JUNE 1994 PHYSICS 12 PROVINCIAL EXAMINATION
KEY AND SCORING GUIDE

ITEM CLASSIFICATION

TOPICS:
1. Kinematics and Dynamics
2. Energy and Momentum
3. Equilibrium
4. Circular Motion and Gravitation
5. Electrostatics and Circuitry
6. Electromagnetism
7. Quantum Physics
8. Fluid Theory
9. AC Circuitry and Electronics

PART A: MULTIPLE-CHOICE QUESTIONS

Q	C	T	K	S	CGR	Q	C	T	K	S	CGR
1.	K	1	A	2	I C4	16.	K	5	C	2	VII A4, A5
2.	U	1	D	2	II B6	17.	U	5	A	2	VI A2, A5
3.	U	1	A	2	I B7	18.	U	5	B	2	VI B2
4.	U	1	A	2	II A2, A5, A6	19.	U	5	A	2	VII A10
5.	H	1	B	2	I C6	20.	U	5	B	2	VII A8, A6
6.	K	2	B	2	III A3, A1	21.	U	5	D	2	VII B4
7.	U	2	B	2	III C7, I C3	22.	K	6	C	2	VIII A5
8.	U	3	C	2	IV A3	23.	K	6	C	2	VIII B14
9.	U	3	B	2	IV B8	24.	U	6	D	2	VIII A3, A4
10.	H	3	D	2	IV B8	25.	U	6	A	2	VIII A7
11.	K	4	B	2	V A1, A2	26.	U	6	B	2	VIII A9
12.	U	4	D	2	V B5	27.	U	6	D	2	VIII B2
13.	U	4	B	2	V A4	28.	U	6	D	2	VIII B7
14.	H	4	B	2	V B6	29.	U	6	B	2	VIII B8
15.	K	5	C	2	VI A7	30.	H	6	C	2	VIII A6, A5

PART B: PROBLEMS

Q	B	C	T	S	CGR
1.	1	U	1	7	II B3, A2
2a.	2	U	2	5	III A4, A1, A6, C9
2b.	3	H	2	4	III A4, A1, A6, C9
3.	4	U	3	7	IV B8
4.	5	U	4	7	V B5, B6
5.	6	U	5	7	VII A8, A11
6.	7	U	6	7	VIII B11, B10
7.	8	H	5	4	VI B3

PART C: ELECTIVE TOPICS

Only **ONE** of the following sections will be chosen. Score only *one* set of boxes: (9, 10, 11) **OR**(12,13,14) **OR** (15, 16, 17). Maximum possible score for Part C is 12.

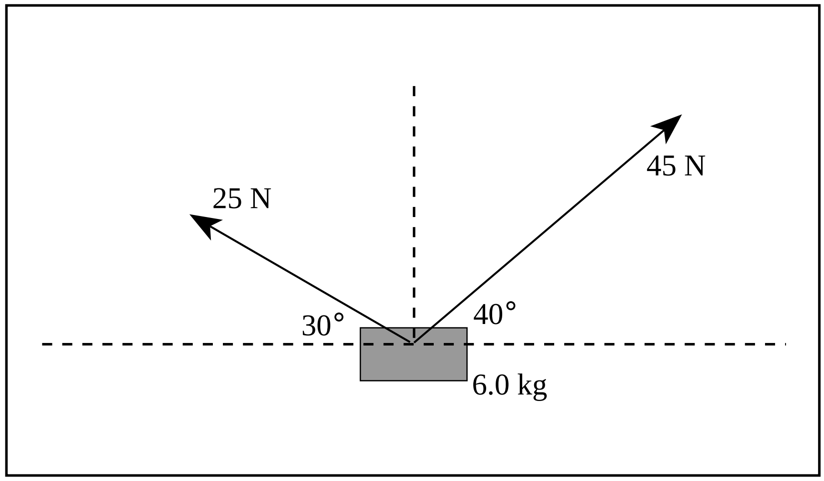
	Q	B	C	T	S	CGR
SECTION I	1.	9	U	7	3	II A14
	2.	10	U	7	4	II A6, B5
	3.	11	U	7	5	II B6
			OR			
SECTION II	1.	12	U	8	3	III A11
	2.	13	U	8	4	III B12, C9
	3.	14	U	8	5	III A9, A2
			OR			
SECTION III	1.	15	U	9	3	I B3
	2.	16	U	9	4	I A3, A5
	3.	17	U	9	5	I C7, B3

Multiple-choice total	=	60	(30 questions)
Written-response total	=	60	(10 questions)
EXAM TOTAL	**=**	**120**	

KEY:
Q = Question | **B** = Score box number | **C** = Cognitive level
T = Topic | **S** = Score | **CGR** = Curriculum Guide Reference
K = Keyed response

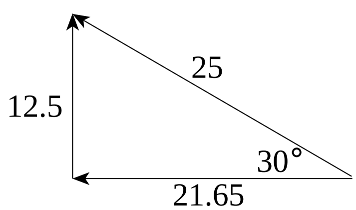
1. A 6.0 kg block is held at rest on a horizontal, frictionless air table. Two forces are pulling on this block in the directions shown in the diagram below.

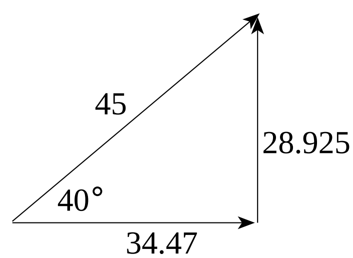
Table Viewed from Above



What will be the magnitude of the acceleration on the 6.0 kg block at the moment it is released?

(7 marks)





Components:

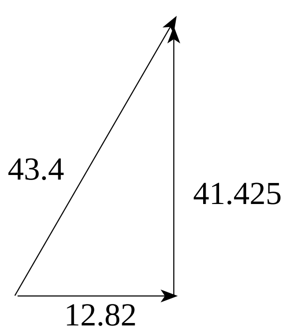
y direction

$F_y = (12.5 + 28.925) = 41.425\ \text{N}$ ← **1½ marks**

x direction

$F_x = 34.47 - 21.65 = 12.82\ \text{N}$ ← **1½ marks**

$F_{net} = 43.4\ \text{N}$ **2 marks**



Answer:

$$\left.\begin{aligned} a &= \frac{F_{net}}{m} \\ &= \frac{43.4\ \text{N}}{6.0\ \text{kg}} \\ &= 7.2\ \text{m/s}^2 \end{aligned}\right\}\ \textbf{2 marks}$$

SEE ALTERNATE SOLUTION OVER:

Alternate Solution:

If viewed as a 'hanging' mass, no penalty:

- this approach is more difficult

Then:

Components:

$F_x = 12.82\ \text{N}$ $\leftarrow$ **1½ marks**

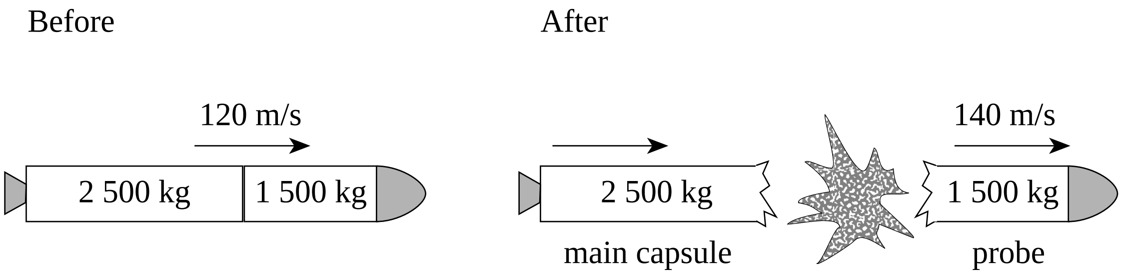
$F_y = 58.8 - 41.43 = 17.37\ \text{N down}$ $\leftarrow$ **1½ marks**

$F_{net} = 21.6\ \text{N}$ **2 marks**

Answer:

$$\left.\begin{aligned} a &= \frac{F_{net}}{m} \\ &= \frac{21.6\ \text{N}}{6.0\ \text{kg}} \\ &= 3.60\ \text{m/s}^2 \end{aligned}\right\} \textbf{2 marks}$$

2. A 4 000 kg space vehicle consists of a 2 500 kg main capsule and a 1 500 kg probe. The space vehicle is travelling at 120 m/s when an explosion occurs between the capsule and the probe. As a result, the probe moves forward at 140 m/s, as shown in the diagram below.



a) (i) What is the speed of the main capsule after the explosion? **(3 marks)**

$$\left.\begin{aligned} m_1v_1 + m_2v_2 &= m_1v_1' + m_2v_2' \\ (m_1 + m_2)v &= m_1v_1' + m_2v_2' \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$(4\,000)(120) = (1\,500)(140) + (2\,500)v_2' \quad \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} 270\,000 &= 2\,500v_2' \\ v_2' &= 108 \text{ m/s} \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$\therefore \text{speed} = 1.1 \times 10^2 \text{ m/s}$$

(ii) What is the magnitude of the impulse given to the probe? **(2 marks)**

$$\Delta p = mv_f - mv_0 \quad \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} F\Delta t &= \Delta p \\ &= 1\,500(140) - 1\,500(120) \\ &= 3.0 \times 10^4 \text{ N} \cdot \text{s} \end{aligned}\right\} \quad \leftarrow \textbf{1 mark}$$

b) Define *impulse* and briefly explain why the impulse on the probe is equal in magnitude to the impulse on the main capsule.

Impulse is a force acting for a given time interval, or a change in momentum. **(1 mark)**

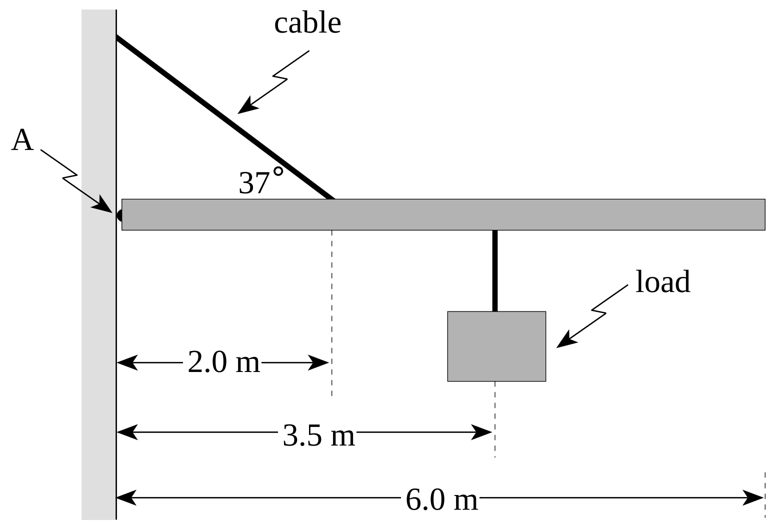
(i) Newton's Third Law states that for every force there is an equal and opposite reacting force. As the time of the explosion is equal for both the probe and the capsule, the impulse $(F\Delta t)$ must be equal and opposite also.

OR

(ii) Impulse is equal to a change in momentum. As momentum is conserved, the momentum gained by the probe must equal the momentum lost by the capsule

3 marks

3. A uniform beam 6.0 m long, and with a mass of 75 kg, is hinged at A. The supporting cable keeps the beam horizontal.



If the maximum tension the cable can withstand is 2.4×10^3 N, what is the maximum mass of the load?

(7 marks)

$\tau_{\mathrm{CW}} = \tau_{\mathrm{CCW}}$ $\leftarrow$ **1 mark**

$$\left.\begin{aligned} F\perp &= \left(2.4 \times 10^3\right)\sin 37^\circ \\ &= 1\ 444.3\ \mathrm{N} \end{aligned}\right\} \leftarrow 2\ \textbf{marks}$$

$\therefore$ Using torque about A:

$$3.0(735) + 3.5\left(F_L\right) = 1\ 444.3(2.0) \quad \leftarrow 3\ \textbf{marks}$$

$$\left.\begin{aligned} 2\ 205 + 3.5\left(F_L\right) &= 2\ 888.6\ \mathrm{N} \\ 3.5\left(F_L\right) &= 683\ \mathrm{N} \\ \mathrm{Load} &= 195.4\ \mathrm{N} \\ \mathrm{Mass} &= \frac{F_L}{9.8} \\ &= 19.9\ \mathrm{kg} \\ &= 20\ \mathrm{kg} \end{aligned}\right\} \textbf{1 mark}$$

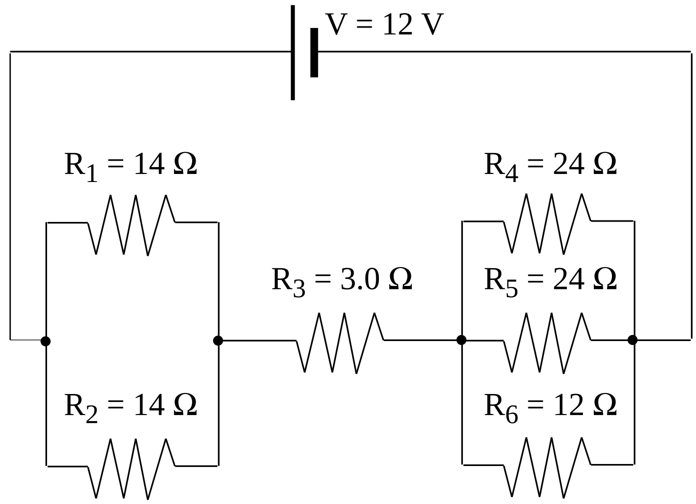
4. A 900 kg satellite which is travelling at 8 600 m/s around a planet of mass 8.1×10^{25} kg has an orbital radius of 7.3×10^{7} m. What is the total orbital energy of this satellite relative to infinity?
(7 marks)

$$E_p = \frac{-GMm}{r} = -6.66\times10^{10}\ \text{J} \qquad \leftarrow \textbf{3 marks}$$

$$E_k = \frac{1}{2}mv^2 = 3.33\times10^{10}\ \text{J} \qquad \leftarrow \textbf{3 marks}$$

$$\left.\begin{array}{l} E_T = E_p + E_k = -3.3\times10^{10}\ \text{J} \\ \text{or} \\ E_T = \dfrac{E_p}{2} = -E_k = -3.3\times10^{10}\ \text{J} \end{array}\right\} \textbf{1 mark}$$

5. What is the power dissipated by the 3.0 Ω resistor in the circuit below? **(7 marks)**



$$\frac{1}{R} = \frac{1}{14} + \frac{1}{14}$$

$R_{p1} = 7.0\ \Omega$ ← **1 mark**

$$\frac{1}{R} = \frac{1}{24} + \frac{1}{24} + \frac{1}{12} = \frac{4}{24}$$

$R_{p2} = 6.0\ \Omega$ ← **1 mark**

$$R_T = 7.0\ \Omega + 3.0\ \Omega + 6.0\ \Omega$$

$= 16.0\ \Omega$ ← **1 mark**

$I = \frac{V}{R} = \frac{12}{16.0} = 0.75\ \text{A}$ ← **2 marks**

$P = I^2R = 0.75^2\ \text{A} \times 3.0$ ← **2 marks**

$= 1.69\ \text{W}$

6. A motor is connected to 117 V and draws a current of 32.5 A when it first starts up. At its normal operating speed, the motor draws a current of 4.20 A.

a) What is the resistance of the armature coil? **(3 marks)**

$$V = IR \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$117 = (32.5)R \quad \leftarrow 2 \textbf{ marks}$$

$$R = 3.60\ \Omega \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

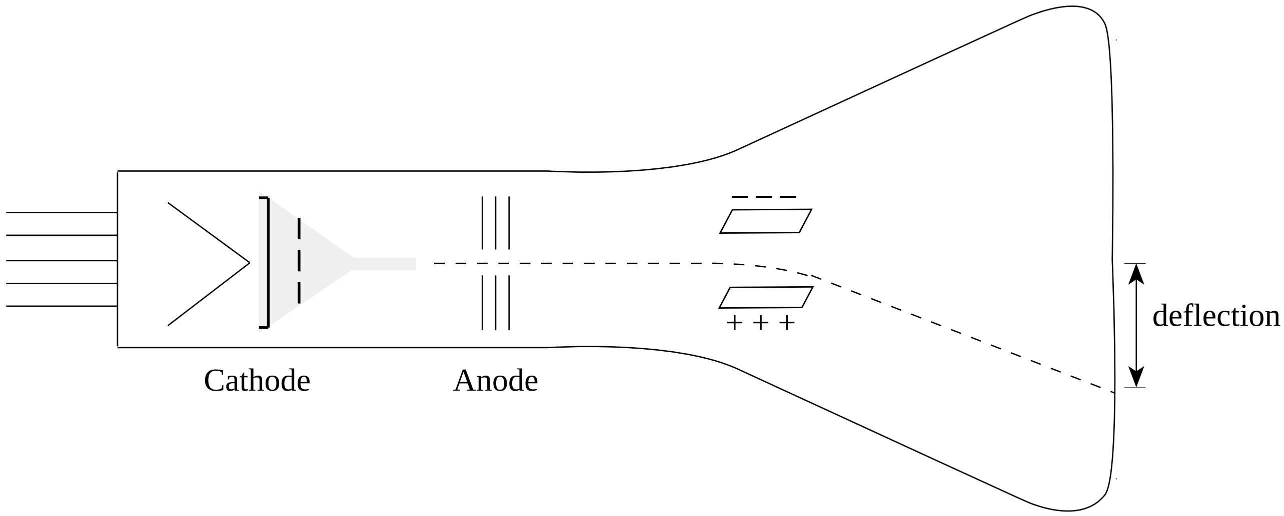
b) What is the back emf developed at normal operating speed? **(4 marks)**

$$V = E - IR \quad \leftarrow 1\tfrac{1}{2} \textbf{ marks}$$

$$= 117 - (4.20)(3.60) \quad \leftarrow 2 \textbf{ marks}$$

$$V = 102\ \text{V} \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

7. In a cathode-ray tube, electrons are accelerated from the cathode towards the anode by an accelerating voltage V_a. After passing through the anode, the electrons are deflected by the two oppositely-charged parallel plates.



If the accelerating voltage V_a is increased, will the deflection increase, decrease, or remain the same? Using principles of physics, explain your answer. **(4 marks)**

The deflection y will decrease.

If V_a is increased, the electrons are given a greater kinetic energy: e.g., $V_a = \dfrac{\Delta E_k}{q}$. Hence, the electrons are moving faster, so they spend less time between the plates. A force accelerates the electrons transversely between the plates; however, as the acceleration occurs for a shorter time, their deflection is reduced; e.g., $y = \dfrac{1}{2}at^2$.

PART C: ELECTED TOPICS

SECTION I: Quantum Physics

1. What is the de Broglie wavelength of a proton travelling at 5.0×10^{7} m/s? **(3 marks)**

$$\left.\begin{aligned}\lambda &= \frac{h}{p}\\ &= \frac{h}{mv}\end{aligned}\right\} \leftarrow \mathbf{1\tfrac{1}{2}\ marks}$$

$$\left.\begin{aligned}&= \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times5.0\times10^{7}}\\ &= 7.94\times10^{-15}\ \text{m}\end{aligned}\right\} \leftarrow \mathbf{1\tfrac{1}{2}\ marks}$$

2. a) What is the energy of a photon of light with a frequency of 5.0×10^{16} Hz? **(2marks)**

$E = hf$

$= (4.14\times10^{-15})(5.0\times10^{16})$

$= 207\ \text{eV}$ $\leftarrow$ **2 marks**

or

$3.31\times10^{-17}\ \text{J}$ $\leftarrow$ **2 marks**

b) Through what potential difference must electrons be accelerated to have the same amount of energy as that of the above photon? **(2 marks)**

$E = qV$

$V = \dfrac{E}{q} = \dfrac{3.31\times10^{-17}\ \text{J}}{1.6\times10^{-19}} = 207\ \text{V}$ $\leftarrow$ **2 marks**

3. What is the wavelength of photons emitted when electrons in the n = 5 energy level drop to the n = 2 energy level in hydrogen atoms? **(5 marks)**

For n = 5

$$E_{n=5} = \frac{-13.6\text{ eV}}{5^2} = -0.54\text{ eV}$$

For n = 2

$$E_{n=2} = \frac{-13.6\text{ eV}}{2^2} = -3.40\text{ eV}$$

$$\left.\begin{aligned}\Delta E_{\text{photon}} &= E_5 - E_2\\ &= -0.54\text{ eV} - (-3.40\text{ eV})\\ &= 2.86\text{ eV}\end{aligned}\right\}\ \textbf{½ mark}$$

3½ marks

$$\lambda = \frac{hc}{\Delta E}$$

$$= \frac{(4.14\times10^{-15}\text{ eV}\cdot\text{s})(3.0\times10^{8}\text{ m/s})}{2.86\text{ eV}}$$

$$= 4.3\times10^{-7}\text{ m}\ \ (435\text{ nm})$$

1½ marks

END OF SECTION I: Quantum Physics

SECTION II: Fluid Theory

1. A fire hose of area $4.0\times10^{-4}\ \text{m}^2$ is connected to a fire hydrant. Water enters the hydrant at a speed of 3.5 m/s through an underground pipe of area $5.6\times10^{-3}\ \text{m}^2$. What is the speed of the water in the fire hose? **(3 marks)**

$A_1v_1 = A_2v_2$ ← **1 mark**

$(5.6\times10^{-3})(3.5) = (4.0\times10^{-4})(v_2)$ ← **1 mark**

$v = 49\ \text{m/s}$ ← **1 mark**

2. Very fine dust particles are suspended in air at a temperature of $22°$ C. If the rms speed of the dust particles is 4.5×10^{-3} m/s, what is their average mass? **(4 marks)**

$E_k = \frac{3}{2}kT$ ← **1 mark**

$\frac{1}{2}mv^2 = \frac{3}{2}kT$ ← **1 mark**

$$\left.\begin{aligned} m &= \frac{3kT}{v^2} \\ &= \frac{3\,(1.38\times10^{-23})(295)}{(4.5\times10^{-3})^2} \\ &= 6.0\times10^{-16}\ \text{kg} \end{aligned}\right\} \leftarrow 2\ \textbf{marks}$$

3. The Goodyear airship contains 5 400 m^3 of helium having a density of 0.179 kg/m^3. The solid parts of the airship have a weight of 5.10×10^4 N. How much extra weight can the airship carry in equilibrium if the density of air is 1.29 kg/m^3? **(5 marks)**

$F_B = \rho_A V g$ ← **1½ marks**

$W_{He} = \rho_{He} V g$ ← **1 mark**

$F_B = W_{He} + W_S + W_x$ ← **1½ marks**

$W_x = 7.8 \times 10^3$ N ← **1 mark**

END OF SECTION II: Fluid Theory

SECTION III: AC Circuitry and Electronics

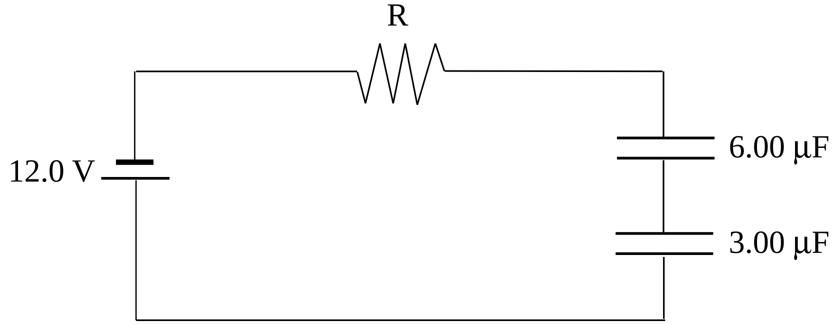
1. A coil has an inductance of 0.420 H. Determine the inductive reactance of the coil if 120 V_{rms} at 50.0 Hz is applied to it. **(3 marks)**

$X_L = 2\pi f L$ ← **1 mark**

$= 2\pi(50.0\ \text{s}^{-1})(0.420\ \text{H})$ ← **1 mark**

$= 132\ \Omega$ ← **1 mark**

2. Calculate the maximum charge that can be stored in the 6.00 μF capacitor shown below. **(4 marks)**



(1) Series $\dfrac{1}{C_T} = \dfrac{1}{3} + \dfrac{1}{6}$

$= \dfrac{2}{6} + \dfrac{1}{6} = \dfrac{3}{6}$

$\therefore C_T = \dfrac{6}{3} = 2.0\ \mu\text{F}$ **2 marks**

(2) Series $Q_T = C_T V_T$

$= (2.0\ \mu\text{F})(12.0\ \text{V})$

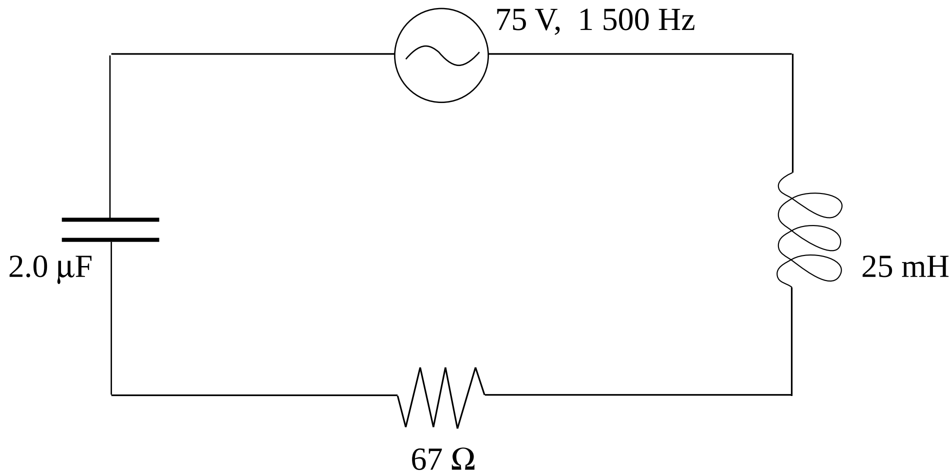
$= 24.0\ \mu\text{C}$

2 marks

(3) $Q_T = Q_6 = Q_3$

$\therefore Q_6 = 24.0\ \mu\text{C}$

3. What is the voltage drop across the inductor in the LCR circuit shown in the diagram below, when the applied voltage is 75 V_{rms} at a frequency of 1 500 Hz? **(5 marks)**



$$\left.\begin{aligned} X_C &= \frac{1}{2\pi f C} \\ &= \frac{1}{2\pi(1\,500)(2.0\times10^{-6}\ \text{F})} \\ &= 53.1\ \Omega \\ X_L &= 2\pi f L \\ &= 2\pi(1\,500\ \text{Hz})(25\times10^{-3}\ \text{H}) \\ &= 236\ \Omega \end{aligned}\right\}\ \mathbf{1\tfrac{1}{2}\ marks}$$

$$\therefore Z = \sqrt{67^2 + (236-53)^2} = 195\ \Omega \quad \leftarrow \mathbf{2\ marks}$$

$$\left.\begin{aligned} &\therefore I = \frac{V}{Z} = \frac{75\ \text{V}}{195\ \Omega} = 0.385\ \text{A} \\ &\therefore V_L = IX_L = 0.385\ \text{A}\ (236\ \Omega) = 91\ \text{V} \end{aligned}\right\}\ \mathbf{1\tfrac{1}{2}\ marks}$$

END OF KEY