Physics 12

August 1996 Provincial Examination

ANSWER KEY / SCORING GUIDE

TOPICS:

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

PART A: Multiple Choice

Q	C	T	K	S	CGR	Q	C	T	K	S	CGR
1.	K	1	A	2	I B1	16.	U	5	C	2	VI B3
2.	U	1	D	2	I B5	17.	U	5	B	2	VI A3
3.	U	1	C	2	I C3, 6	18.	U	5	A	2	VI B2
4.	U	1	D	2	I A1, B8	19.	K	5	A	2	VII B2
5.	U	1	C	2	II B6	20.	U	5	D	2	VII A11
6.	K	2	D	2	III A1	21.	U	5	C	2	VII B4
7.	U	2	C	2	III B1, C11	22.	U	5	C	2	VII A11, 7
8.	H	2	C	2	III D2	23.	H	5	D	2	VII A6, 7, 8
9.	K	2	B	2	III A5, 7, C8	24.	K	6	D	2	VIII A2
10.	K	4	C	2	V A3	25.	U	6	C	2	VIII A9
11.	U	4	A	2	V A6, II B6, A5	26.	U	6	B	2	VIII B4
12.	U	4	B	2	V B6, II A2	27.	U	6	C	2	VIII B11
13.	U	4	B	2	V B11	28.	K	6	D	2	VIII B6
14.	H	4	B	2	V A4	29.	H	6	A	2	VIII A6, IIIA1
15.	K	5	B	2	VI B1	30.	U	6	A	2	VIII B13

PART B: Written Response

Q	B	C	T	S	CGR
1.	1	H	1	9	II B6, A2
2.	2	U	2	7	III B1, 2, C5, 9
3.	3	U	3	7	IV B8
4.	4	U	4	7	V B6
5.	5	U	5	7	VII A7, 10
6.	6	U	6	7	VIII A3, 4
7.	7	H	3	4	IV A1, 2

PART C: Elective Topics

Only **one** of the following sections will be chosen. Score only **one** set of boxes: (8, 9, 10) **or** (11, 12, 13) **or** (14, 15, 16). Maximum possible score for Part C is 12.

	Q	**B**	**C**	**T**	**S**	**CGR**
Section I	1.	8	U	7	3	II A6, 14
	2.	9	U	7	4	II A9
	3.	10	U	7	5	II B6

or

	Q	**B**	**C**	**T**	**S**	**CGR**
Section II	1.	11	U	8	3	III A11
	2.	12	U	8	4	III A7, A2
	3.	13	U	8	5	III B11, 12

or

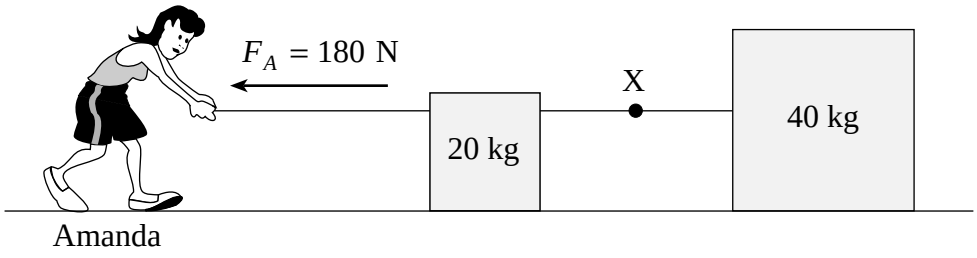
	Q	**B**	**C**	**T**	**S**	**CGR**
Section III	1.	14	U	9	3	I E5
	2.	15	U	9	4	I C5, 4
	3.	16	U	9	5	I A5

Multiple Choice = 60 (30 questions)
Written Response = 60 (10 questions)
Total = 120 marks

LEGEND:

Q = Question Number
B = Score Box Number
C = Cognitive Level
S = Score
T = Topic
K = Keyed Response
CGR = Curriculum Guide Reference

1. a) Amanda exerts a horizontal force of 180 N on a piece of rope causing two blocks of mass 20 kg and 40 kg to accelerate. Friction on the blocks is negligible. Find the tension force at **X** in the rope joining the two blocks together. **(5 marks)**



$F = ma$ (system as a whole) ← **1 mark**

$180 = (20 + 40)a$ ← **1 mark**

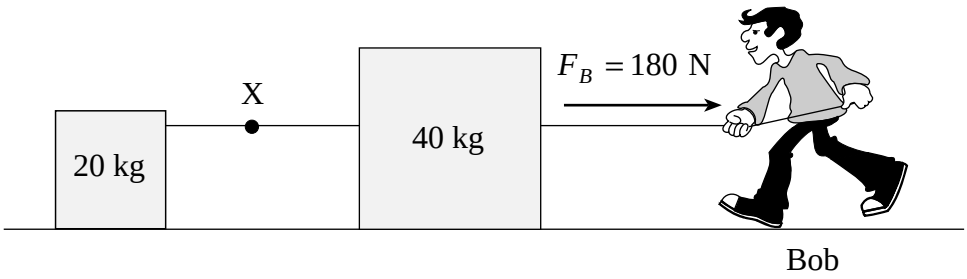
$\therefore a = 3.0 \text{ m/s}^2$ ← **1 mark**

$F = ma$ (40 kg mass only)

$F_T = 40(3.0)$ ← **1 mark**

$F_T = 120$ N ← **1 mark**

b) Bob exerts a force of equal magnitude in the opposite direction on an identical pair of blocks



How does the tension force at **X** compare to the value in part a)? (Circle one.) **(1 mark)**

i) The tension force is the same.

ii) The tension force is greater than in a).

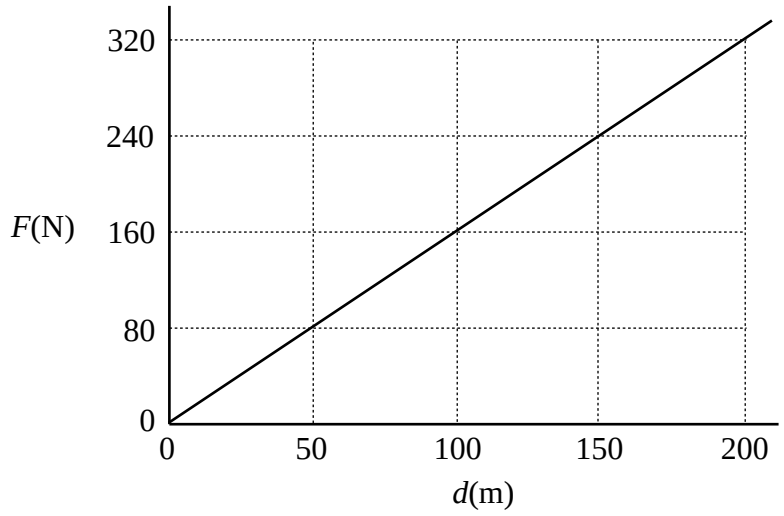
iii) The tension force is smaller than in a).

c) Using principles of physics, explain your answer to part b). **(3 marks)**

In both situations the **total mass** is the same so both **systems** accelerate at the same rate.

In b) the tension must accelerate a **smaller mass** at the **same rate** hence, from Newton's second law, $F = ma$, a smaller tension force will cause this.

2. A 24 kg rocket car is initially at rest on a frictionless horizontal surface. The engine is ignited and the graph below shows thrust force, ***F***, versus distance travelled, ***d***, for the rocket car. Find the rocket car's speed after it has travelled 200 m. **(7 marks)**



$W =$ area bounded by graph and d - axis ← **1 mark**

$= \frac{1}{2}\ bh$

$= \frac{1}{2} \times 200 \times 320$

$= 32\ 000$ J ← **2 marks**

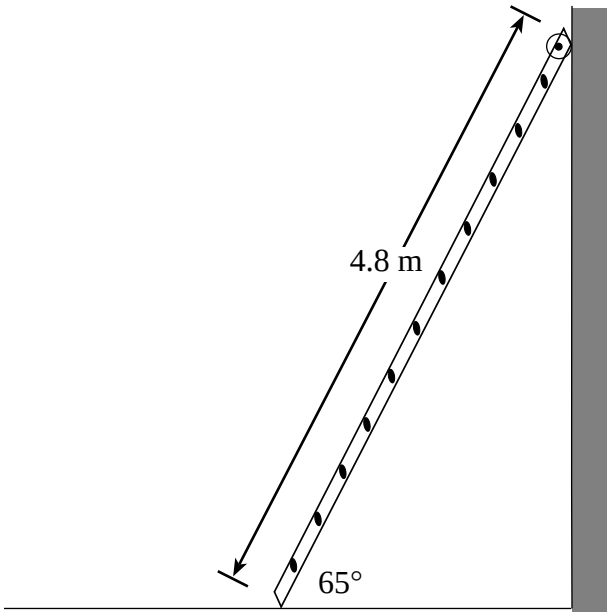
$W = \Delta E_k = E_k'$ ← **1 mark**

$32\ 000 = \frac{1}{2}(24)(v')^2$ ← **1 mark**

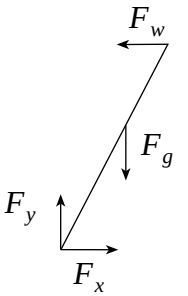
$32\ 000 = 12(v')^2$

$v' = 52$ m/s ← **2 marks**

3. A uniform 4.8 m long ladder of mass 16 kg leans against a **frictionless** vertical wall as shown in the diagram below.



a) Draw and label a free body diagram showing the forces acting on the ladder. **(2 marks)**



2 marks

b) What minimum force of friction is needed at the base of the ladder to keep it from sliding? **(5 marks)**

$\tau_{cw} = \tau_{ccw}$

$F_{g_\perp}(2.4) = F_{w_\perp}(4.8)$ ← **3 marks**

$(16)(9.8)(\cos 65)(2.4) = F_w \sin 65(4.8)$

$159 = F_w(4.35)$

$F_w = 37$ N ← **1 mark**

$\sum F_x = 0 \quad F_x = F_w$

$F_f = 37$ N ← **1 mark**

4. A 4.2×10^{3} kg spacecraft orbits a 5.6×10^{26} kg planet. If it takes the spacecraft 8.9×10^{4} s to complete one orbit, how far is it from the planet's centre? **(7 marks)**

$$F_{net} = F_G$$

$$F_C = F_G \quad \leftarrow \textbf{2 marks}$$

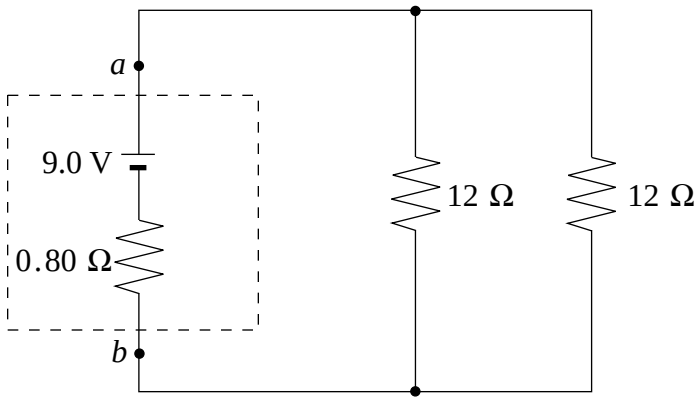
$$\frac{m_1 4\pi^2 r}{T^2} = \frac{G m_1 m_2}{r^2} \quad \leftarrow \textbf{2 marks}$$

$$r^3 = \frac{G m_2 T^2}{4\pi^2} \quad \leftarrow \textbf{1 mark}$$

$$= \frac{\left(6.67\times10^{-11}\right)\left(5.6\times10^{26}\right)\left(8.9\times10^{4}\right)^2}{4\pi^2} \quad \leftarrow \textbf{1 mark}$$

$$r = 2.0\times10^{8} \text{ m} \quad \leftarrow \textbf{1 mark}$$

5. A $9.0\ \text{V}$ battery with an internal resistance of $0.80\ \Omega$ is connected to two resistors as shown below. Determine the terminal voltage V_{ab} of the battery. **(7 marks)**



$$\frac{1}{R\ \text{parallel}} = \frac{1}{12} + \frac{1}{12},\ R\ \text{parallel} = 6.0\ \Omega \qquad \leftarrow \textbf{1 mark}$$

$$R_t = 6.8\ \Omega \qquad \leftarrow \textbf{1 mark}$$

$$I_t = \frac{V_t}{R_t} = \frac{9.0\ \text{V}}{6.8\ \Omega} = 1.32\ \text{A} \qquad \leftarrow \textbf{1 mark}$$

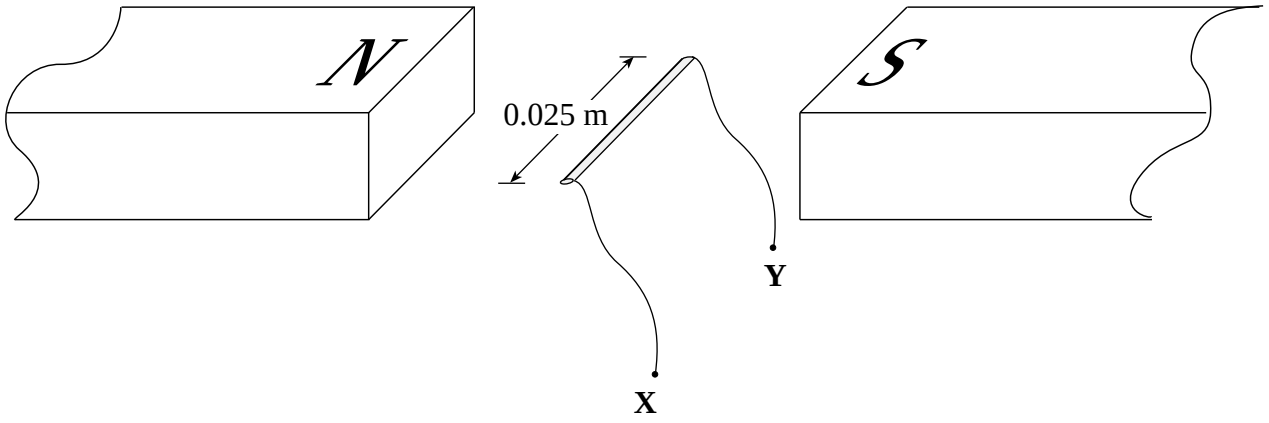
$$V_r = Ir = 1.32(0.8) = 1.06\ \text{V} \qquad \leftarrow \textbf{1 mark}$$

$$\left.\begin{aligned} \therefore V_{ab} &= \mathcal{E} - Ir \\ &= 9.0 - 1.06 \\ V_{ab} &= 7.9\ \text{V} \end{aligned}\right\} \leftarrow \textbf{3 marks}$$

OR

$$V_{ab} = 1.32(6) = 7.9V \leftarrow \textbf{3 marks}$$

6. A 0.025 m wire segment is positioned in a 0.75 T magnetic field as shown in the diagram below. When a current is passed through this wire segment it experiences a 0.20 N force upwards.



a) What is the direction of the current? (Circle one.) **(2 marks)**

From **X** to **Y** (From **Y** to **X**)

b) What is the magnitude of the current? **(5 marks)**

$F = BI\ell$ ← **1 mark**

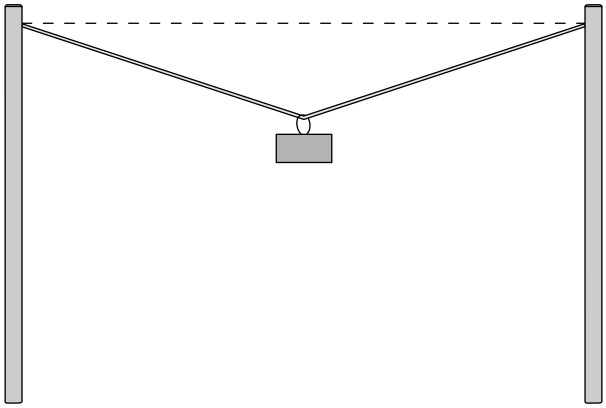
$I = \dfrac{F}{B\ell}$ ← **1 mark**

$= \dfrac{0.20\ \text{N}}{0.75\ \text{T} \times 0.025\ \text{m}}$ ← **2 marks**

$= 10.7\ \text{A}$

$= 11\ \text{A}$ ← **1 mark**

7. A wire is stretched between two posts. A mass is suspended near the centre as shown below.



If the tension in the wire were increased, is it possible to make the wire perfectly horizontal? Explain your answer in terms of forces. **(4 marks)**

No, it is not possible to make the wire perfectly horizontal. Since the mass has a vertical force of gravity acting on it, the tension in the wire must have an opposite vertical component. A horizontal tension has no vertical component; therefore, it is not possible to make the wire perfectly horizontal.

PART C: ELECTED TOPICS

SECTION I: Quantum Mechanics

1. What is the momentum of a photon with a frequency of 5.09×10^{14} Hz ? **(3 marks)**

$$p = \frac{h}{\lambda} = \frac{hf}{c} = \frac{6.63\times10^{-34}\left(5.09\times10^{14}\right)}{3\times10^{8}} = 1.1\times10^{-27}\ \text{kg}\cdot\text{m/s}$$

↑ **1 mark** ↑ **1 mark** ↑ **1 mark**

2. A metal surface has a work function of 3.68 *e*V. Incident light causes photoelectrons to be emitted with a maximum kinetic energy of 1.36×10^{-19} J. What is the wavelength of the incident light? **(4 marks)**

$$E_{k_{\max}} = \frac{hc}{\lambda} - w_0 \quad \leftarrow \textbf{1 mark}$$

$$\frac{1.36\times10^{-19}}{1.6\times10^{-19}} = \frac{\left(4.14\times10^{-15}\right)\left(3.0\times10^{8}\right)}{\lambda} - 3.68 \quad \leftarrow \textbf{1 mark}$$

$$0.85 = \frac{\left(1.24\times10^{-6}\right)}{\lambda} - 3.68 \quad \leftarrow \textbf{1 mark}$$

$$4.53 = \frac{\left(1.24\times10^{-6}\right)}{\lambda}$$

$$\lambda = 274\ \text{nm} \quad \leftarrow \textbf{1 mark}$$

3. The electron in a hydrogen atom is in the excited state $n = 3$.

a) As the atom emits energy, how many different frequencies of light can be produced? **(2 marks)**

Three

b) Calculate the lowest frequency of light emitted by this atom. **(3 marks)**

$$E_3 = -13.6\left(\frac{1}{3^2}\right) = -1.51\ eV$$

$$E_2 = -13.6\left(\frac{1}{2^2}\right) = -3.40\ eV$$

$$\Delta E_{3\text{-}2} = (-1.51) - (-3.40) = 1.89\ eV$$

$$\Delta E = hf$$

$$1.89 = 4.14 \times 10^{-15}\ f$$

$$f = 4.57 \times 10^{14}\ \text{Hz}$$

END OF SECTION I: Quantum Mechanics

SECTION II: Fluid Theory

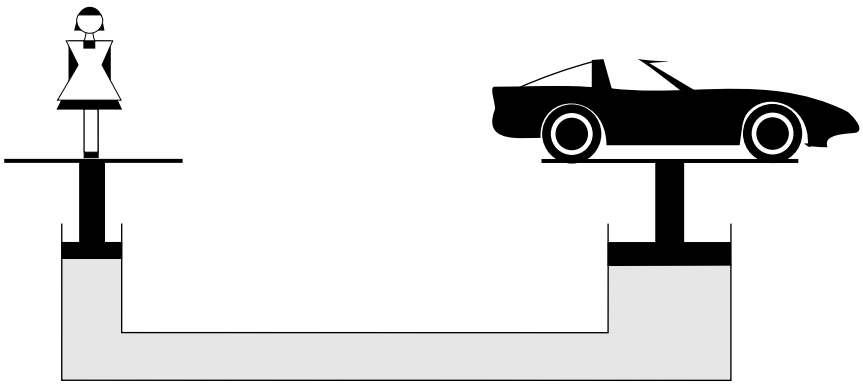
1. A horizontal pipe of cross-sectional area 3.0×10^{-2} m^2 tapers to a cross-sectional area of 1.5×10^{-2} m^2. If the speed of water in the wide section of pipe is 4.0 m/s, what is the speed of the water in the narrow section of pipe? **(3 marks)**

$$A_1v_1 = A_2v_2 \qquad \leftarrow \textbf{ 1 mark}$$

$$\left(3.0\times10^{-2}\right)(4.0) = \left(1.5\times10^{-2}\right)(v_2) \qquad \leftarrow \textbf{ 1 mark}$$

$$v_2 = 8.0 \text{ m/s} \qquad \leftarrow \textbf{ 1 mark}$$

2. A 48 kg girl and a car of mass m are placed on a hydraulic lift as shown in the diagram below. The area of the piston the girl stands on is 7.0×10^{-3} m^2, while the area of the piston under the car is 0.12 m^2.



What maximum car mass m can be supported in this situation? **(4 marks)**

$$P_i = P_o \qquad \leftarrow \textbf{ 1 mark}$$

$$\frac{F_i}{A_i} = \frac{F_o}{A_o} \qquad \leftarrow \textbf{ 1 mark}$$

$$\frac{m_Gg}{A_i} = \frac{m_Cg}{A_o} \qquad \leftarrow \textbf{ 1 mark}$$

$$\frac{(48)(9.8)}{7.0\times10^{-3}} = \frac{m_C(9.8)}{0.12}$$

$$m = 820 \text{ kg} \qquad \leftarrow \textbf{ 1 mark}$$

3. An 18 m^3 container holds 1 200 moles of oxygen at a pressure of 1.5×10^5 Pa. If the mass of an oxygen molecule is 5.3×10^{-26} kg, what is the rms speed of the molecules? **(5 marks)**

$PV = nRT$

$$T = \frac{PV}{nR} = \frac{\left(1.5\times10^5\right)(18)}{(1\ 200)(8.31)}$$

$T = 271$ K ← **2 marks**

$$E_k = \frac{3}{2}kT = \frac{3}{2}\left(1.38\times10^{-23}\right)(271)$$

$= 5.6\times10^{-21}$ J ← **2 marks**

$$E_k = \frac{1}{2}mv^2$$

$v = \sqrt{\frac{2E_k}{m}}$ $v = 460$ m/s ← **1 mark**

END OF SECTION II: Fluid Theory

SECTION III: AC Circuitry and Electronics

1. A transistor has a current gain of 150. When the base current increases from $5.0\ \mu A$ to $7.5\ \mu A$, what is the change in the collector current? **(3 marks)**

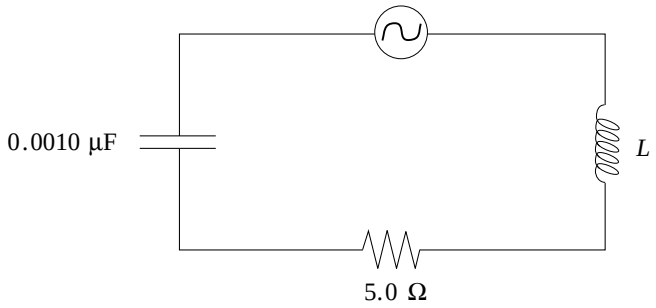
$$\beta = \frac{\Delta I_C}{\Delta I_B} \qquad \leftarrow \textbf{ 1 mark}$$

$$\Delta I_C = \beta \cdot \Delta I_B$$

$$= 150 \times (7.5 - 5.0)\ \mu A$$

$$= 375\ \mu A \qquad \leftarrow \textbf{ 2 marks}$$

2. The circuit show in the diagram below resonates at 1 410 kHz.



What is the inductance? **(4 marks)**

$$X_L = X_C$$

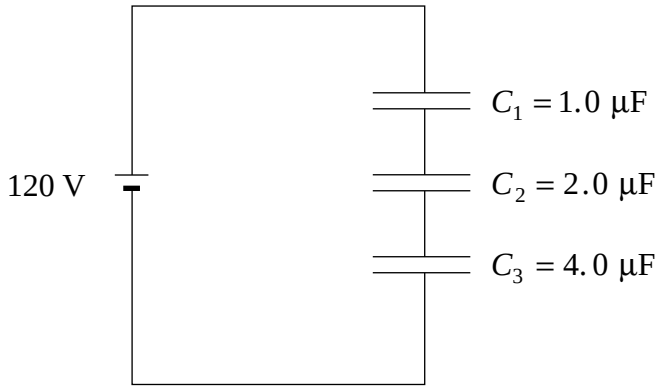
$$2\pi f_0 L = \frac{1}{2\pi f_0 C} \qquad \leftarrow \textbf{ 2 marks}$$

$$L = \frac{1}{4\pi^2 f_0^{\,2} C}$$

$$= \frac{1}{4\pi^2 \left(1.410 \times 10^6\right)^2 \times 0.0010 \times 10^{-6}\ \text{F}} \qquad \leftarrow \textbf{ 1 mark}$$

$$= 1.3 \times 10^{-5}\ \text{H} \qquad (0.013\ \text{mH}) \qquad \leftarrow \textbf{ 1 mark}$$

3. Determine the voltage across capacitor C_2. **(5 marks)**



$$\frac{1}{C_T} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$
$$= \frac{1}{1.0} + \frac{1}{2.0} + \frac{1}{4.0}$$

$\therefore C_T = 0.57\ \mu F$ $\leftarrow$ **2 marks**

$$Q_T = C_T V_T$$
$$= (0.57\ \mu F)(120\ V)$$
$$= 6.86 \times 10^{-5}\ C \quad \leftarrow \textbf{1 mark}$$

$$\therefore V_2 = \frac{Q_T}{C_2}$$
$$= \frac{6.86 \times 10^{-5}\ C}{2.0 \times 10^{-6}\ F} \quad \leftarrow \textbf{1 mark}$$
$$= 34\ V \quad \leftarrow \textbf{1 mark}$$

END OF SECTION III: AC Circuitry and Electronics

END OF KEY