Level 3 Physics
2013
Study Answer-Booklet

Contents:

Unit Review Answers:

(equation symbol, unit and situation to use with things to remember AND descriptions of diagrams)
It is up to YOU to make sure you know the VOCABULARY used in these answers

Answers to the 15 Revision Question Sets

For more questions check out this website for past national exams:
http://www.nzqa.govt.nz/qualifications-standards/qualifications/ncea/subjects/physics/levels/

Level 3 Physics Waves Review Sheet – ANSWERS –

KNOW THE EQUATIONS:

Equation		Symbol's **complete** name And SI unit	Situation where equation is most commonly used (or notes about this equation). Use your own paper
$d\sin\theta = n\lambda$	d	Distance between slits (m)	1. D = lines per meter. D gives d by inversing and converting units. Can be used when **angle is large**: for **diffraction grating** laser/sound/white-light Also used to talk about "extra path distance" to create nodes or antinodes (destructive or constructive interference).
	θ	Angle at diffraction grating from n=0 to n=? antinode (°)	
	n	Number (order) of antinode (no unit)	
	λ	Wavelength of light (m)	
$n\lambda = \frac{dx}{L}$	x	Distance between n=0 and n=1 antinode (m)	2. See above. Used to talk about how x changes with L, d or λ. **This equation assumes** angle is SMALL. So small that sinθ = tanθ. **This equation assumes** fringes are evenly spaced. In reality: as n gets larger the distance between antinodes, x, gets larger. **Only use this equation for double slit or where fringes very close together!**
	L	Length from diffraction grating to screen (m)	
$v = f\lambda$	v	Velocity of wave (ms^{-1})	3. Can be used for any wave. If sound: fλ must equal speed of sound. If electromagnetic (light): fλ must equal speed of light.
	f	Frequency (Hz)	
	λ	Wavelength (m)	
$f' = f\frac{v_w}{v_w \pm v_s}$	f'	Observed frequency (Hz)	4. Doppler Equation. Must choose + OR – for motion towards OR away. Also used to discuss "red shift" or "blue shift". Usually requires diagram with circles "squished" to one side or graph of f vs t
	f	Frequency made (Hz)	
	v_w	Wave velocity (ms^{-1})	
	v_s	Sound source velocity (ms^{-1})	

Be familiar with the COMMON DIAGRAMS and GRAPHS in this unit:

1. Doppler Effect diagram:
   - A = stationary observer #1 on left
   - B = stationary observer #2 (on right)
   - C = Elongated apparent wavelength of sound waves reaching stationary observer #1.
   - D = Compressed apparent wavelength of sound waves reaching stationary observer #2.
   - E = constant velocity (22m/s) of source (bat)
   - Using 330m/s for speed of sound
   - Wavelength of sound bat is making:

     $\lambda = \frac{v}{f} = \frac{330}{11{,}000}$ = 0.03m:
   - Doppler equation for observer INFRONT of bat $f' = f\frac{v_w}{v_w - v_s} = 11{,}000\frac{330}{330-22}$ = 11,786Hz
   - Apparent wavelength reaching observer

     INFRONT: $\lambda = \frac{v}{f} = \frac{330}{11{,}786}$ = 0.028m
   - Doppler equation for observer BEHIND bat:

     $f' = f\frac{v_w}{v_w + v_s} = 11{,}000\frac{330}{330+22}$ = 10,312.5Hz
   - Apparent wavelength reaching observer

     BEHIND bat: $\lambda = \frac{v}{f} = \frac{330}{10{,}312.5}$ = 0.032m.

2. Graph of apparent frequency vs time for Doppler shift of constant speed object passing stationary observer.
   - A = apparent frequency (Hz) measured at stationary observer.
   - B = time (s)

- C = high apparent frequency that observer hears as object approaches at constant speed.
- D = time that object passes observer and apparent frequency shifts from higher to lower.
- E = lower apparent frequency that observer hears as object gets farther away at const speed.

3. Graph of how beats are made by superposition of 2 waves of near identical wavelength or frequency.
   - A = 1st wave, B = 2nd wave. Both happening at the same time.
   - C = average wavelength (or frequency) of A and B that person will hear.
   - C has TALL PARTS (twice as tall as A or B) that are made when A and B are in phase (constructively interfering).
   - D is the spot where A and B are ½ wave out of phase and destructively interfering.
   - Person will hear tall bits as pulse of sound and flat bit as quiet.
   - Thus BEAT frequency is $f_A - f_B$.

4. Diagrams of standing waves in strings, open pipes and closed pipes of 75cm length.
   - All standing waves are made from 2 waves interfering with each other.
   - D is an ANTINODE where the two waves are always in-phase (constructive interference).
   - E is a NODE where the two waves are always ½ λ out of phase (destructive interference).
   - A = string with 4th harmonic or 3rd overtone standing wave.
   - 2 wavelengths in 75cm make λ = 0.75/2 = 0.375m
   - Not knowing the speed of the wave in the string we CANNOT find the frequency. Speed of sound is NOT used for strings.
   - B = open pipe with 4th harmonic or 3rd overtone.
   - Air particles vibrate horizontally even though we draw imaginary strings moving vertically in the pipe.
   - λ = 0.75/2 = 0.375m
   - $f = v_{sound}/\lambda$ = 330 / 0.375 = 880Hz
   - C = closed pipe with 7th harmonic or 6th overtone.
   - Closed pipes DON'T have even harmonics or odd overtones so the names are very TRICKY.
   - 1¾ λ = 0.75. so λ = 0.75/1.75 = 0.42857…m
   - $f = v_{sound}/\lambda$ = 330 / 0.42… = 770Hz

5. Diagram for Young's Double Slit Diffraction and Interference of coherent laser light.
   - Fringes are evenly spaced and angle is very tiny thus $n\lambda = \frac{dx}{L}$ can be used
   - A = central maxima, also called the n=0 fringe. Brightest constructive interference spot where there is no path difference from the 2 slits.
   - B = n=1 fringe. 1st constructive interference stop away from the central maxima where there is 1 λ of path difference (the wave from the top slit travels 1 λ more than the wave from the bottom slit) so that both waves are in phase at this position.
   - C = n=2 destructive interference (dark spot). There is 1½λ path difference (top wave travels farther) so that both waves are completely out of phase at this location and destructively interfere.
   - $n\lambda = \frac{dx}{L}$ gives:

     $$x = \frac{n\lambda L}{d} = \frac{1 \times 630 \times 10^{-9} \times 7.5}{0.0017} = 0.002779\ldots$$

     = about 3mm

6. Evenly spaced speakers set up to make interference pattern along person's path.
   - Person will hear loud and quiet sounds as they move sideways (in diagram). Loud spots are constructive interference where all 4 speaker's waves are in phase.
   - Angles are large and antinodes are not evenly spaced so $d\sin\theta = n\lambda$ must be used
   - Unknown A distance: angle to n=1:

     $$\sin^{-1}\frac{n\lambda}{d} = \sin^{-1}\frac{1 \times {}^{330}\!/_{950}}{3.5} = 5.695\ldots\,°$$
   - Using tangent: $x = L\tan\theta = 18 \times \tan 5.69\ldots =$ 1.7953… = 1.8m
   - Unknown B distance: angle to n=2:
   - $$\sin^{-1}\frac{n\lambda}{d} = \sin^{-1}\frac{2 \times {}^{330}\!/_{950}}{3.5} = 11.449\ldots\,°$$
   - Using tangent: $x = L\tan\theta = 18 \times \tan 11.4\ldots =$ 3.645…m to n=0 spot
   - B = 3.645… - 1.7953… = 1.8501… = 1.9m
   - Distance between antinodal spots gets larger as n increases.

Level 3 Physics Translational & Circular Motion Review Sheet – ANSWERS

KNOW THE EQUATIONS:

Equation		Symbol's **complete** name And SI unit	Situation where equation is most commonly used (or notes about this equation).
$F_{net} = ma$	F_{NET}	Net Force (N)	1. Newton's 2nd Law: Net (resultant or total) force proportional to acc. Also F and a are in same direction.
	m	Mass (kg)	
	a	Acceleration (ms^{-2})	
$p = mv$	ρ	Momentum ($kgms^{-1}$)	2. For 1D type problems: remember opposite direction means NEGATIVE. For 2D type problems: need TRIAGLE for conservation of momentum And for negative velocity (or subtraction) must draw arrow 180° (backwards)
	v	Velocity (ms^{-1})	
$\Delta p = F\Delta t$	Δρ	Impulse ($kgms^{-1}$)	3. Alternative unit for $kgms^{-1}$ (Ns). Force used to change momentum (and speed) for impacts, crashes or collisions. Can be paired with F=ma or W=Fd. Also: any Δ = final quantity – initial quantity
	F	Average force (N)	
	Δt	Time of contact (s)	
$\Delta E_p = mgh$	ΔE_P	Change in gravitational potential energy (J)	4. can be paired with $E_{K(LIN)} = \frac{1}{2}mv^2$ and maybe $E_{K(ROT)} = \frac{1}{2}I\omega^2$ for energy conservation (assumes no friction or energy-loss) Used to find elastic vs inelastic collisions (no energy loss vs energy loss)
	g	Gravity (acceleration) (ms^{-2})	
	h	Height (m)	
$W = Fd$	W	Work (change in energy) (J)	5. Can be used in most "change in energy" situations. Average Force must be PARALLEL to distance moved. Work = "energy lost" for "stopping on carpet" problems
	d	Distance (m)	
$E_{K(LIN)} = \frac{1}{2}mv^2$	$E_{K(LIN)}$	Kinetic Energy (linear) (J)	6. see #4 above
	v	Velocity (ms^{-1})	

$F_g = \frac{GMm}{r^2}$	F_G	Gravitational Force (N)	7. Used for finding weight of space-station or astronaut (NOT ZERO!). Common mistake: not including height above earth into r or converting km into m OR not including radius of Earth, planet or moon into r. Could be paired with $F_c = \frac{mv^2}{r}$ with mass in orbit cancelling out. Or can be paired with F = mg to find gravity at any height or on any planet.
	G	Universal Grav Const ($N\ m^2\ kg^{-2}$)	
	M	Parent Mass (planet) (kg)	
	m	Other Mass (orbiting) (kg)	
	r	Radius of Orbit (distance between mass centres) (m)	
$F_c = \frac{mv^2}{r}$	F_C	Centripetal Force (N)	8. Can be paired with F = ma or $F_g = \frac{GMm}{r^2}$ for satellite situations. F towards centre of circle (as well as acc).
	m	Spinning Mass (kg)	
	v	Tangential Velocity (linear) (ms^{-1})	
	r	Radius of Orbit (m)	

Be familiar with the COMMON DIAGRAMS and GRAPHS in this unit:

1. Diagram used for centre of mass (CoM).
   - The centre of the beam, "A" is not the centre of mass, "B" unless both large masses (left and right) are equal.
   - "C" is the distance between the centres of each mass.
   - The equation $m_1 x = m_2 (d - x)$ can be used to find the location of the CoM, x.
   - Which ever mass you use for m_1 is where x starts at.
   - If a force is acted at the CoM there will be no torque and the entire mass will move without rotating.
   - If a force is acted on at the centre of the beam (or any place not at the CoM) there will be a torque with $\tau = Fd$ with d being the distance between the force and the CoM.

2. A 2-dimentional conservation of momentum situation (air hockey or ice usually).
   - No friction so that no external forces so that the law of conservation of momentum can be used.
   - All 3 arrows, "A", "B" and "C", must be momentums – not speeds – because they fit together in the vector diagram so that "B" and "C" make "A" and momentum is conserved.
   - The vertical component of B is equal and opposite to C's.
   - And the horizontal component of B and C together make A.
   - If the time of contact is known then the impulse $\Delta p = F\Delta t$ or the force of collision can be found.

3. Graph of Force vs time for impulse:
   - "A" is force in Newtons.
   - "B" is time in seconds.
   - The area under any line is impulse, Δρ because of the formula $\Delta p = F\Delta t$.
   - Each area, "C" and "D", would be equal (assuming the object travels at the same speed before collision)
   - The 2 curves on this graph are a comparison of a collision with double the time but half the maximum force.
   - This is used to explain why crumple-zones in cars are used (or helmets).

4. A conical pendulum with a free-body force diagram AND a vector triangle force diagram.
   - "A" is the weight force (straight down).
   - "B" is the centripetal force (or net force) straight to the centre of the circle (horizontal).
   - "C" is the tension up the string.
   - All 3 forces can be redrawn as a vector triangle, "D" with the same angle between weight and tension as in the original diagram.
   - The vector triangle can be used to make the equation $\tan\theta = \frac{F_C}{F_W} = \frac{mv^2/r}{mg} = \frac{v^2}{rg}$ which is NOT given on the exam.
   - This can be rearranged to give $v^2 = rg\tan\theta$ to find the tangential velocity of the mass or the radius of the horizontal circle.

5. A banked corner diagram that uses the same idea as #4.
   - "A" is the weight force (down).
   - "B" is the centripetal force OR the net force (to the centre of the corner) horizontal.
   - "C" is the support or reaction force 90° to the surface of the ramp.
   - "D" is the vector triangle that has the same angle of the ramp between weight and reaction force.
   - The same equation $v^2 = rg\tan\theta$ can be used to find the maximum speed around the corner.
   - Usually there is ice or water on road so that friction does not "mess up" the force triangle.

6 and 7. Both vertical circle force diagrams.

In both diagrams:
   - "A" is the centripetal force as plane enters and leaves loop (to centre of circle)
   - "B" is the weight force as plane enters and leaves loop (down).
   - "C" is the top of the loop where both weight and centripetal force are downwards.
   - "D" is the tangent velocity at the top and "E" is the tangent velocity entering and leaving.
   - From tangential velocity arrows it looks like we are assuming constant speed.

In diagram #6:

- Since centripetal force = weight force then the pilot will feel 2g's entering the loop but will feel 0g's (weightless) at the top of the loop.
- This means they are travelling at the minimum speed around the loop.
- As they cross the top of the loop they will be in freefall, thus no net force between their body and their seat.
- The equation $F_C = F_W$ can be used to make $\frac{mv^2}{r} = mg$ which gives: $v^2 = rg$ to find the minimum velocity to go around the loop

In diagram #7

- Centripetal force looks twice as large as weight force – thus they are traveling much faster than the minimum speed.
- As the pilot enters and leaves the loop they will feel 3g's.
- As the pilot crosses the top they will feel -1g which is like regular gravity but upwards.
- The equation $F_C = 2F_W$ can be used to make $\frac{mv^2}{r} = 2mg$ which gives: $v^2 = 2rg$ to find the velocity required for negative 1g at the top of the loop

Level 3 Physics Rotational Motion Review Sheet – ANSWERS

KNOW THE EQUATIONS:

Equation		Symbol's **complete** name And SI unit	Situation where equation is most commonly used (or notes about this equation).
$d = r\theta$	d	Distance moved around arc (m)	1,2,3. Known as "conversion equations" for Angular to Linear values. Can be used to find distance for wheel to stop (d) from radius of wheel and radians wheel spins. Can be used to find v_f, v_i, ω_f, ω_i during acceleration problems as well.
	r	Radius of circle (m)	
	θ	Angular displacement (radians)	
$v = r\omega$	v	Tangential velocity (ms^{-1})	
	ω	Angular velocity (rad s^{-1})	
$a = r\alpha$	a	Centripetal acceleration (ms^{-2})	
	α	Angular acceleration (rad s^{-2})	
$\omega = \frac{\Delta\theta}{\Delta t}$	Δ θ	Change in angular displacement (rad)	4. ONLY for constant angular speed! NO acceleration!
	Δ t	Change in time (s)	
$\alpha = \frac{\Delta\omega}{\Delta t}$	Δ ω	Change in angular velocity (rad s^{-1})	5. Definition of angular acceleration. Also one of the angular mechanics equations in "simple" form. Assumes constant angular acceleration.
$\omega = 2\pi f$	ω	Angular freq (or velocity) (rad s^{-1})	6. Conversion equation since EVERY CIRCLE = 2π RADIANS In SHM, ω = angular frequency = rate of change of angle in reference circle.
	f	Frequency (Hz)	
$f = \frac{1}{T}$	T	Period (s)	7. Can be seen as $T = \frac{1}{f}$. f also known as "number of cycles per second"
$E_{K(ROT)} = \frac{1}{2}I\omega^2$	$E_{K(ROT)}$	Rotational Kinetic Energy (J)	8. can be paired with $E_{K(LIN)} = \frac{1}{2}mv^2$ and maybe $\Delta E_p = mgh$ for energy conservation (assumes no friction or energy-loss)… usually to find I
	I	Rotational Inertia (kg m^2)	

$\omega_f = \omega_i + \alpha t$	ω_f	Final Angular Velocity (rad s^{-1})	9,10,11,12. Angular Mechanics Set: Assumes constant angular acceleration. In same pattern as year 12 physics linear mechanics equation set. Must know 3 values to find other 2 values. Common mistake: using $\omega = \frac{\Delta\theta}{\Delta t}$ (constant speed equation) when NOT allowed (i.e. no acceleration).
	ω_i	Initial Angular Velocity(rad s^{-1})	
$\theta = \frac{(\omega_i + \omega_f)}{2} t$	α	Angular Acceleration (rad s^{-2})	
$\omega_f^2 = \omega_i^2 + 2\alpha\theta$	θ	Angular Displacement (rad)	
$\theta = \omega_i t + \frac{1}{2}\alpha t^2$	t	Time (s)	
$\tau = I\alpha$	τ	Torque (Nm)	13. Can be paired with $E_{K(ROT)} = \frac{1}{2} I\omega^2$ or $\tau = Fr$ or $L = I\omega$
	I	Angular Inertia (kg m^2)	
	α	Angular Acceleration (rad s^{-2})	
$\tau = Fr$	F	Force (N)	14. Can be paired with $\tau = I\alpha$. When doing angular acceleration with rope and mass: F = mg can be involved.
	r	Radius (or distance from fulcrum to force) (m)	
$L = mvr$	L	Angular Momentum (kg m^2 s^{-1})	15. Used for "car driving onto turntable", "bullet hitting spinner" and "astronauts on rope".
	m	Mass (kg)	
	v	Linear (tangential) Velocity (ms^{-1})	
$L = I\omega$			16. Used for helicopters, ice scatters and solid spinning masses.

Be familiar with the COMMON DIAGRAMS and GRAPHS in this unit:

1. Graphs of angular displacement vs time and angular velocity vs time
   - Gradient of θ vs t graph = angular velocity (ω)
   - Gradient of ω vs t graph = angular acceleration (α) and AREA of this graph = angular displacement (θ)
   - 1st graph shows constant angular velocity, then stationary (flat line) then negative angular velocity (spinning opposite direction) at a faster speed than at the start. Graph finishes with wheel exactly as it started (zero angular displacement).
   - 2nd graph shows stationary wheel, then spins backwards at constant angular velocity, then stops, then spins backwards again (at the same velocity) then finally stops.
   - 3rd graph shows constant angular acceleration from rest to a constant angular velocity (flat line) then an angular deceleration to a stop. Area of this parallelogram is the angular displacement.
   - 4th graph shows constant angular velocity, then a deceleration to a stop, then an angular acceleration in the OPOSITE direction to spin up the other way to a constant negative angular velocity.
2. Experiment diagram from angular acceleration of turntable (horizontal wheel) from linear motion of mass.
   - $?_1$ = tension force which equals $?_4$
   - $?_2$ = weight force (mg) which is theoretically slightly larger than tension so that mass accelerates downwards but the acceleration will be very small (usually less than 1m/s/s)
   - $?_3$ = net force on hanging mass (weight minus tension). Again, usually very small and most books ignore this and use tension = weight.
   - The turntable will acceleration because of the torque and $\tau = I\alpha = Fr$ can be used with the tension to find the rotational inertia of the table.

3. ball starting from rest uniformly accelerating (linearly and rotationally) down the ramp.
   - Conservation of energy situation.
   - Ball starts with gravitational potential energy (mgh). At bottom of ramp ball has BOTH linear kinetic and rotational kinetic energies.
   - Equation used is: $mgh = \frac{1}{2}mv^2 + \frac{1}{2}I\omega^2$.
   - With values given we can find rotational inertia (eventually):
   - $\theta = s/r = 9.6/0.07 = 137.14\ldots$ rad
   - $h = 9.6 \times \tan 22 = 3.878\ldots$m
   - $\theta = \frac{(\omega_i + \omega_f)}{2}t$ gives $\omega_f = \frac{2\theta}{t}$ with initial speed of zero: $\omega_f = 19.591\ldots$ rad/s
   - $v_f = r\,\omega_f = 1.37\ldots$ m/s
   - $I = \frac{2mgh - mv^2}{\omega^2}$ gives 0.00347… kg m^2

4. Solid and hollow cylinders rolled down same ramp from rest.
   - If both have the same mass, then the hollow object will reach the bottom LAST because the hollow object has MORE rotational inertia.
   - Mass distribution for the hollow object is farther from the centre of rotation, thus more rotational inertia.
   - Solid objects have mass distribution closer to the centre thus solid object have LESS rotational inertia.
   - Objects with less rotational inertia will have more of their gravitational potential energy converted into LINEAR kinetic energy and less into rotational kinetic energy, thus they reach the bottom faster.

5. Diagram for "helicopter" example where 2 masses rotate in opposite directions but angular momentum is conserved.
   - $?_1$ = the blades of the helicopter with smaller mass and smaller rotational inertia.
   - $?_2$ = the angular velocity of the blades
   - $?_3$ = the body of the helicopter with much more mass and much more rotational inertia
   - $?_4$ = the angular velocity of the body of the helicopter (assuming the rear rotors aren't working).
   - The angular momentum of the blades ($L=I_1\omega_1$) must equal the angular momentum of the body ($L=I_2\omega_2$) IF we ASSUME there are NO EXTERNAL TORQUES from friction or rear rotors.

6. Conservation of angular momentum example with turntable and movable masses that rotates at angular velocity ($?_1$).
   - As the masses move inwards like an ice skater pulling their arms inwards (the mass distribution changes) so that there is LESS rotational inertia.
   - Since L is conserved (because of no external torques) then the angular velocity INCREASES.
   - $L_{before} = L_{after}$ can be used with $L=I\omega$
   - The extra rotational kinetic energy (with masses closer to the center) comes form the work done pulling the masses closer to the centre (W=Fd).

7. Conservation of angular momentum with a bullet ($?_1$) moving at linear velocity ($?_2$) being "caught" by a pocket on a vertically mounted turntable.
   - The pocket has a smaller radius ($?_3$) than the wheel's radius ($?_4$).
   - The torque supplied by the bullet lodging into the pocket give the wheel rotational momentum with L=mvr using the pocket's radius and the bullet's mass and velocity.
   - Once spinning, if the pocket is moved to a larger radius ($?_4$) then the mass distribution is altered (like an ice skater letting their arms go out) and the wheel SLOWS down.
   - $L_{before} = L_{after}$ can be used with $L=I\omega$

Level 3 Physics SHM Review Sheet – ANSWERS

KNOW THE EQUATIONS:

Equation		Symbol's **complete** name And SI unit	Situation where equation is most commonly used (or notes about this equation).
$\omega = 2\pi f$	ω	Angular freq (or velocity) (rad s^{-1})	1. Conversion equation since EVERY CIRCLE = 2π RADIANS In SHM, ω = angular frequency = rate of change of angle in reference circle.
	f	Frequency (Hz)	
$f = \frac{1}{T}$	T	Period (s)	2. Can be seen as $T = \frac{1}{f}$. f also known as "number of cycles per second"
$a = -\omega^2 y$	a	Acceleration (linear) (ms^{-2})	3. SHM Equation. Both rules must be stated if asked "what is SHM?": 1st rule of SHM: $a = -\omega^2 y$ negative because acceleration ALWAYS back towards equilibrium (opposite direction to y) Also fulfils 2nd rule: acc directly proportional to y
	ω	Angular frequency (or velocity) (rad s^{-1})	
	y	Displacement from Equilibrium (m)	
$F = -ky$	F	Restorative Force (N)	4. Force could be paired with F=mg for springs to find k. NEGATIVE to show F opposes extension (y) and is in same direction as acceleration (#25)
	k	Spring Constant (Nm^{-1})	
$T = 2\pi\sqrt{\frac{l}{g}}$	T	Period (of pendulum) (s)	5. For simple 2D pendulums only. Can be paired with $f = \frac{1}{T}$ or $\omega = 2\pi f$ for SHM situations
	l	Length (of pendulum) (m)	
	g	Gravity (acceleration) (ms^{-2})	
$T = 2\pi\sqrt{\frac{m}{k}}$	m	Mass on spring (kg)	6. Period of mass on spring. For simple 1D mass motion (vertically usually). Can be paired with $f = \frac{1}{T}$ or $\omega = 2\pi f$ for SHM situations
$E = \frac{1}{2}ky^2$	E	Elastic Potential Energy (in spring) (J)	7. Can be paired with $E_{K(LIN)} = \frac{1}{2}mv^2$ or $\Delta E_p = mgh$ for energy conservation. At maximum amplitude y can be replaced with A to find "total energy".
$y = A\sin\omega t$	A	Amplitude of SHM (m)	8/9/10. Calculator MUST be in "radian" mode to do sin properly. SHM equation set for object starting at equilibrium moving UPWARDS. Can be expressed as PHASORS with y horizontal to right, v vertical and acc horizontal to left – all spinning anticlockwise at ω.
	ω	Angular Frequency (rad s^{-1})	
	t	Time since sine wave started (s)	
$v = A\omega\cos\omega t$	v	Linear velocity (ms^{-1})	
$a = -A\omega^2\sin\omega t$	a	Linear acceleration (ms^{-2})	
$y = A\cos\omega t$			11/12/13. Calculator MUST be in "radian" mode to do sin properly. SHM equation set for object starting at top of motion (momentarily motionless). Can be expressed as PHASORS with y vertically upwards, v horizontal to left and acc vertically downwards – all spinning anticlockwise at ω.
$v = -A\omega\sin\omega t$			
$a = -A\omega^2\cos\omega t$			

Be familiar with the COMMON DIAGRAMS and GRAPHS in this unit:

1. SHM phasors and graphs for mass on a spring STARTING from equilibrium moving UPWARDS.
   - ?$_1$ = equilibrium (where mass would be stationary). V_{max} happens here. a = 0 and y = 0 here as well.
   - ?$_2$ is the top of the SHM motion where y = A, v = 0 and a_{max} is downwards.
   - ?$_3$ is the bottom of the SHM motion where y = -A, v = 0 and a_{max} is upwards.
   - Linear acceleration is always towards equilibrium and always proportional to displacement.
   - ?$_4$ is the angular velocity of all 3 phasors which can be found with $\omega = 2\pi f$
   - The 1st phasor is for the displacement. Radius of circle = amplitude (A) of motion. The arrow points RIGHT to show location at equilibrium and moving upwards.
   - Time for each phasor = period of motion (T)
   - The 1st phasor makes a sine wave of height A and wavelength = period T
   - The 2nd phasor is for the linear velocity of the mass. Radius = $v_{max} = \omega A$. The arrow points upwards showing max velocity upwards at this location (equilibrium).
   - The 2nd phasor makes a cosine graph of height ωA and wavelength = period T.
   - The 3rd pasor is for the linear acceleration of the mass. Radius = $a_{max} = \omega^2 A$. The arrow points LEFT to show zero acceleration and that it will be negative just after leaving equilibrium.
   - The 3rd phasor makes a negative sine wave of height ω^2 A and wavelength = period T.
   - The 3 equations $y = A\sin\omega t$ $v = A\omega\cos\omega t$ and $a = -A\omega^2 \sin\omega t$ can be used for THIS situation but the calculator MUST be in RADIAN MODE.

2. Pendulum under SHM with forces drawn.
   - ?$_1$ = tension up the string. This changes while the mass swings but is only drawn at the left or right edge. At the centre the tension helps to create the centripetal force.
   - ?$_2$ = weight (mg)
   - ?$_3$ = net force which is 90° to the string (and tension)
   - ?$_4$ = the angle at the max amplitude from vertical
   - ?$_5$ = the horizontal amplitude of motion (A)
   - ?$_6$ = the force triangle made of these 3 forces. The angle in the triangle is between the tension and weight is the SAME as the angle between the string and the vertical.
   - Since the 3 forces are linked by the angle we can find forces by sine, cosine or tangent.
   - The hypotenuse in this triangle is always the weight force.

3. A phasor diagram for SHM showing how long a mass is MORE THAN 12cm from equilibrium in one complete cycle.
   - The amplitude of this motion is 14cm (radius of the circle). The period of motion is 2.5s (given).
   - Using $\cos^{-1}\frac{12}{14}$ we get θ = 31°
   - There are FOUR of these angles so total angle = 124°
   - Using $\frac{total\,\theta}{360} = \frac{time}{T}$ we can get t = $\frac{124 \times 2.5}{360}$ = 0.86s

4. Graph of pendulum's ENERGIES vs time
   - ?$_1$ = energy axis (in joules)
   - ?$_2$ = total energy of pendulum
   - ?$_3$ = time axis (in sec)
   - ?$_4$ = is the location of equilibrium (middle of swing) where EK is max and EP is minimum
   - ?$_5$ = the gravitational potential energy curve
   - ?$_6$ = the kinetic energy curve
   - At any time the gravitational potential energy and linear kinetic energy must add to the total energy (assuming there is no rotational energy involved)

5. Graph of displacement vs time for DAMPED SHM for 3 complete cycles of motion
   - $?_1$ = displacement axis (m)
   - $?_2$ = staring displacement BELOW equilibrium (mass on spring pulled down and let go)
   - $?_3$ = period of oscillation (T)
   - $?_4$ = 2nd period of oscillation (same as 1st)
   - $?_5$ = 3rd period of oscillation (same as 1st 2)
   - The amplitude of motion shrinks as energy of the system is lost to heat through friction but the period and frequency of motion does NOT change.

Level 3 Physics Int R, Kirchoff, Cap Review Sheet – ANSWERS

KNOW THE EQUATIONS:

$V = Ed$	V	Voltage of capacitor (V)	1. For DC capacitor circuit. E has direction (+ to -) and shows direction positive charge would move. V should eventually equal V of power source for charging capacitor
	E	Electric Field in capacitor (Vm^{-1})	
	d	Separation distance of plates (m)	
$\Delta E = Vq$	Δ E	Work (change in energy (J)	2. Can be used for moving charges (or test charges) through potential difference lines and the energy required (or released) as charges move. + charge moved to higher potential: GAINS energy. - charge moved to higher potential: LOSES energy.
	q	Charge (C)	
$E_{cap} = \frac{1}{2}QV$	E_{CAP}	Electrical Potential Energy (J)	3. can be paired with $Q = CV$ to give other equations of Energy like $\frac{1}{2}CV^2$ Only ½ of energy stored in capacitor. Other ½ lost to heat through R in DC circuit Can be used to find energy supplied by power source by removing ½
	Q	Charge stored on capacitor plates (C)	
$Q = CV$	C	Capacitance (F)	4. Charge and Voltage commonly used for descriptions of SERIES vs PARALLEL capacitors.
$C = \frac{\varepsilon_o \varepsilon_r A}{d}$	ε_o	Absolute Permittivity of Free Space ($F\ m^{-1}$)	5. Can be seen without ε_r if no dielectric between plates. Explains geometric relationships between C and A or d (directly proportional or inversely proportional).
	ε_r	Dielectric Constant (no unit)	
	A	Area of single capacitor plate (m^2)	
	d	Separation distance of plates (m)	
$\tau = RC$	τ	Time Constant (s)	6. Uses total R and total C of DC circuit. For charging: V_C is ≈ 63% maximum at τ and I is ≈ 37% of beginning value (max). For discharging V and I both drop. Takes ≈ 5 time constants to reach asymptote of graph (max or zero).
	R	Total Resistance (Ω)	
$V = IR$	V	Voltage (V)	7. OHM'S LAW for DC and AC ohmic resistor circuits.
	I	Current (A)	
$P = VI$	P	Power (W) aka "rate of energy used" (Js^{-1})	8. Commonly paired with $V = IR$ for alternative equations. Used in DC and AC circuits. For AC: ONLY "rms" values are allowed!!!
$R_T = R_1 + R_2 + \ldots$	R_T	Total Resistance (series) (Ω)	9. For DC or AC series resistors. Can be used with complex circuits once parallel parts reduced to singe R's.

$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+...$ R_T	Total Resistance (parallel) (Ω	10. For DC or AC parallel resistors. Can be used with complex circuits once series parts in single parallel row reduced to singe R's.
$C_T=C_1+C_2+C_3+\ldots$ C_T	Total Capacitance (parallel) (F)	11. For parallel (single capacitor per branch). Can be paired with $Q=CV$ for explanation of charge or voltage $E_{cap}=\frac{1}{2}QV$ for energy
$\frac{1}{C_T}=\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}+\ldots$ C_T	Total Capacitance (series) (F)	12. For series (single line of capacitors). Can be paired with $Q=CV$ for explanation of charge or voltage $E_{cap}=\frac{1}{2}QV$ for energy

Be familiar with the COMMON DIAGRAMS in this unit:

1. Circuit diagram for a **battery**. The emf is labelled "A" and the internal resistor is labelled "B".
   - The emf (or ε) is the voltage **without** current **AND** the voltage read if the battery is connected to a voltmeter without a circuit or current.
   - The internal resistor is always drawn on the **negative side** of the ε to show that electrons must go through this **imaginary** resistor before leaving the battery (using some of their voltage before getting to the circuit components).

2 and 3. This is the experimental circuit (#2) and the graph made from its reading (#3) for calculating internal resistance of **old** batteries.

In #2: "A" is the emf (ε), "B" is the internal resistor (r) and "C" is the variable resistor (R). The variable resistor, R, is changed many times to get measurements of current and voltage drop across R.

These values are graphed in #3.

- "A" is the voltage axis: voltage drop across R in volts.
- "B" is the current axis in amps.
- "C" is the vertical intercept with is not measurable AND is **equal to the emf** of the battery.
- "D" is the gradient of the straight line which is the **internal resistance**, r, of the battery.

The equation of the straight line: **V = -rI + ε** can be written as **IR = -Ir + ε** or **ε = I(R+r)**

None of these are given on the exam.

4. This is the diagram to make Kirchoff Voltage Law equations in closed loops where all **volts must add to zero**.
   - When crossing an emf moving towards the positive terminal, like "A", we write a **POSITIVE ε** in our equation.
   - When crossing an emf moving towards the negative terminal, like "B", we write a **NEGATIVE ε** in our equation.

5. This is the resistor diagram for Kirchoff's Voltage Law.
   - When moving WITH current, like "B", we write a **negative IR** in our equation.
   - When moving AGAINST current, like "A", we write a **positive IR** in our equation.

6. This circuit diagram with 2 switches is used for charging AND discharging the capacitor.
   - When the **top switch** is closed the capacitor will charge to the ε in **five time constants** τ which is found by τ = RC using the R in the charging circuit.
   - The **top** of the capacitor will be negative Q and the **bottom** plate will have positive Q from Q=CV.
   - The electric potential **energy stored** in the uniform electric field inside the capacitor is **HALF** of the energy given by the power source and can be found by: $E_{cap}=\frac{1}{2}QV$.
   - The other half of the energy has been **lost to heat** by the resistor, R.
   - When the top switch is then **opened** and the right switch is then **closed** the capacitor will **drain** through the bulb AND the resistor with a new time constant of **$\tau = R_{total}$ C**.
   - The bulb may light up brightly at first and then dim to nothing during the 5 time constants of dropping current as **electrons flow clockwise** through the right-loop circuit.

7. Circuit diagram of a charged capacitor with a dielectric between the plates.
   - The **right plate will be negative** Q (connected to the negative of the power source) and the left plate will be positive Q from Q=CV.
   - The dielectric is an **insulator** with a **dielectric constant of ε_o** that has **no units**.
   - The only equation used is: $C = \frac{\varepsilon_o \varepsilon_r A}{d}$.
   - The right side of the dielectric will **become positive by induction** (near the negative plate) and the left side will become negative, thus creating layers of charges **increasing the electric field and capacitance**.

8. This is the charging-capacitor graph of voltage across the capacitor vs time.
   - "A" is the voltage across the capacitor in volts.
   - "B" is the time after the switch is closed in seconds.
   - "C" is the voltage of the power source.
   - "D" is **63% of this voltage** that happens **at one time-constant** τ = RC which is labelled "E".
   - At **five** time-constants "F" the voltage reaches its maximum.

9. This could by MANY different graphs:
   - the current in a charging OR discharging capacitor circuit,
   - the voltage across the resistor in a charging-capacitor circuit,
   - the voltage across a resistor OR capacitor in a discharging circuit.

   If it is the current vs time graph:
   - "A" = current in amps,
   - "B" is time in seconds",
   - "C" is the maximum current when the switch is closed found by $I=V/R_{total}$,
   - "D" is **37% of this maximum** current at one time-constant τ = RC which is labelled "E".
   - The current finally stops at **five** time-constants, "F".

   If it is the voltage across the resistor in charging or discharging circuits then
   - "A" is voltage,
   - "C" is the voltage of the power source (for charging circuits) or the capacitor (for discharging).
   - "D" is still **37%** of this voltage.

Level 3 Physics Induced Voltage Review Sheet – ANSWERS

KNOW THE EQUATIONS:

$\phi = BA$	ϕ	Flux (Wb)	1. B and A have to be 90° to each other. If not 90° then a sin or cos of angle will be needed to find perpendicular bit of B.
	B	Magnetic Field (T)	
	A	Cross-sectional Area (m^2)	
$\phi = LI$	L	Inductance (H)	2. Alternative equation for flux. Used for solenoids (coils).
	I	Current (A)	
$\varepsilon = -L\frac{\Delta I}{\Delta t}$	ε	Induced Voltage (or EMF) (V)	3. Lens' Law: Usually for DC inductor circuits (aka: solenoid, electromagnet, coil). Negative because voltage induced creates current that oppose change in current (and induces B-field to oppose changing B-field). Right hand grip rule used for current/B-field directions.
	L	Inductance of coil (H)	
	Δ I	Change in Current (in coil) (A)	
	Δ t	Change in time (s)	

<table>
<tr><td rowspan="2">$\varepsilon = -\frac{\Delta\phi}{\Delta t}$</td><td>$\varepsilon$</td><td>Induced voltage (or emf) (V)</td><td rowspan="2">4. Faraday's Law: Usually for bar magnet (or electromagnet) moving (or turning on/off) next to coil or loop. Negative because voltage induced creates B-field to oppose changing B-field.
Right hand grip rule used for current/B-field directions.</td></tr>
<tr><td>$\Delta\ \phi$</td><td>Change in flux (Wb)</td></tr>
<tr><td rowspan="2">$\varepsilon = -M\frac{\Delta I}{\Delta t}$</td><td>$\varepsilon$</td><td>Induced voltage (secondary coil) (V)</td><td rowspan="2">5. Lens' Law for Transformers:
Secondary coil induced voltage is NEGATIVE to show opposing induced B-field or induced current.</td></tr>
<tr><td>M</td><td>Mutual Inductance (H)</td></tr>
<tr><td rowspan="4">$\frac{N_p}{N_s} = \frac{V_p}{V_s}$</td><td>$N_P$</td><td>Number of Turns (primary) (no unit)</td><td rowspan="4">6. Transformer Equation:
Used with $P_{in} = P_{out}$.
Can be used with $\varepsilon = -M\frac{\Delta I}{\Delta t}$</td></tr>
<tr><td>N_S</td><td>Number of Turns (secondary) (no unit)</td></tr>
<tr><td>V_P</td><td>Voltage (primary) (V)</td></tr>
<tr><td>V_S</td><td>Voltage (secondary) (V)</td></tr>
<tr><td rowspan="3">$E = \frac{1}{2}LI^2$</td><td>E</td><td>Electrical Potential Energy (J)</td><td rowspan="3">7. Electrical Potential Energy stored in inductor (coil/solenoid) while current flows (and electromagnetic field exists).
Similar to $E_{cap} = \frac{1}{2}QV$. Same use of ½ in equation.</td></tr>
<tr><td>L</td><td>Inductance (H)</td></tr>
<tr><td>I</td><td>Current (A)</td></tr>
<tr><td rowspan="2">$\tau = \frac{L}{R}$</td><td>τ</td><td>Time Constant of Coil (s)</td><td rowspan="2">8. Similar to $\tau = RC$. Uses total R and total L of DC circuit.
For closing switch: V_L is ≈ 37% beginning value at τ and I is ≈ 67% of maximum.
For opening switch: large negative emf made since Δt small and $\varepsilon = -\frac{\Delta\phi}{\Delta t}$
Takes ≈ 5 time constants to reach asymptote of graph (max or zero).</td></tr>
<tr><td>R</td><td>Resistance of circuit (Ω)</td></tr>
</table>

Be familiar with the COMMON DIAGRAMS and GRAPHS in this unit:

1. Coil entering magnetic field (into page), going through magnetic field and then coming out of magnetic field at constant speed.
   - As coil enters there is a change in magnetic field INSIDE the coil, thus there is a change in flux inside the coil.
   - $\phi = BA$ can be used with the number of turns added (N).
   - This change in flux will induce a voltage (back EMF) $\varepsilon = -\frac{\Delta\phi}{\Delta t}$.
   - This induced back-EMF will induce its own current in the coil (V=IR).
   - This induced current will create a NEW magnetic field inside the coil in a direction to FIGHT THE CHANGE in flux.
   - While coil enters magnetic field, coil makes its own magnetic field out of the page (dots).
   - With right-hand-grip-rule this tells us the current induced is anticlockwise.
   - When the coil is entirely inside the magnetic field there is no more change in flux, thus no votage or current induced.
   - When the coil exits the magnetic field the flux drops to zero, thus there is a new back-EMF, current and magnetic field induced to fight the change in flux.
   - The coil induced a magnetic field INTO the page (x's) which means the induced current is clockwise.
   - The graph of induced EMF vs time would have one positive "bump" as coil enters, zero volts as coil glides through field, and one negative "bump" as coil exits. Since constant speed both "bumps" are mirror images of each other.

2. Bar magnet dropped through solenoid with galvanometer attached in series (as ammeter that reads microAmps)
   - Similar to #1 but this time the magnet moves instead of the coil.
   - Since the magnet accelerates with gravity (freefall) the positive "bump" on the graph will not be mirror image to the negative "bump".
   - The voltage and current induced while the magnet leaves will be LARGER because the magnet will be going faster and Δt will be SMALLER.
   - The negative "bump" (of the magnet leaving) will be taller and thinner than the positive "bump" (of the magnet entering).

3. Coil spinning in magnetic field (dynamo or generator).
   - Flux vs time graph would be a COSINE graph because of the original position of the horizontal coil having a maximum number of magnetic field lines going perpendicular to it's area.
   - Induced emf vs time graph would be a SINE graph because the induced emf is made by the change in flux… thus the gradient of the flux vs time graph tells us how much emf is induced.
   - Both graphs would have the same wavelength, which is the period T of rotation.
   - BUT the negative in the equation $\varepsilon = -\frac{\Delta\phi}{\Delta t}$ tells us the emf is induced to fight the change in flux, thus we don't get a negative sine wave (but a positive sine wave!)

4. DC circuit with resistor (R_1), ammeter, power-source (V), coil with self-inductance ($?_1$= L measured in Henrys (H)).
   - The inductor (coil) has its own resistance ($?_2$) because of it own very long wire, thus the total resistance must be R_1 plus this other resistance.
   - When the switch is closed the current will take time to reach its maximum value (found by $I = V/R_{total}$).
   - The 1st graph could be I vs t with $?_3 = I_{max}$.
   - $?_4$ = 63% of this max value.
   - $?_5$ = the time constant $\tau = \frac{L}{R_{Total}}$.
   - $?_6$ = 5 time constants (time needed to reach max value)
   - The 1st graph could ALSO BE a voltmeter reading. As the current rises the voltage used by R_1 will also rise. And even a voltmeter around the inductor could be this shape with $V_{max} = Ir$.
   - The 2nd graph is the INDUCED back-emf when the switch is closed.
   - $\varepsilon = -L\frac{\Delta I}{\Delta t}$ can be used.
   - $?_7$ = the power-source voltage (in the opposite direction to the power source)
   - $?_8$ = 37% of this voltage which happens at the 1st time constant.
   - Like the 1st graph, this should take 5 time constants to reach zero.

5. A transformer with a DC power-source ($?_1$) for the primary coil ($?_2$). The secondary coil ($?_3$) is connected to its "load" of resistance $?_4$.
   - When the switch is closed the primary coil will become an electromagnet and create a change in flux inside the secondary coil.
   - This change in flux will induce a voltage (emf) in the secondary coil with the equation: $\varepsilon_{Secondary} = -M\frac{\Delta I_{Primary}}{\Delta t}$.
   - M is the "mutual inductance" in Henrys that explains how the coils work against eachother to create this emf.
   - The ratio of voltages (primary vs secondary) is the same as the ratio of turns.
   - The equation $\frac{N_p}{N_s} = \frac{V_p}{V_s}$ explains this.
   - If we ASSUME 100% efficiency then we can use $P_{primary} = P_{secondary}$ to calculate current in the secondary circuit.
   - But some energy will always be lost to heat (and possible motion and sound) in transformers.
   - To minimise eddy-currents and eddy-magnetic fields LAMINATED iron cores are used.

6. Inductors wired in series to a "regular bulb" and in parallel to a "neon bulb" with a 9V source.
   - In the 1st circuit (series) the regular bulb will take some time to reach full brightness (see description of diagram #4).
   - When the switch is opened there MIGHT be a spark across the switch and the bulb MIGHT flash (or blow) because of the very large induced emf as the current falls to zero in a very short time.
   - In the 2nd circuit (parallel) the neon bulb will NEVER work with only 9V. Much more is needed.
   - So even with the switch closed no light will be seen BUT the inductor will store energy in its magnetic field.
   - When the switch is opened the current falls to zero in a very short time and a LARGE emf is induced. This will create a current in the neon bulb and it will FLASH then go off.

Level 3 Physics Alternating Current Review Sheet – ANSWERS

KNOW THE EQUATIONS:

Equation	Symbol	Symbol's **complete** name And SI unit	Situation where equation is most commonly used (or notes about this equation). Use your own paper
$I = I_{MAX}\sin\omega t$	I	Current (generator wave) (A)	1, 2. Both for generators spinning at ω making AC. Both are in phase.
	I_{MAX}	Maximum Current (wave ht) (A)	
	ω	Angular frequency (rad s^{-1})	Can use V=IR. V_{MAX}=BANω from generator. Can use "rms" conversions.
	t	Time since sine wave started (s)	
$V = V_{MAX}\sin\omega t$	V	Voltage (generator wave) (V)	Calculator must be in "radian" mode for correct answer.
	V_{MAX}	Maximum Voltage (wave ht) (V)	
$I_{MAX} = \sqrt{2}\,I_{rms}$	I_{MAX}	Current wave height (A)	3, 4. Conversion equations based on AC and DC circuit having equal POWER. "rms" values given on DIGITAL meters. "max" values show as wave heights on oscilloscope.
	I_{RMS}	Current as from DC (A)	
$V_{MAX} = \sqrt{2}\,V_{rms}$	V_{MAX}	Voltage wave height (V)	
	V_{RMS}	Voltage as from DC (V)	
$X_C = \frac{1}{\omega C}$	X_C	Reactance of Capacitor (Ω)	5, 6. Usually paired with $\omega = 2\pi f$. X_C and X_L in "opposite direction" Explain how C and L and f relate to how capacitor or coil BECOME resistors with AC circuits. Can be used with PYTHAGORAS to find Impedance, Z. Can be set EQUAL to each other with $\omega = 2\pi f$ to find **resonant frequency**. X_L = resistance to changing current. Capacitors "like" changing current, inductors "hate" changing current.
	ω	Angular frequency (rad s^{-1})	
	C	Capacitance (F)	
$X_L = \omega L$	X_L	Reactance of Inductor (Ω)	
	L	Inductance (H)	
$\omega = 2\pi f$	ω	Angular Frequency (rad s^{-1})	7. Also known as "angular velocity". In AC section: used for generator frequency.
	f	Frequency (Hz)	
$V = IZ$	V	Voltage (V)	8. OHM'S LAW for entire AC circuit. V = source voltage. Z = impedance (like total R) includes R can include X_C and/or X_L but using Pythagoras. Z = resistance to current AND resistance to changing current COMBINED
	I	Current (A)	
	Z	Impedance (Ω)	

Be familiar with the COMMON DIAGRAMS and GRAPHS in this unit:

1. AC circuit with one resistor, generator, ammeter and voltmeter.
   - The phasor is for the voltage across the resistor.
   - The radius of the circle is the V_{max} and the arrow $?_1$ is drawn to the right.
   - The arrow spins at $?_3$ the angular velocity (or angular frequency) $\omega = 2\pi f$.
   - The current arrow $?_2$ is also drawn to the right to be IN PHASE with the voltage V_R.
   - The graph is the voltage across the resistor, V_R, and the current in the circuit.
   - $?_4$ is the period, T.

2. AC circuit with capacitor, generator, ammeter and voltmeter.
   - The phasor is for the voltage across the capacitor.
   - Capacitors in AC act like resistors because of the continually changing direction of the electrons and the continual "flip-flop" of the polarity of the capacitor plates.
   - This is called reactance and $X_C = \frac{1}{\omega C}$ can be used with $\omega = 2\pi f$.
   - The arrow $?_1$ is the $V_{C\,MAX}$ and is drown DOWNWARDS and spins at the angular velocity $?_3$.
   - The current arrow, $?_2$, is still drawn to the right.
   - The graph shows that the V_C is ¼ λ out of phase with the current.
   - The current LEADS the capacitor voltage by 90° or ¼ λ.
   - $?_4$ is the period, T.

3. AC circuit with "perfect" inductor, generator, ammeter and voltmeter.
   - The phasor is for the voltage across the perfect inductor (no resistance of long wire included).
   - Inductors in AC act like resistors because of the continually changing flux inside the coil with continually induces voltage to oppose the change in flux.
   - This is called reactance and $X_L = \omega L$ can be used with $\omega = 2\pi f$.
   - The arrow $?_1$ is the $V_{L\,MAX}$ and is drown UPWARDS and spins at the angular velocity $?_3$.
   - The current arrow, $?_2$, is still drawn to the right.
   - The graph shows that the V_L is ¼ λ out of phase with the current.
   - The inductor voltage LEADS the current by 90° or ¼ λ.
   - $?_4$ is the period, T.

4. RC AC circuit with an ammeter and 3 voltmeters: V_S, V_C and V_R
   - This time the voltage phasor has 3 arrows:
   - $?_1 = V_{R\,MAX}$ and is drawn to the RIGHT
   - $?_2 = V_{C\,MAX}$ and is drawn DOWNWARDS
   - $?_3$ = the source voltage, V_S, and if found by PYTHAGORAS.
   - The reactance of the capacitor, X_C, and the resistance, R, make the impedance, Z, also with pythagoras.
   - All 3 arrows spin anticlockwise at the angular frequency, $?_4$, of $\omega = 2\pi f$.
   - $?_5$ = the current and is still drawn to the RIGHT.
   - The graph is for $V_{R\,MAX}$ of $?_1$ and $V_{C\,MAX}$ of $?_2$ that have the period, T of $?_6$.
   - The resistor voltage LEADS the capacitor voltage by 90° or ¼ λ.

5. LR AC circuit with an ammeter and 3 voltmeters: V_S, V_L and V_R
   - This time the voltage phasor has 3 arrows:
   - $?_1 = V_{R\,MAX}$ and is drawn to the RIGHT
   - $?_2 = V_{L\,MAX}$ and is drawn UPWARDS
   - $?_3$ = the source voltage, V_S, and if found by PYTHAGORAS.
   - The reactance of the inductor, X_L, and the resistance, R, make the impedance, Z, also with pythagoras.
   - All 3 arrows spin anticlockwise at the angular frequency, $?_4$, of $\omega = 2\pi f$.
   - $?_5$ = the current and is still drawn to the RIGHT.
   - The graph is for $V_{R\,MAX}$ of $?_1$ and $V_{L\,MAX}$ of $?_2$ that have the period, T of $?_6$.
   - The inductor's voltage LEADS the resistor's voltage by 90° or ¼ λ.

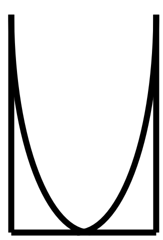
6. LRC AC circuit with an ammeter and 4 voltmeters: V_S, V_C, V_L and V_R
   - This time the voltage phasor has 4 arrows:
   - ?$_1$ = $V_{R\ MAX}$ and is drawn to the RIGHT
   - ?$_2$ = $V_{L\ MAX}$ and is drawn UPWARDS
   - ?$_3$ = $V_{C\ MAX}$ and is drawn DOWNWARDS
   - ?$_4$ = the source voltage, V_S, and if found by pythagoras… BUT first you have to SUBTRACT V_C and V_L before using V_R
   - The reactance of the inductor, X_L, the reactance of the capacitor, X_C, and the resistance, R, make the impedance, Z, also with pythagoras. Again you have to SUBTRACT X_L and X_C before squaring.
   - ?$_6$ = the current and is still drawn to the RIGHT.
   - The graph is for $V_{C\ MAX}$ of ?$_3$, $V_{R\ MAX}$ of ?$_1$ and $V_{L\ MAX}$ of ?$_2$ that all have the period, T of ?$_7$.
   - V_C and V_L are 180° or ½ λ out of phase.

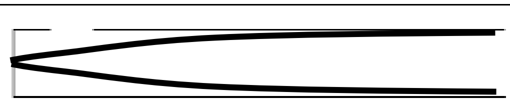
7. Graph of Current vs Frequency of generator
   - Vertical axis is Current in an LRC circuit
   - Horizontal axis is the frequency of the generator in the LRC circuit.
   - As frequency increases it changes BOTH reactances: X_L and X_C.
   - At the RESONANCE frequency, ?$_3$, the 2 reactances are EQUAL and the 2 voltages (V_C and V_L) are equal and opposite (180° out of phase).
   - We use this to put the 2 equations together and calculate the resonant frequency, f_o:

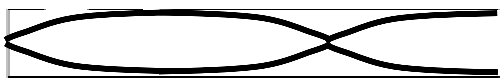
$$X_C = X_L = \frac{1}{\omega C} = \omega L$$

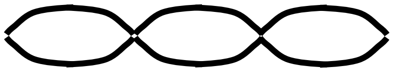
   - At resonance fregquncy we get MAXIMUM current in the LRC circuit because the impedance, Z, is the smallest value possible of Z = R.
   - The source voltage is also the smallest possible value of $V_S = V_R$ at this frequency.

Standing Waves & Beats Revision Questions - answers

One (a)	Standing waves / Resonance	[1] Correct		
(b)		[1] Correct		
(c)	λ=4L = 4 x 0.640 = 2.56 m f = v/λ = 330/2.56 = 129Hz		[2] Correct working	
(d)	3rd harmonic frequency = 3 x 129Hz = 387Hz	[2] Correct		
(e)	Increase the pitch/frequency of his song (not change wavelength)	[1] Change the pitch / Frequency	[1] Increase pitch / Frequency	
(f)	There is now an antinode at each end of the tube, making the wavelength shorter, and the frequency higher.		[1] Incomplete/ 2 nodes/ got it backwards	[1] Complete explanation

TWO (a)		[1] Correct answer.		

(b)	$\lambda = 4L$ $= 4 \times 0.60$ $= 2.40$ m	[2] Correct answer.		
(c)	He has blown hard enough to excite a higher harmonic. As there is more energy being put in, the response of the tube is at a higher frequency.	[1] He has blown hard enough to excite a higher harmonic.	[1] Achievement plus valid explanation.	
(d)		[1] Correct pattern, consequential on (a), antinode must be at the hole.		
(e)	A hole at 20 cm allows an antinode to exist at this point. This means that ¼ of a wavelength fits into 1/3 of a tube. As ¾ of a wavelength takes up 60cm, 1/3 0f this must be at 20 cm.		[1] Correct answer	[1] Correct answer, clearly stating the connection between the pattern, the length of the tube and presence of an antinode at the hole
(f)	$\lambda/4 = 0.20$ m $\lambda = 4 \times 0.20$ m $= 0.80$ m $f = v/\lambda = 340 \div 0.8 = 425$ Hz	[2] correct calculation of wavelength, consequential on (d).	[2] Correct answer	
(g)	$\Delta f = \lvert f_1 - f_2 \rvert = 5.0 Hz$ $\Rightarrow \lvert 560 - f_2 \rvert = 5$ $\Rightarrow f_2 = 560 \pm 5$ i.e. 555Hz or 565Hz	[2] One correct frequency.	[2] Both frequencies correct.	
(h)	Because there is a frequency difference between them, the two waves arrive either in or out of phase at Stuart's ear at a rate of 5 times a second. When they are out of phase the net sound is quiet, when they are in phase, they sound loud. Diagram will attempt to show two sine waves of slightly different frequencies adding together to make a resultant sin wave with regular fluctuations in amplitude		[1] correct explanation or diagram.	[1] correct explanation with clear linkage between concepts of waves in and out of phase and their arrival at Stuart's ear, in a regular fashion.
THREE (a)	$\lambda = 2 \times 0.75m = 1.5m$ $v = f\lambda = 128 \times 1.5 = 192 ms^{-1}$		[2] Correct answer.	
(b)	The quality depends on the relative amplitude of each of the harmonics stimulated by the playing action. The piano string can support twice as many harmonics as the flute and consequently more frequencies can contribute to the overall sound		[1] *different harmonics present.*	[1] Correct answer.

(c)(i)	 New wavelength is 0.5m which is 1/3 of fundamental. So new frequency is 3 times the fundamental which is 128 x 3 = 384 Hz	[1] Correct diagram.	[2] Correct frequency	
(c)(ii)	Unit is s^{-1} (not Hertz)	[1] Correct answer.		

Doppler Revision Questions ANSWERS

ONE(a)	Doppler Effect	[1] Correct		
(b)	The craft travels away from earth during each period. This increases the apparent wavelength of the wave, which decreases the frequency of waves received, as the speed of light must remain constant.		[1] Increased wavelength: constant speed of light.	
(c)	$f = \dfrac{4\times10^6 \times 299{,}792{,}458}{(299792458+28853)}$ $= 3999620Hz$ [accept 3999615, 4000000, 3999600]	[2] Correct answer		
(d)	Beats: superimpose the two waves: reflected wave must be significantly amplified first or both waves should be of similar amplitude: observe the frequency of oscillation of the change in amplitude.	[1] Beats	[1] Super-impose the waves.	[1] Complete explanation
(e)	Since the light source is moving away, any light detected by the observer will experience a Doppler shift. The increased wavelength resulting from this causes light to be shifted to the red end of the spectrum.	[1] Doppler Effect	[1] Explanation including increased wavelength.	[1] Red Shift

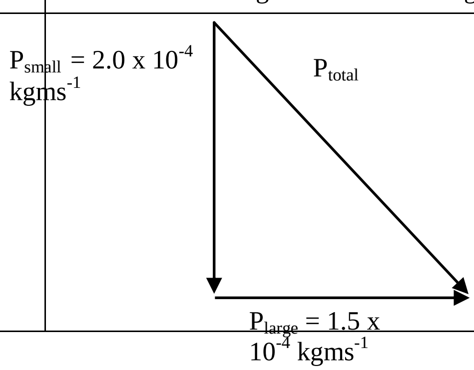
TWO (a)	The apparent change in frequency of a wave due to the motion of the source or of the receiver	[1] Correct explanation		
(b)	$\lambda' = \dfrac{c}{f'} = \dfrac{3.00 \text{ x } 10^8}{1.276\times10^{10}}$ = 0.0235	[2] Correct working and answer		
Sf	3 sf	[1] Correct sf		
(c)	$f' = f(\dfrac{v_w}{v_w - v_s})$ $= 630(\dfrac{330}{330-25.0})$ = 681.63 Hz = 682 Hz		[2] Correct working and answer	
(d)	As the ambulance approaches the policeman the same number of waves is contained in a shorter distance. So the apparent wavelength is shorter. Since the speed of sound in air is constant the apparent decrease in wavelength causes an apparent increase in frequency.		[1] Correct answer	

Diffraction & Interference Revision questions - ANSWERS

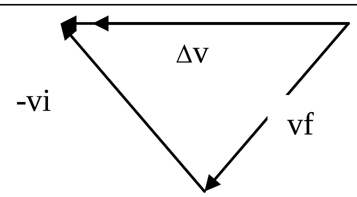
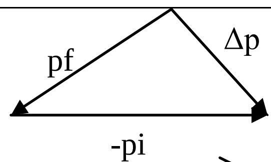
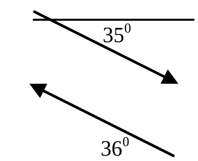
		Achieved	Merit	Excellence
1(a)	Central maximum	Correct answer.		
(b)	$\lambda = \frac{v}{f} = \frac{340}{680} = 0.5m$ $n\lambda = d\sin\theta$ gives: $\theta = \sin^{-1}\frac{n\lambda}{d}$ = 9.59… $x = L\tan\theta$ = 2.535… = 2.5m Using other formula: $\lambda = \frac{d\Delta x}{L} \Rightarrow \Delta x = \frac{L\lambda}{d} = \frac{15\times 0.5}{3} = 2.5m$	*Correct calculation of λ but inability to proceed.*	*Correct calculation of Δx using incorrect value of λ.*	Correct answer.
(c)	Sin wave shape graph (or cosine) but B must have high loudness	Correct diagram.		
(d)	It is not possible to observe an interference pattern with red lights in this fashion as the spacing of the two sources is too much bigger than the wavelength. The sources are also not point sources and the lack of coherence in the waves will also mean that a clear interference pattern will not be seen.		Correct answer.	
(e)	Requires use of the blue wavelength and determining the value of 'n' for which the diffracted angle is 90 $d\sin\theta = n\lambda$ $n = \frac{d\sin\theta}{\lambda} = \frac{1\times 10^{-6}\times\sin 90^\circ}{4.5\times 10^{-7}} = 2.2$ Hence there are only 2 full spectra to be seen.		*Correct idea but incorrect maximum angle or incorrect interpretation of value of n.*	Correct answer
(f)	$n\lambda = \frac{dx}{L}$ $n = 1 \Rightarrow \lambda = \frac{dx}{L} = \frac{1\times 10^{-6}\times 5\times 10^{-2}}{0.1}$ $\Rightarrow \lambda = 5\times 10^{-7} m$	Correct answer.		
2(a)	The path difference is half a wavelength so if the transmitters broadcast in phase one signal will cancel the other as the signals will arrive out of phase.	Destructive interference	Explanation including path difference or crest meets trough.	
(b)	A and/or B as are both antinodes/ places of constructive interference.	A or B plus explanation.	A & B plus concise explanation.	
(c)	It would get louder, quieter, louder before the corner: after the corner it remains loud as he drives along the central maximum.		Central maximum remains loud OR Louder and quieter (as he passes nodes and antinodes.	Louder and quieter (as he passes nodes & antinodes) AND stays loud after corner.
(d)	$1 \times 200 = \frac{1.00\times 10^4}{4.00\times 10^4}\,x$ x = 800m	Correct calculation		

(e)	$\lambda = c / f$ $\lambda = \frac{3.00 \times 10^8}{89.2 \times 10^6} = 3.36m$ $\frac{0.5 \times 3.34 \times 40 \times 10^3}{10 \times 10^3} = 6.72m$		Correct calculation	
(f)	$\frac{n_1 \lambda_1 L}{d} = \frac{n_2 \lambda_2 L}{d}$ $\frac{n_1 c}{f_1} = \frac{n_2 c}{f_2}$ $\frac{n_1}{n_2} = \frac{f_1}{f_2} = \frac{90}{99} = \frac{10}{11}$ $n_1 = 10$ $x = \frac{10 \times 3.33 \times 4.00 \times 10^4}{1.00 \times 10^4}$ $x = 133m$			Correct answer [accept rounded answer with correct working]

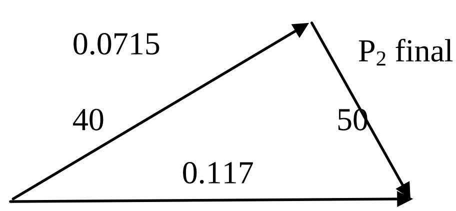
Centre of Mass and Translational Motion Revision Questions

ONE (a)	**SHOW CoM 44cm to the stacked trolleys:** $\frac{m_1}{m_2} = \frac{d_2}{d_1} = \frac{1}{2}$ hence 132cm is split on a 2:1 ratio 88:44 with the 44cm closest to the stacked trolleys	[2] Correct working shown (can be diagrammatic).		
(b)	**SHOW momentum = 0.11kgms^{-1}:** The only moving object is the single trolley hence its momentum is the total momentum which is the momentum of the COM, p = mv = 0.5 kg x 0.22 ms^{-1}	[2]Calculation performed to show that the total momentum is 0.11kg ms^{-1}.	***[1] Statement that total momentum held by trolley 1 before collision but no clear link to COM.***	***[1]Correct answer linking total momentum and COM momentum.***
(c)	P_{after} = 0.11kg ms^{-1}	[1]Correct answer.		
(d)	$v_{CoM} = P_{after}/m_{total}$ = 0.11kg ms^{-1} ÷ 1.5kg = 0.0733333 ms^{-1}	[2]Correct answer.		
	Significant figures	[1]2 s.f.		
(e)	**SHOW each momentum:** P_{large} = mv =0.005 kg x 003 ms^{-1} = 15 x 10^{-5} kgms^{-1} = 1.5 x 10^{-4} kgms^{-1} P_{small} = mv =0.002 kg x 010 ms^{-1} = 20 x 10^{-5} kgms^{-1} = 2.0 x 10^{-4} kgms^{-1}	[2]Correct answer.		
(f)		1Correct arrow directions and labels.		

ONE (g)	$P_{total} = \sqrt{\left(P_{large}^2 + P_{small}^2\right)}$ $= 2.5\times10^{-4}\,kgms^{-1}$ $v_{CoM} = \frac{P_{total}}{m_{total}} = \frac{2.5\times10^{-4}\,kgms^{-1}}{7\times10^{-3}\,kg}$ $= 3.6\times10^{-2}\,ms^{-1}$		2calculation of vCoM total without use of vector nature of momentum	*2correct calculation of vCoM*

TWO (a)	Disc has lost speed therefore lost KE Therefore collision is **inelastic**	**inelastic**	correct reason	
(b)	the disc has an outside force on it so momentum is not conserved	correct reason		
(c)	Δp= $p_f - p_i$ = 0.225(-0.47 - 0.53) = **-0.225 ≈ -0.23 kgms^{-1}** Δp is to the **LEFT**	correct **size**	***correct size and*** *direction*	
(d)	F = Δp/ Δt = -0.225/0.12 = **-1.875 ≈ -1.9 N** **1.9 N to LEFT**	correct **size**	***correct size and*** *direction*	
(e)	**1.875 ≈ 1.9 N to RIGHT**	correct **size**	***correct size and*** *direction*	
(f)	 Δv = 2 x (0.4cos 30^0) = **0.6928…≈ 0.69 ms^{-1}** to the **LEFT** (or West)	correctly labelled vector **diagram**.	correctly labelled vector diagram. correct **size**	***correctly labelled vector diagram. correct size and*** *direction*
TWO (g)	 This shows the change in momentum of the black puck. Δp = 0.068… kgms^{-1} at 35.85…^{0}  The change in momentum of the white puck is equal and opposite. . Δp = 0.068 kgms^{-1} at 36^0 velocity of black puck is **0.30 ms^{-1} at 36^0**	correct **diagram**	Correct **calculation** of momentum	correctly labelled vector diagram. correct **size and direction**

3. (a) p initial = p final (vectors)



magnitudes

p_1 initial = 0.065 x 1.8 = 0.117 kg ms^{-1}

p_1 final = 0.065 x 1.1 = 0.0715 kg ms^{-1}

p_2 final = ?

Using Pythagoras. (p_2 final)^2 + 0.0715^2 = 0.117^2

(P_2 final)^2 = 0.0137 - 0.00511 = 0.00859

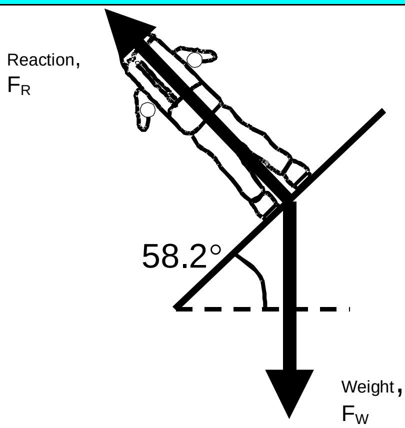
p_2 final = 0.0927 kg ms^{-1}

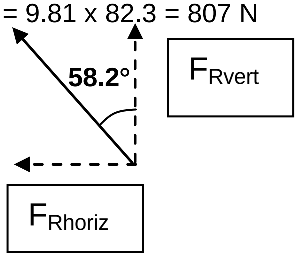
v = p/m = 0.0927/0.065 = 1.43 ms^{-1}

(b) KE (1.before) = ½ mv^2 = ½ x .065 x 1.8^2 = 0.105 J

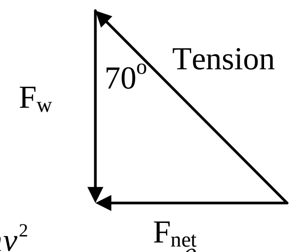
KE (1.after) = ½ mv^2 = ½ x .065 x 1.1^2 = 0.0393 J
KE (2.after) = ½ mv^2 = ½ x .065 x 1.43^2 = 0.0665 J
KE (total after) = 0.0393 + 0.0665 = 0.106 J
So energy is not lost so the collision is elastic.

Circular Motion Revision Questions ANSWERS

One (a)		1. Forces drawn in but no labels	1. Both forces correctly drawn and labelled including reaction at right angles to slope	
(b)	The horizontal component of the reaction force provides the necessary centripetal force to create the circular motion	1. idea of centripetal force linked to another force	1. Correct answer or labelled diagram	

(c)	F_W = 9.81 x 82.3 = 807 N  $F_{Rvert} = F_W$ = 807 N $F_R = \dfrac{F_{Rvert}}{\cos 58.2°} = \dfrac{807....}{\cos 58.2°}$ = 1530 N	[2] correct answer for F_w / F_{Rvert}	[2] correct answer for F_{Rvert} some attempt at finding F_R	[2] correct working and answer
(d)	F_{Rhoriz} = 807….tan58.2° = 1300 N	[2] correct working and answer		
(e)	$F_C = F_{Rhoriz}$ = 1301… N $v = \sqrt{\dfrac{F_C r}{m}} = \sqrt{\dfrac{1301....x7.93}{82.3}}$ = 11.2 ms^{-1}	[1] Correct to 3 sig figs	Correct working except forgot to √	[2] correct working and answer
(f)	She would slide down the slope to the inside of the turn. This is because she no longer has vertical equilibrium as F_{Rhoriz} is lower (from lower F_C needed now to turn) so F_R is lower so F_{Rvert} is less than F_W		[1] Slide down to the inside	[1] Succinct and clear answer

TWO (a)	Any object moving in a circular path must have a net force on it, directed towards the centre in order for it to maintian that circular path.	[1]Correct answer		

(b)	$g = \frac{F_g}{m_{ball}} = \frac{Gm_{earth}m_{ball}}{r^2} \div m_{ball}$ $= \frac{Gm_{earth}}{r^2}$ $= \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{(6.37 \times 10^6)^2}$ $= 9.83ms^{-2}$		[2]Correct answer	
(c)	 $\frac{mv^2}{r} \div mg = \tan\theta$ $v^2 = rg\tan\theta$ $v = \sqrt{rg\tan\theta}$ $r = 1.18\sin 70 = 1.11m$ $\Rightarrow v = \sqrt{1.11 \times 9.83\tan 70}$ $\Rightarrow v = 5.48ms^{-1}$		[2] Incorrect answer showing some appropriate reasoning involving vector arrangement of forces (e.g. vector triangle is a closed one)	[2]Correct answer, must show use of vector forces and appropriate trigonometric relationship.

THREE (a)	$F_G = \frac{GM_1M_2}{R^2}$ $F_G = \frac{6.67 \times 10^{-11} \times 5.41 \times 10^{24} \times 4.32 \times 10^4}{(6.682 \times 10^6)^2}$ $F_G = 349135 = 3.49 \times 10^5$	[2] All working correct.		
(b)	Towards the centre of Venus	[1] Centre		
(c)	$F_G = F_C = \frac{mv^2}{R}$ $v = \sqrt{\frac{F_G R}{m}} = \sqrt{\frac{3.49 \times 10^5 \times 6.682 \times 10^5}{4.32 \times 10^4}}$ $v = \sqrt{54002843} = 7348.66 = 7350ms^{-1}$		[2] Correct working and answer.	
sf	3 sf	[1] 3 sf		

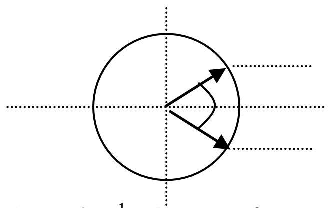
Angular Mechanics Revision Questions

1(a)	L = Iω = 10.8 kg m^2 × 3.4 rad s^{-1}= 37 kg m^2 s^{-1}	[2]Correct answer	[1]Correct Unit (no radians!)	
(b)	I depends on mass position and amount. By bringing his arms closer he decreases I by bringing their mass closer to the axis of rotation.	[1]Decrease in I	[1]Decrease in I linked to change in m distribution.	
(c)	Conservation of angular momentum $E_{k(rot)} = {}^1/_2 I\omega^2 = 0.5 \times 10.8 \times 3.4^2 = 62J$	[2]Correct answer		

(d)	Conservation of energy says the total energy remains constant. As there are no outside forces to transfer energy away from him (ignoring friction), it has come from the energy stored in his muscles, transfered to rotational kinetic energy. This transfer requires work to be done and hence a torque to be applied over a certain angle of rotation to pull the arms in.	[1]Correct idea of it coming from stored energy in his body.	[1]Idea of your body doing work to pull the arms and leg in and this energy transfer results in greater KE.	[1]Correct answer plus clear knowledge exhibited that in order to pull his arms and legs in, a torque had to be exerted and work was done over a number of turns against the tendency of them to stay rotating as they were.
(e)	950rpm = $950\times2\pi\div60 = 99.5$ rad s^{-1}	[2]Correct substitution		
(f)	Estmate drum mass as 2kg, drum radius as 0.4m. Use $I = mr^2 = 2 \times 0.16 = 0.32 kgm^2$. $\alpha = \Delta\omega \div \Delta t = 99.5$ rad $s^{-1} \div 5s = 19.9 r\ s^{-2}$ Hence $\tau = I\ \alpha = 0.32 kgm^2 \times 19.9 r\ c = 6.4\ kg\ m^2 s^{-2}$		2 Valid approach that does not use sensible estimates or miscalculates α	2 Sensible value synthesising calculation of I and α
Two (a)	Paddle stroke is a force applied offset from centre of mass creating a torque which acts about the centre of mass of canoeist and Kayak.	[1.]Paddle stroke supplies a torque.	[1] Full explanation	
(b)	Using the principle of conservation of angular momentum due to the system having negligible external torques. Total $\mathbf{L_i} = 0$ so Total $\mathbf{L_f} = 0$ so anticlockwise **L** of hips = clockwise **L** of kayak, hence kayak swivels clockwise.	[1.]Quoting **L** conserved	[1] same as for Excellence but not giving reason that **L** is conserved	[1] quote conserve **L**; reason being neg external torques; resultant movements since $\mathbf{L_i} = 0$
(c)	Turn of kayak would be more pronounced as his anticlockwise **L** is greater due to increased **I** from paddle being held further from body. **L** total is conserved so clockwise **L** is greater by same amount thus kayak's clockwise **ω** is greater.	more pronounced due to greater **I**	[1] more pronounced due to greater **I** since paddle further from centre of mass	[1] more pronounced due to greater **I** as paddle held further from centre of mass increasing **L** of system.
(d)	$\theta = \omega o t + \frac{1}{2}\alpha t2$ but $\omega o = 0$ so $\alpha = \frac{2\theta}{t^2} = \frac{2x3.05}{1.03^2} = 5.75$ rads-2		2 correct working and answer	

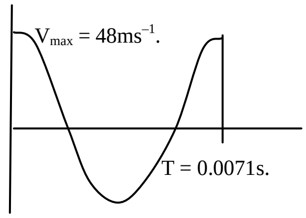
Simple Harmonic Motion Revision Questions ANSWERS

ONE (a)	$F = kx$ $\Rightarrow k = \frac{F}{x} = \frac{mg}{0.075} = \frac{6.5\times9.8}{0.15} = 424.6$ $k = 420 Nm^{-1} (2 sigfig)$	[2]Correct answer		
(b)	$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi\sqrt{\frac{6.5}{420}} = 0.78s$	[2]Correct answer		
(c)	$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.78} = 8.06 rads^{-1}$	[2]Correct answer		

(d)	$a=\omega^2 A = 8.06^2 \times 0.075 = 4.87 ms^{-2}$	[2]Correct answer		
(e)	At the end points, or positions of maximum displacement	[1] Correct answer		
(f)	When the bouncinette is depressed more than 17cm the net acceleration it applies to the baby exceeds that of ‘g’ (9.8). This will result in the baby still moving upward as it moves through an amplitude of + 15cm. If the baby is not well secured there is the potential for him to be catapulted out of the bouncinette and the baby will go into ‘freefall’.	[2] Calculation of acceleration as a value greater than 9.8 ms^{-2} (11 ms^{-2})	[1]concept of baby’s acceleration exceeding ‘g’ and resultant ‘catapult’ motion.	[1]Correct answer clearly expressed.
TWO (g)	Recognition that angle between the two phasors for this scenario will be 60° by use of sinθ =3.75/7.5 = 30°  θ = 60° = $^1/_6$ th circumference. Hence the time between A and B is $^1/_6$ th a period = 0.78s ÷ 6 = 0.13s (2 s.f.) Alternatively, $y = A\sin\omega t$ can be used to determine t_A (-0.0649s) and t_B (0.0649s) and the difference obtained (0.13s) .	[2]Attempt to use reference circle to get angle. OR Unsuccessful attempt to use the equation y = A sinωt	[2]recognition of relationship between phasor position and time elapse.	[2]Correct answer, linking $^1/_6$ th circumference to $^1/_6$ th period and then calculation of time.

TWO (a)	x = $\frac{F_W}{k} = \frac{74.4x9.81}{208}$ = 3.51 m		[2] correct working and answer	
(b)	Length to O = 3.51 + 5.08 = 8.59 m	[2] correct answer		
(c)	$T = 2\pi\sqrt{\frac{m}{k}} \Leftrightarrow$ = $2\pi \sqrt{\frac{74.4}{208}}$ = 3.76 s	[2] correct working to get correct answer		
(d)	$\omega = 2\pi f$ and $f = \frac{1}{T}$ thus $\omega = \frac{2\pi}{T} = \frac{2\pi}{3.76} = 1.67 rads^{-1}$ $a_{max} = \omega^2 A = 1.67^2 \times 3.21$ = 8.97 ms^{-2} (8.95 – 8.97)		[2] correctly gets **ω** but not $\mathbf{a}_{max}$.	[2] correct working and answer
(e)	At the extremities of this motion	[1] correct answer.		
(f)	This is slightly less than “1g”. It would feel like he was being stopped by a force that would feel slightly less than holding his own weight up – not particularly uncomfortable compared to the several “g’s” that fighter pilot and astronaut trainees are tested as being tolerant to.		[1] comments about “g’s” or comparing to weight leading to reasonable comment.	[1] well reasoned case
(g)	It means that the amplitude of the oscillation is made to die away to zero over 5 periods. To achieve	[1] states what damping in 5 oscillations is.	[1] correct description and explanation of	

	this the design of the structure of this rope must dissipate energy out to the environment.		needing to dissipate energy to environment.	

THREE (a) (i)	In SHM the displacement and acceleration are directly proportional but opposite in direction.	1 proportional AND opposite direction		
(a) (ii)	$\omega = 2\pi f = 2\pi 140Hz = 879.64$	2 Correct working		
(b)	Angular frequency unit is **rad s^{-1}**.	1 Correct unit		
(c)	$d = 4 \times A = 4 \times 0.055$ $d = 0.22m$	2 Correct working and answer.		
(d)	$v = A\omega = 0.055 \times 880$ $v = 48.38 = 48ms^{-1}$	2 Correct working and answer.		
(e)		1 Correct shape.	1 Correct shape AND data values.	
(f)	$a_{max} = A\omega^2 = 0.055 \times 880^2$ $a_{max} = 42592 = 4.3 \times 10^4 ms^{-2}$	2 Correct working and answer.		

Internal Resistance & Kirchoff Revision Questions - ANSWERS

ONE (a)	K's loop law says the sum of the potential differences around a closed loop is zero. Starting at point B, there is a net increase in PD of 9V followed by a loss of 0.62A x 3.00Ω = 1.86V and then a loss of of $I_b \times 4.00\ \Omega$ to reach the same potential value.		1 Correct answer.	
(b)	$9.00 - 1.86 + 4.00I_b = 0 \Rightarrow 4.00I_b = 9.00 - 1.86$ $4.00I_b = 7.14$ $I_b = -7.14 \div 4 = -1.79A$ Equation assumes I_b flows from A to B like arrow in diagram. Negative result is obtained so I_b flows from B to A	2 Correct answer 1 B to A		
(c)	$I_a - 1.79 + 0.62 = 0$ Hence $I_a = 1.79 - 0.62 = 1.17A$	2 reasonable attempt at using Kirchoff's current law. May have sign convention confused and used inconsistently.	2 Correct working and answer.	
(d)	Let resistance of the device be R. $8.50 - 1.17 \times R - 3.00 \times 0.62 = 0$ $1.17 \times R = 8.50 - 1.86$ $\Rightarrow R = 5.70\Omega$.		2 Correct calculation	

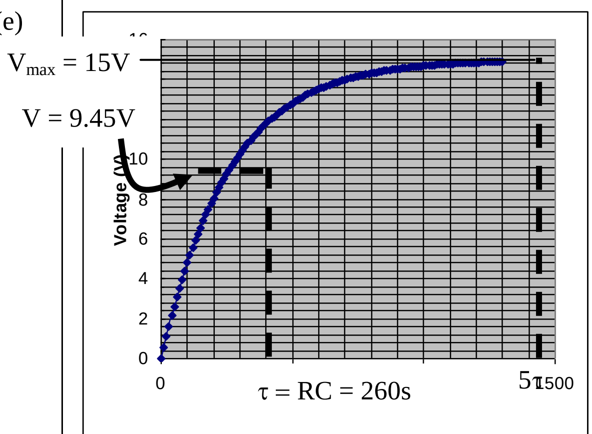
(e)	The presence of internal resistance means that some of the energy available through the emf of the battery is 'used' internally in the battery and converted to heat by this resistance. The amount used is found according to Ohm's law, as $V_r = Ir$, where r = the internal resistance and I is the current drawn in the circuit. Hence the actual voltage that is 'seen' by the rest of the circuit is $V_T = \varepsilon - Ir$.		[1] Explanation	[1] Clear explanation
(f)	As $V_T = \varepsilon - Ir$ then In the top loop $V_T = 9.00 = 9.4 - Ir$. So $Ir = 0.4 \Rightarrow r = 0.4 \div 1.79 = 0.22\ \Omega$. And in the bottom loop $V_T = 8.5 = 8.8 - Ir$. So $Ir = 0.3 \Rightarrow r = 0.3 \div 1.17 = 0.26\ \Omega$.			[2] Correct calculation for both

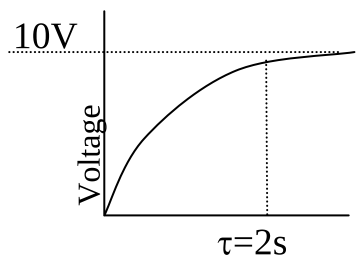
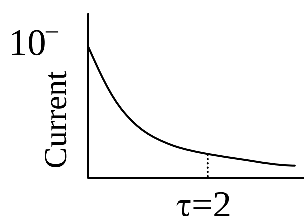
TWO (a)	The total current into a junction equals the total current out of the junction	[1] As per evidence		
(b)	Law of conservation of charge	[1.] Correct answer – not current		
(c)	V = 10.5 – 6 = 4.50 V	[2] 4.50 V		
(d)	$I_1 = V/R = 4.50/25.0 = 0.180$ A	[2] 0.180 A		
(e)	$I_2 = 0.400 - 0.180 = 0.220$ A	[2] 0.220 A – or consequential from 1 (c)		
(f)	V = 12.6 – 6.00 = 6.60 V R = V/I = 6.60 / 0.220 = 30.0Ω	[2] V correct or R subsequently correct Consequential from 1 (d)	[2] R = 30.0 Ω	

THREE (a)	$V = IR = 50.0 \times 0.145 = 7.25$V $r = (\varepsilon - V)/I$ $= (12.0 - 7.25)/50.0$ $= 9.50 \times 10^{-2}\ \Omega$	[2] 7.25 V	[2] Correct formula / voltage of r $r = (\varepsilon - V)/I$	[2] Correct substitution and answer $9.50 \times 10^{-2}\ \Omega$
(b)	As the internal resistance increases the voltage drop over the internal resistance increases so the terminal voltage decreases	[1] Terminal voltage decreases	[1] correct answer	

FOUR (a)	$-5.5 \times I_2 - 1.2 \times 0.603 + 12 = 0$ $5.5 \times I_2 = 11.2764$ $I_2 = 2.05$ A	[2] Correct sum to zero		
(b)	$I_2 = I_1 + 0.603$ $I_1 = 2.05 - 0.603$ $I_1 = 1.45$ A	[2] Correct answer		
(c)	Internal Resistance increases	[1] Correct answer		

Capacitors (DC) Revision Questions - ANSWERS

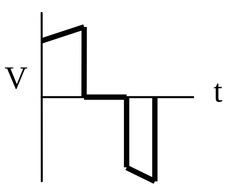
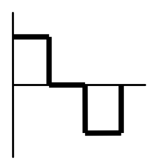
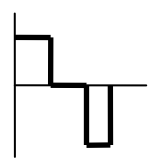
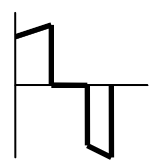
ONE (a)	$C = \frac{\varepsilon_o A}{d} \Rightarrow A = \frac{Cd}{\varepsilon_o} = \frac{65\times10^{-6}\times2\times10^{-4}}{8.85\times10^{-12}}$ $\Rightarrow A = 1470m^2$	[2] Correct working.		
(b)	Use foil and roll it up in a cylinder. NOT: move plates closer together. This capacitor already has its plates very close and it would not be practical for them to become closer.	[1]Correct answer.		
(c)	$A = 0.1\text{m}\times0.1\text{m} = 0.01\text{m}^2$ $C = \frac{\varepsilon_r\varepsilon_o A}{d} \Rightarrow \varepsilon_r = \frac{Cd}{A\varepsilon_o}$ $\Rightarrow \varepsilon_r = \frac{65\times10^{-6}\times2\times10^{-4}}{0.01\times8.85\times10^{-12}}$ $\Rightarrow \varepsilon_r = 1.47\times10^5$	[2] *Correct approach, incorrect area.*	[2] Correct answer.	
(d)	I = V/R = 15/4.00 × 10^6 = 3.75 × 10^{-6} Amps	[2] Correct working and answer.		
(e)		[1]*Exponential curve sketched.*	[1]*Exponential curve sketched with indications of time constant voltage value reached at that time.*	[1]Graph axes include correct time constant and voltage value reached by this time. i.e. V must be correct for one integral number of τ e.g. τ calculated and matched to 9.5V (approx.) or 5τ matched to maximum V.
(f)	Q = CV = 6.5 ×10^{-5}F × 15V = 9.75 × 10^{-4}C	[2] Correct working and answer		
	2 s.f.	[1]Correct s.f.		
	Unit: Coulombs (C)	[1]Correct unit		
ONE (g)	Energy = ½CV^2 The arrangement is a parallel one so the voltage across the two will be the same. It will be less than the previous amount and is found using V = Q/C where Q is now less as it is shared over the two capacitors. Thus need new Q. As they are in parallel, the charge is shared proportionate to the ratio of the capacitances. As this 1: 2 (65μF: 130μF) the charge on the 65μF capacitor is 1/3 the original (the original charge is split on a 1:2 basis). Hence new Q = 3.25 × 10^{-4}C. ⇒ V = 3.25 × 10^{-4}C ÷ 6.5 ×10^{-5}F = 5.0V ⇒ E = ½CV^2 = ½ × 3.25 × 10^{-4} × 5^2 ⇒ E = 4.1 × 10^{-3} J		[2] *Correct approach for Energy, incorrect result due to wrong V.*	[2] Correct answer

Two (a)	The function of the capacitor is to store electric charge.	[1] Correct answer		
(b)	The electrical field between the plates is strengthen allowing more charge and hence a stronger Electric field to be maintained	[1] increases ability to store charge	[1] by increasing the electric field	
(c)	Increasing Area of overlap between plates OR Decreasing the distance between plates.	[1] One correct answer		
(d)	$\tau = RC = 2.0\times10^{-6}\times1.0\times10^{6}$ $\tau = 2.0s$	[2] Correct answer		
(e) (i)		1 Correct graph shape	1 Graph correctly drawn with 10V, and 2s correctly marked.	
(e) (ii)		1 Correct graph shape	1 Graph correctly drawn with 10–5A, and 2s correctly marked.	
(f)	Q = CV = 2.0 x 10^{-6} x 10 = 2.0 x 10^{-5} C E = ½ QV = ½ x 2.0 x 10^{-5} x 10 = 1.0 x 10^{-4} J	[2] 100 J Calculated without using 10^{-6}	[2] correct value for Q	[2] Correct answer
(g)	$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{1}{2.0\times10^{-6}} + \frac{1}{3.0\times10^{-6}}$ $C_T = 1.2\times10^{-6}F$	[2] Use of formula		
(h)	$Q = C\times V = 1.2\times10^{-6}\times55 =$ 6 x 10^{-5} C	[2] 6.6 C, i.e., without converting to SI	[2] Correct answer	
(i)	$V = \frac{Q}{C} = \frac{6.6\times10^{-5}}{2.0\times10^{-6}}$ = 33 V	[2] emf but without converting to SI	[2] Correct answer	

Induction of Voltage Revision Questions ANSWERS

One (a)	The induced current/voltage in a loop produces a force/magnetic field that opposes the change that produced it	[1] General idea of opposing change	[1] As per evidence	
(b)	The conservation of energy	[1] The conservation of energy		

(c)	Anticlockwise – As magnetic flux through the loop (into page) increases as the loop enters the field, the coil opposes this change by producing a magnetic field out of the page (Lenz's Law). To produce a magnetic field out of the page an anticlockwise current is induced in the loop (right hand grip rule) NB: ANTICLOCKWISE ON ITS OWN COUNTS FOR NOTHING		[1] Anticlockwise + partial explanation including a <u>description</u> of Lenz's law (opposes change)	[1] Anticlockwise + explanation as in evidence
(d)	$\Delta\phi = \varepsilon\Delta t = 1.30\times1\times10^{-2} = 0.0130\text{Wb}$ $\therefore \phi_{final} = 0.0130\text{Wb}$ $\therefore B = \frac{\phi}{A} = \frac{0.0130}{1.44\times10^{-2}\times40}$ $= 2.26\times10^{-2}$			[2] $B = 2.26\times10^{-2}$ (magnitude only, ignore +/-)
	Units of B given as T / Wbm^{-2} / NA^{-1} / $\text{kgs}^{-2}\text{A}^{-1}$	[1] Correct unit		
(e)	$\Delta\phi = 0 \therefore \varepsilon = 0\text{V}$	[2] 0 V		

(f)	A and D equal 1st – both have no $\Delta\phi$ and so no opposing force B 3rd – experiences upwards force as it enters the field C 4th – experiences upwards force as it enters and as it leaves the field	[1] A 1st as no $\Delta\phi$ and so no opposing force (B, C & D neutral)	[1] A followed by B followed by C with reasons (D neutral)	[1] As per evidence
(g)	 SHAPE ONLY 2nd pulse is opposite in sign to 1st, has a larger voltage, and takes less time. Pulses increase in magnitude	[1]  1st and 2nd pulses have same V and t Constant V Inverted OK	[1]  2nd pulse <u>clearly</u> larger V and shorter t than 1st pulse Constant V Inverted OK	[1]  2nd pulse <u>clearly</u> larger V and shorter t than 1st pulse Increasing V Inverted OK

TWO (a) Ø = B x A = 2.4 x 10^{-2} x 0.033 = 7.9 x 10^{-4} Wb

(b) V = ΔØ/Δt = 7.9 x 10^{-4}/3.5 = 2.3 x 10^{-4} V

THREE.

(a) The light bulb with the inductor lights up more slowly because as the current changes through the inductor (zero to maximum), a back Emf is induced in the inductor which opposes the current producing it. This causes the forward current to build up more slowly to its maximum steady value.

(b) The lower bulb lights up because the AC Voltage applied to it causes the normal current to flow through it (Ohms law) and makes the filament glow as normal.

The upper light bulb has an inductor in series which produces a back Emf that always opposes the AC current. This means that the current passing through the light in series with the inductor is always small and so the light bulb does not light up.

Another way to answer this is to use the AC theory approach. Ie the inductor has a reactance which causes the supply voltage to be split between the inductor and the resistance of the light bulb. The voltage available for the light bulb is reduced to a value that does not allow it to glow.

FOUR.

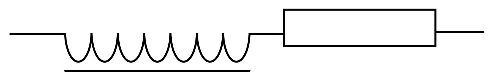
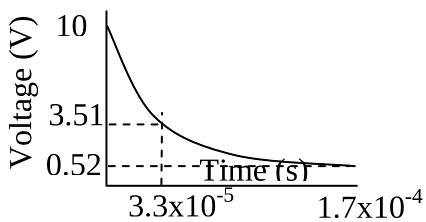
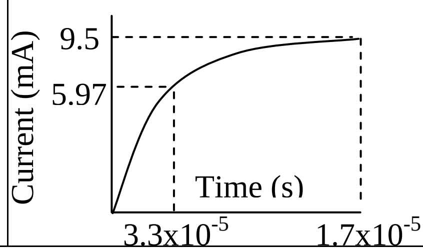
(a) As the circuit is broken the magnetic field in the coil collapses and a voltage is induced in the coil in such a direction as to keep the current going that produced the original field. This voltage is quite large and drives a current across the gap in the form of a spark.

(b) V = -L(ΔI/Δt) = 10 x 3/0.12 = 250 V

(c) E = ½ LI^2 = ½ x 10 x 9 = 45 J

(d) When the switch is opened, the magnetic field in the coil collapses. This decreasing magnetic field induces a voltage across the coil that tries to stop it decreasing. This means that the induced current will flow in the same direction that it originally did as it tries to maintain the magnetic field.

Inductors & Transformers Revision questions – ANSWERS

	Answer	Achieved	Merit	Excellence
One (a)		Correct diagram		
(b)	The function of an inductor is to slow the growth of current in a DC circuit or to provide a back emf.	correct answer		
(c) 1st graph	 $\tau = L/R = 0.035 / 1055 = 3.3\text{x}10^{-5}$ s I = V/R = 10/1055 = 9.478…mA V_L = 9.478…x 55 = 0.52V	Correct graph shape with axis labelled correctly	Correct values on each axis	
(c) 2nd graph	 	Correct graph shape with axis labelled correctly	Correct values on each axis	

TWO (a)	$V_{initial}$ = -15Volts	[2] *Correct absolute value.*	[2] Correct answer with sign.	
(b)	$\varepsilon = -L\dfrac{\Delta I}{\Delta t}$ L = 15.0/45 = 0.33 Henry	[1] 2 sig. fig. [1] Unit = Henry (H).	[2] Correct working and answer.	
(c)	When the switch is opened the current flowing begins to drop. The magnetic field created by the flowing current also begins to fall in size and the inductor self induces an opposing voltage to this, according to Lenz and Faraday's Laws. The size of this voltage is extremely large as the contact breaking time is very short. If it is large enough, it can exceed the breakdown voltage of air over the switch gap size and create a spark.		[1] Explanation refers to rate of change of current and induced voltage causing spark.	[1] Clear explanation touching on magnetic field collapse and size of voltage exceeding breakdown voltage.
(d)	$I_{max} = \varepsilon / R$ = 15.0/4.5 = 3.3 A $E_{max} = ½LI^2$ $= 0.5 \times 0.330 \times 3.3^2$ = 1.85 J		[2] *Correct approach, wrong I*	[2] Correct working and answer.

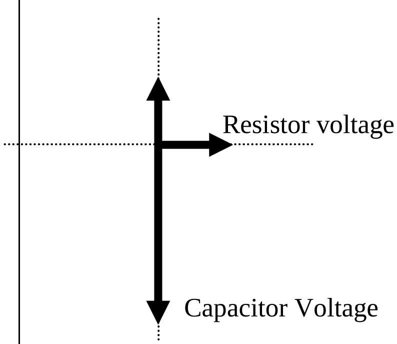
Three (a)	The transformer reduces the 230 V AC to a lower voltage ... about 5 V AC, This is because there are less turns in the secondary, causing lowering of the mutual inductance of the transformer	[1] voltage lowered	[1] by having a lower number of turns in the secondary than in the primary	[1] They cause less mutual inductance lowering the value of the output voltage
(b)	$\frac{N_p}{N_s} = \frac{V_p}{V_s}$ $\frac{1250}{N_S} = \frac{230}{5}$ So $N_S = \frac{5}{230} \times 1250 = 27.17$	[2] Correct answer		
(c)	Only half of the AC cycle is used, because the diode stops half of the AC cycle being used. A whetstone bridge arrangement would allow the whole cycle to be utilised. And a capacitor correctly positioned would smooth the current flow making it closer to 5 V DC.	[1] half AC cycle recognised.	[1] ½ AC AND The diodes function OR Bridge arrangement identified OR Use of a capacitor to smooth current flow	[1] Full answer
(d)	$230 \times \sqrt{2} = 325\,\text{V}$	[2] correct answer		

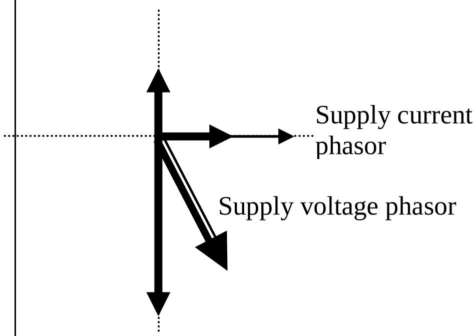
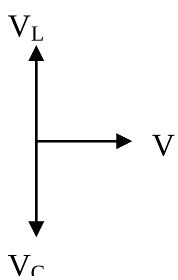
FOUR(a) $V_2/V_1 = N_2/N_1$ $V_2 = (1.5 \times 15000)/500 = 45$ V
(b) $I = V/R = 0.096$ A
(c) $V_1 I_1 = V_2 I_2$ $I_1 = 2.87$ A
(d) $V_2 = -M(\Delta I_1/\Delta t)$ $M = (23 \times 0.8)/0.22 = 83.6$ H

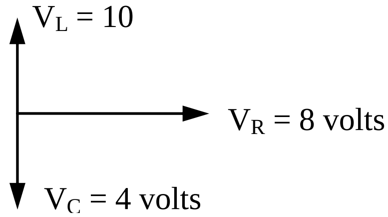
(e) If a single piece of iron is used as the core, eddy currents will be produced in it and energy will be lost due to heating effects. To achieve maximum efficiency the two coils are wound on a laminated iron core. The large number of sheets in the core which are electrically insulated from one another causes eddy currents to be minimised and so energy lost to heat is reduced significantly.

(f) (i) $V_2 = -M(\Delta I_1/\Delta t) = 98 \times 2.8/3 = 0.75$ V
(ii) $V_2/V_1 = N_2/N_1$ $V_2 = 240$ V $I = 0/062$ A

Alternating Current Revision Questions ANSWERS

ONE (a)	$V_{\max} = \sqrt{2} V_{rms} = \sqrt{2} \times 12 = 17V$	[2] Correct working and answer.		
(b)	$X_L = \omega L \Rightarrow 0.25 = 2\pi f L \Rightarrow L = 0.25 \div 2\pi f$ $\Rightarrow L = 0.25 \div 2\pi \times 0.5 = 0.080\text{H}$	[2] Correct working.		
(c)	$V = IZ \Rightarrow Z = V/I = 2.0/0.16 = 12.5\ \Omega$	[2] Correct working.		
(d)		[1] Both phasor directions correct.	[1] Plus relative sizes correct ($V_c > V_L, V_R$).	

(e)		1 *Current phasor correct.*	1 *Both phasors correct directions*	1 Plus supply phasor size looks like the vector addition of V_C, V_L, V_R
(f)	5.3 Ω	2 Correct value		
(g)	Several approaches: $V = IX_C$ Get I from $I = V_{supply} \div R = 2.0 \div 5.3 = 0.38A$ Get $X_C = X_L = 2\pi fL = 2\pi \times 3.32 \times 0.08 = 1.67\ \Omega$ $V = 0.38 \times 1.67 = 0.63V$		2 *Correct calculation of I and X_C* OR *recognition of their need in $V = IX_C$.*	2 Correct calculation with both steps involved.
TWO (a)	As AC, changing current causes a changing magnetic field and that field threads the coil which produces it. This results in a change in the magnetic flux linked with the coil which produces an induced voltage		1 Linking changing current to changing magnetic field	1 Linking changing current to changing magnetic field and magnetic flux to induced voltage
(b)	The maximum current flows	1 As per evidence		
(c)		1 Correct orientation	1 Correct orientation + V_C and V_L equal length	
(d)	$X_L = 2\pi fL$ $= 2\pi \times (9.0 \times 10^{7}) \times (7.69 \times 10^{-9})$ = 4.4 Ω (4.35 Ω)	2 Correct answer		
	Answer to 2 s.f.	2 2 s.f.		
(e)	Z = R = 33.0 Ω		2 33.0 Ω	
(f)	Larger capacitance → more charge stored at same voltage → longer to fully charge plates → allows current to flow for longer → allows lower frequency	1 2 of 4 points	1 3 of 4 points	1 Very concise and complete

(g)	$X_C = X_L$ $\frac{1}{\omega C} = \omega L$ $\frac{1}{2\pi f C} = 2\pi f L$ $f^2 = \frac{1}{4\pi^2 LC}$ $f = \frac{1}{2\pi\sqrt{LC}}$ $f = \frac{1}{2\pi\sqrt{7.69\times10^{-9}\times4.16\times10^{-10}}}$ $f = 8.898\times10^7\ Hz$ f = 8.90 x 10^7 Hz or 89.0 MHz		2 $\frac{1}{\omega C} = \omega L$ or subsequent working or substitution	2 $\frac{1}{\omega C} = \omega L$ or subsequent working or substitution, and correct answer
THREE (a)		1 Correct diagram actual values not required, labelled correctly	1 Correct diagram with labels and values.	
(b)	$V_s = \sqrt{V_R + (V_L - V_C)^2} = \sqrt{(8^2 + (10-4)^2)}$ = 10 V $Z = \frac{V_S}{I} = 20\,\Omega$		2 Correct value for V_s	2 correct answer