

WJEC A-LEVEL PHYSICS • UNIT 4

PHYSICS



EXAM QUESTION PACK

4.5 ELECTROMAGNETIC INDUCTION

SCORE

/

PERCENTAGE

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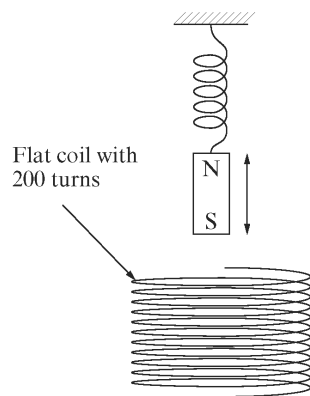
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1. A strong magnet is held on a spring and performs simple harmonic motion near a flat coil as shown.



- (a) Explain briefly why an alternating emf is induced in the coil. [3]

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- (b) (i) The induced emf varies in magnitude sinusoidally with a peak value of ± 0.707 V. Calculate the rms value of the induced emf. [1]

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- (ii) State the value of the rate of change of flux through each turn of the coil when the peak value of 0.707 V is obtained and explain how you obtained your answer. [3]

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- (c) One end of the coil is connected with the other so that there is an induced current. Explain why the magnet's motion is now damped. [3]

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2. (a) State the **two** laws of electromagnetic induction (Faraday's law and Lenz's law). [3]

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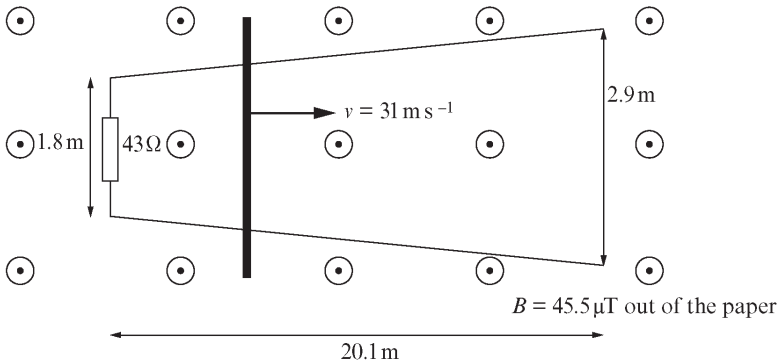
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(b) A thick conducting bar is moved with constant speed over non-parallel conducting rails as shown below. The rails have negligible resistance and the B -field is uniform.



(i) Indicate the direction of the induced current on the diagram and explain how you arrived at your answer. [2]

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(ii) The conductor moves at a constant speed of 31 m s^{-1} . Use Faraday’s law to explain why the induced emf increases. [2]

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(iii) The conductor starts moving from the end near the 43Ω resistor. Calculate the mean current in the resistor when the conducting bar has travelled the full 20.1 m length of the track. [4]

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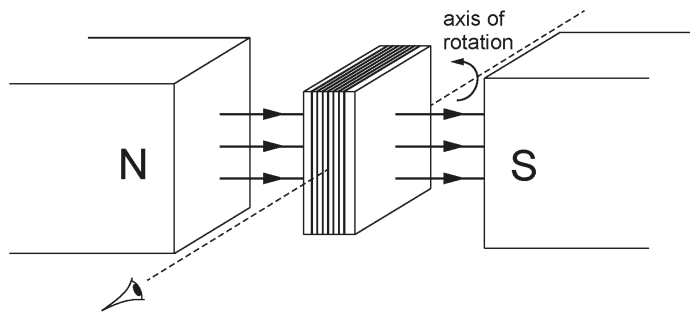
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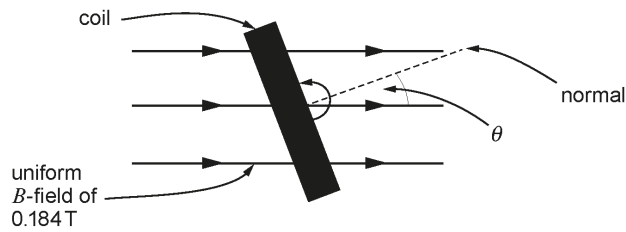
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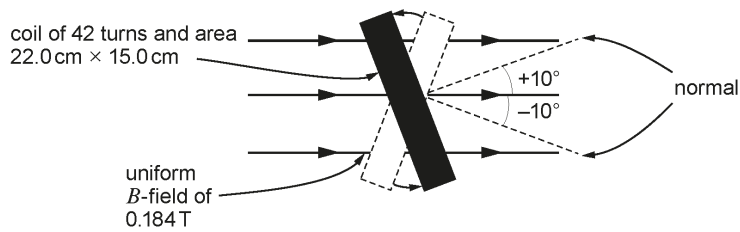
3. A rectangular coil rotates at a constant angular velocity within a uniform magnetic field. The coil has 42 turns and area $22.0\text{ cm} \times 15.0\text{ cm}$. The diagram below is a simplified 3D diagram of the coil when the magnetic field is perpendicular to the coil.



The second diagram is a 2D representation of the coil looking along the axis of rotation.



- (a) (i) Calculate the flux **linkage** of the coil for the angles $\theta = -10^\circ$ and $\theta = +10^\circ$. [2]



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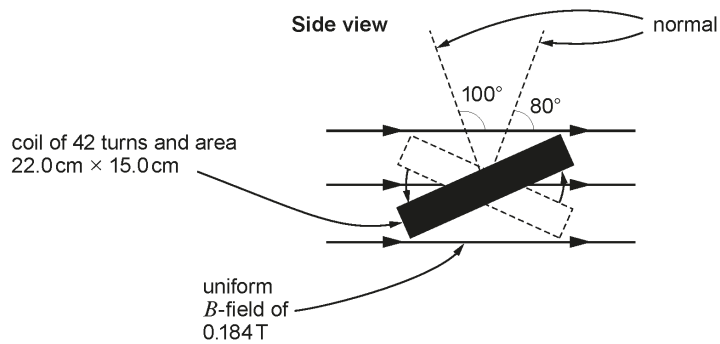
- (ii) Explain why the mean induced emf is zero as the coil moves between $\theta = -10^\circ$ and $\theta = +10^\circ$. [1]

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- (b) Calculate the mean induced emf in the coil when the angle θ changes from 80° to 100° if the period of rotation of the coil is 0.100 s. [4]



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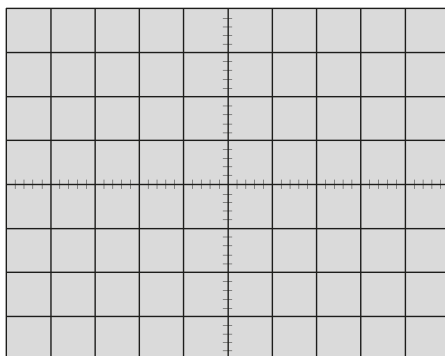
- (c) An oscilloscope is used to display the sinusoidal emf in a different coil rotating at a frequency of 12.5 Hz and producing an **rms** pd of 12.0 V. The oscilloscope settings are 5 V per division (vertically) and 20 ms per division (horizontally). Sketch a trace that might be seen on the oscilloscope. (Space is provided for your workings.) [3]

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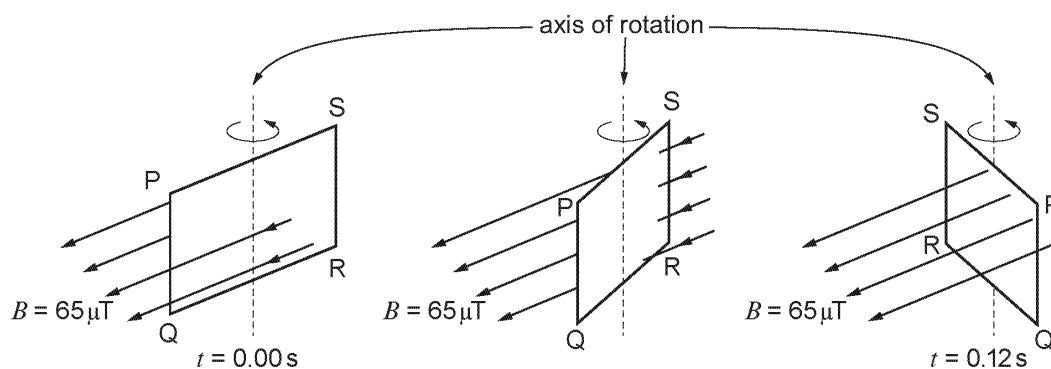
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4.

A large square loop has sides of length 0.815 m and is rotated through 90° in a uniform magnetic field of $65\mu\text{T}$. The diagrams show the same square loop at different times.



(a) Determine the magnetic flux through the square loop: [3]

(i) when $t = 0.00\text{ s}$ (sides QR and SP are parallel to the B -field);

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(ii) and when $t = 0.12\text{ s}$ (PQ, QR, RS and SP are perpendicular to the B -field).

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(b) The square loop is made of copper. Explain why there is a current in the loop as it is rotated. [2]

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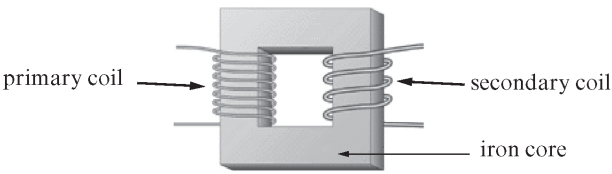
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5.

Option A: Further Electromagnetism and Alternating Currents

- (a) Explain how an alternating current in the primary coil leads to an alternating emf in the secondary coil. [3]



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- (b) State and explain briefly **three** ways in which the design of a transformer reduces energy losses. [3]

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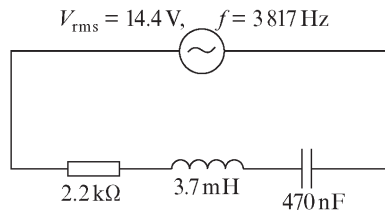
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- (c) (i) Calculate the reactances of the capacitor and inductor at the frequency shown. [3]



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- (ii) How can you tell that this is the resonance frequency of the circuit? [1]

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- (iii) Calculate the current at the resonance frequency of 3817 Hz. [1]

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- (iv) Calculate the current when the frequency is 38.17 kHz (the rms pd remains 14.4 V). [3]

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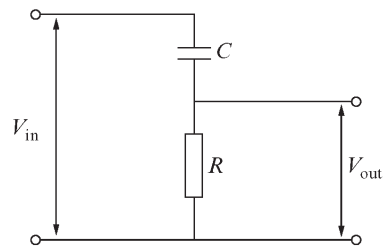
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(d) (i) Explain why the circuit shown is a high pass filter.

[3]



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(ii) $C = 470 \text{ nF}$ and $R = 2.2 \text{ k}\Omega$. Using a phasor diagram or otherwise, calculate the frequency when $V_{out} = \frac{1}{\sqrt{2}} V_{in}$. [Hint: $\cos 45^\circ = \frac{1}{\sqrt{2}}$.] [3]

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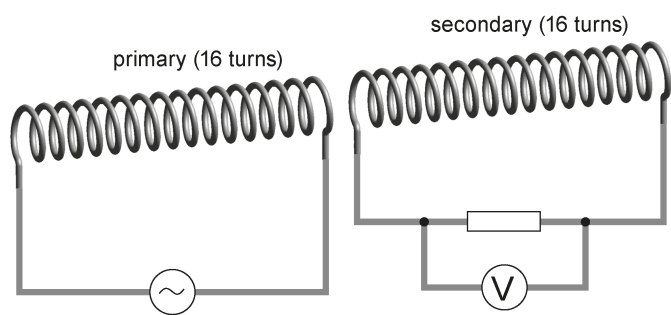
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6. (a) A sinusoidal pd of 6 V (rms) and frequency 0.9 Hz is supplied to the primary solenoid.



(i) State how the reading on the voltmeter varies and explain what causes the voltmeter reading to vary. [4]

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(ii) Give a reason why the rms pd measured by the voltmeter will be much lower than 6 V. [1]

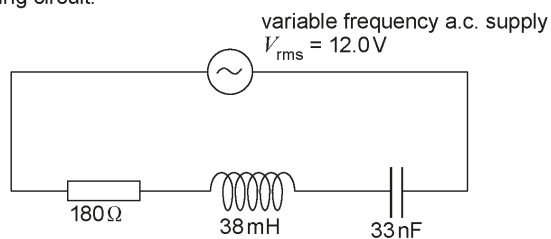
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(b) For the following circuit:



- (i) calculate the resonance frequency; [2]

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- (ii) calculate the rms pd across each component at resonance. [4]

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(c) The frequency of the a.c. supply is now set to 5.8 kHz.

- (i) Calculate the rms current. [3]

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- (ii) Calculate the phase angle between the current and the applied pd (a phasor diagram may assist your calculation). [3]

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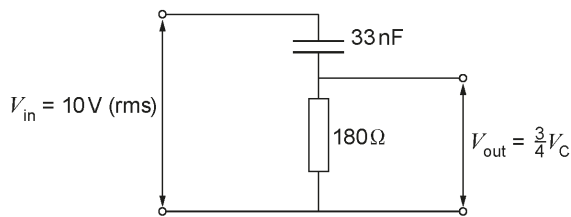
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- (d) In the high pass filter shown the rms output pd is $\frac{3}{4}$ of the rms pd across the capacitor.



Calculate the frequency of the input pd. [3]

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Marking Scheme

1.	(a)	Either Flux changes (1) <u>hence emf induced</u> (1) [Because of RH rule or Faraday → 2nd mark, but not 1st mark] flux increases and decreases [implies 1st mark] [i.e. $\frac{d\Phi}{dt}$ alternates implied](1) NB. "Change in field" not 1st mark but others available]	Or B-lines being cut (1) <u>hence emf induced</u> (1) [Because of RH rule or Faraday → 2nd mark, but not 1st mark] direction of cutting changing (1) [Not "magnet oscillating" accept "magnet changing direction [of motion]"]	3
	(b)	(i) $V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = 0.5 \text{ V}$ (ii) Rate of change of flux (linkage) = 0.707 [V] (1) from Faraday's [or Neuman's] law or $E = N \frac{d\Phi}{dt}$ [allow $E = \frac{\Phi}{t}$](1) [Independent mark – must be stated] For 1 turn = $\frac{0.707}{200} = 0.0035(35) \text{ Wb s}^{-1}$ (1) NB. 0.0025 Wb s^{-1} [from use of $V = 0.5 \text{ V}$] → 2 if 2nd mark awarded.	1	3
	(c)	Stating or implying that there is a magnetic field set up in the coil (1) Opposes motion / due to Lenz's law (1) Detail given, e.g. loss (dissipation) of energy due to current or resistance, polarity of coil discussed [can imply 1st mark], work done against resistive force (1)		3
[10]				

2.	(a)	The [induced] emf is proportional [or equal] to the rate of change [or cutting] of flux [linkage] or $\frac{dBAN}{dt}$ and terms defined Nearly correct statements award 1 out of 2 marks e.g. The emf is equal to the change of flux The current is proportional to the rate of change of flux The emf is proportional to the cutting of flux BAN/t and terms defined Wrong statements get 0 The emf is equal/proportional to the flux linkage The current is equal to the rate of change of flux	2
		Lenz - the [induced] emf [or current] opposes [or tends to oppose etc.] the change [to which it is due]	1
	(b)	(i) Clockwise (1) any 1 of FLHR(must have correct direction), FRHR, right hand grip rule (1)	2
		(ii) Area increases ✓ at an increasing rate ✓ or cutting of flux ✓ inside the loop ✓ or $E = Blv$ ✓ and l is increasing ✓	2
		(iii) $V = \frac{BAN}{t}$ and $t = \frac{20.1}{31} (= 0.648 \text{ s})$ or $E = Blv$ used (1) $A = \frac{1.8+2.9}{2} \times 20.1 [= 47.2]$ or mean $l = 2.35 \text{ [m]}$ (1) $I = \frac{V}{R}$ (1) Correct answer $I = 77 \text{ [}\mu\text{A]}$ (1)	4

3.	(a)	(i)	Flux linkage = $NBA\cos\theta$ used (1) 0.251 [Wb] [and 0.251 Wb] (1)	2
		(ii)	No change in flux [linkage] or field lines cut in one direction and then the opposite direction Don't accept rate of change of flux is 0	1
	(b)		Flux linkage = 0.0443 or -0.0443 (1) Time = $\frac{20}{360} \times 0.1$ (1) Attempt at change of flux (linkage) divided by time (1) Answer = [-] 15.9 [V] (1)	4
	(c)		Peak emf = 17 [V] Sinusoid with peak of 3.4 squares high (ecf) (1) Sinusoid with period of 4 squares (1)	3

4.

Question			Marking details	Marks Available
2	(a)	(i)	0	1
		(ii)	$\varphi = B \times l^2(1)$ Answer = 4.32×10^{-5} [Wb] (1)	2
	(b)		Change in flux or Faraday's law gives emf (1) Complete circuit or accept emf gives current (1) Award 1 mark only for: Current due to Faraday's law	2
		(c)	Force / current / emf opposes the change (1) Force on PQ opposite to SR or the force is clockwise (1)	2
	(d)		$I = \frac{V}{R}$ used (1) $A = \pi \frac{d^2}{4}$ <i>or</i> $\pi \times 3^2 (\times 10^{-6})$ i.e. πr^2 used (1) $R = \frac{\rho \times l}{A}$ used (1) $V = \frac{\Delta N \phi}{\Delta t}$ used (1) Answer = 0.19 [A] ecf on ϕ and πd^2 (1)	5
			Question 2 Total	[12]

5.

(iv) Ignore capacitance (or $\omega L - \frac{1}{\omega C}$ attempted) (1)

Correct calculation for impedance e.g.. $\sqrt{887^2 + 2\,200^2}$ (1)

$$\text{Answer} = \frac{14.4}{2370} = 6.1 \text{ [mA]} \text{ (1)}$$

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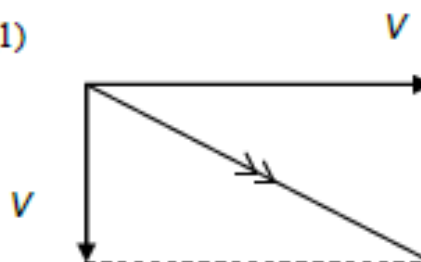
(d) (i) Attempt at an explanation at low and high frequency (1)

Correct variation of X_C with frequency (i.e. large at low frequency or low at high frequency) (1)

Correct division of pd with respect to frequency (e.g. at high frequency $R \gg X_C$ so V_{OUT} is large or the opposite at low frequency) (1)

3

(ii) Phasor diagram drawn or implied (1)



$X_C = R$ or $V_C = V_R$ either derived or quoted (implies diagram correct) (1)

3

$$\text{Answer} = 154 \text{ [Hz]} \text{ (1)}$$

	(iv) Ignore capacitance (or $\omega L - \frac{1}{\omega C}$ attempted) (1) Correct calculation for impedance e.g.. $\sqrt{887^2 + 2\,200^2}$ (1) Answer = $\frac{14.4}{2370} = 6.1$ [mA] (1)	
(d)	(i) Attempt at an explanation at low and high frequency (1) Correct variation of X_C with frequency (i.e. large at low frequency or low at high frequency) (1) Correct division of pd with respect to frequency (e.g. at high frequency $R \gg X_C$ so V_{OUT} is large or the opposite at low frequency) (1) (ii) Phasor diagram drawn or implied (1) $X_C = R$ or $V_C = V_R$ either derived or quoted (implies diagram correct) (1) Answer = 154 [Hz] (1)	3 3 3

6.	(a)	(i) Sinusoidal reading on voltmeter @ 0.9 Hz (or across resistor) (1) Sinusoidal (or changing) B-field in primary (1) Leads to B-field cutting secondary or flux changing in secondary (1) emf induced in secondary due to Faraday's (1)	4
	(ii)	Lost flux or no iron core or low frequency or low turns	1
	(b)	(i) $\omega L = \frac{1}{\omega C}$ or $f = \frac{1}{2\pi} \sqrt{\frac{1}{LC}}$ (1) Answer = 4490 [Hz] (1)	2
	(ii)	$V_R = 12$ [V] (1) $I = 0.067$ [A] (1) $V_L = I \times \omega L$ or $V_C = I \times \frac{1}{\omega C}$ (1) $V_L = 71.5$ [V] and $V_C = 71.5$ [V] or implied e.g. $V_C = \text{same}$ (1)	4
	(c)	(i) $Z = \sqrt{(X_L - X_C)^2 + R^2}$ (1) $Z = 581$ [Ω] or implied (1) Current = $\frac{12}{581} = 21$ [mA] (1)	3
	(ii)	Phasor diagram (1) $\tan \theta = \frac{X_L - X_C}{R}$ (this step implies vector diagram if omitted) (1) Answer = 72° (ecf) (1) (18° and similar slips gain 1/2)	3
	(d)	$\frac{R}{X_C} = \frac{3}{4}$ (1) $X_C = \frac{1}{2\pi f C}$ or $X_C = \frac{1}{\omega C}$ and $\omega = 2\pi f$ used (1) Answer = 20 [kHz] (1)	3