B.
Based on the data given, use a suitable method to identify which coil is the most suitable for the DC electric motor.

[20 *marks*]

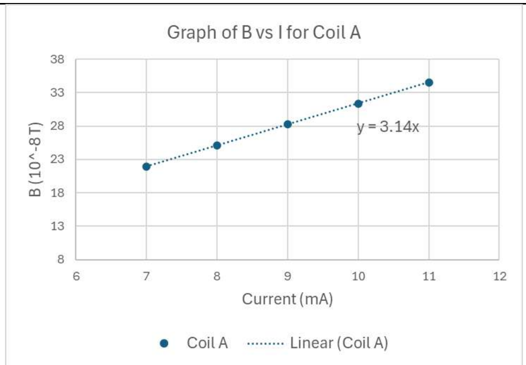
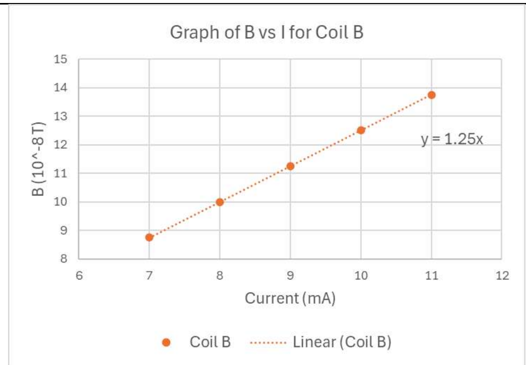
TABLE 1: Coil A

B ($\times 10^{-8}$ T)	21.98	25.12	28.26	31.40	34.54
I (mA)	7	8	9	10	11

TABLE 2: Coil B

B ($\times 10^{-8}$ T)	8.75	10.00	11.25	12.50	13.75
I (mA)	7	8	9	10	11

Suggested Answer

Suggested answer	Mark(s)	Suggested answer	Mark(s)
Coil A		**Coil B**	
Formulating the question, Magnetic field produced by circular coil $$B = \frac{\mu_o I}{2r}$$	K1	Formulating the question, Magnetic field produced by circular coil $$B = \frac{\mu_o I}{2r}$$	K1
Comparing with linear graph equation, $$B = \frac{\mu_o I}{2r} \Leftrightarrow y = mx + c$$		Comparing with linear graph equation, $$B = \frac{\mu_o I}{2r} \Leftrightarrow y = mx + c$$	
$B \Leftrightarrow y$	J1	$B \Leftrightarrow y$	J1
$I \Leftrightarrow x$	J1	$I \Leftrightarrow x$	J1
$\frac{\mu_o}{2r} \Leftrightarrow m$	J1	$\frac{\mu_o}{2r} \Leftrightarrow m$	J1
	For each graph: x-axis and y-axis with correct unit – 1m 5 correct plotted points – 2 m 4 correct plotted points – 1 m 3 correct plotted points – 0 m		For each graph: x-axis and y-axis with correct unit – 1m 5 correct plotted points – 2 m 4 correct plotted points – 1 m 3 correct plotted points – 0 m
$$m = \frac{\mu_o}{2r_A}$$		$$m = \frac{\mu_o}{2r_B}$$	
$$r_A = \frac{\mu_o}{2\text{m}}$$	K1	$$r_B = \frac{\mu_o}{2\text{m}}$$	K1
$$r_A = \frac{4\pi \times 10^{-7}}{2(3.14 \times 10^{-5})} = 0.02m$$	JU1	$$r_B = \frac{4\pi \times 10^{-7}}{2(1.25 \times 10^{-5})} = 0.05m$$	JU1
$$d_A = 2(r_A) = 0.04m;\ d_B = 2(r_B) = 2(0.05) = 0.10m$$			JU1
Since $9.0cm < d$_B $< 11cm$, coil B is the most suitable for the DC electric motor.			J1

By Shafiq R