Physics 12

June 1997 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	D	2	I B1	16.	U	5	B	2	VI B2
2.	K	1	B	2	I C4	17.	U	5	C	2	VI B3
3.	U	1	B	2	II B6	18.	K	5	C	2	VII B2
4.	U	1	A	2	I B10	19.	U	5	C	2	VII B4
5.	K	2	A	2	III A3	20.	U	5	C	2	VII A7, A8
6.	U	3	A	2	III C9	21.	U	5	D	2	VII A10, 11
7.	H	2	C	2	III C5, C9	22.	H	5	D	2	VII A7, A11
8.	U	3	C	2	IV A3	23.	K	6	A	2	VIII A2
9.	H	3	C	2	IV A3	24.	U	6	C	2	VIII A8
10.	U	4	A	2	V A6, II B6	25.	U	6	C	2	VIII A7
11.	U	4	B	2	V B6	26.	H	6	A	2	VIII A2
12.	K	4	D	2	V A3	27.	K	6	B	2	VIII B14
13.	U	4	D	2	V B3	28.	U	6	B	2	VIII B11
14.	K	5	A	2	VI A7	29.	U	6	A	2	VIII B2
15.	U	5	A	2	VI A5, II B3	30.	U	6	A	2	VIII B8, A3

PART B: Written Response

Q	B	C	T	S	CGR
1.	1	U	1	7	I C6
2.	2	U	2	7	III D2
3.	3	U	3	7	IV B8
4.	4	H	4	9	V B6
5.	5	U	5	7	VI A5, B2, IV A3

6.	6	U	6	7	VIII A5, 6
7.	7	H	5	4	VII B6, A6

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 A9
	2.	9	U	7	4	II B6, A6
	3.	10	U	7	5	II A14, B5

or

	Q	**B**	**C**	**T**	**S**	**CGR**
Section II	1.	11	U	8	3	III B12
	2.	12	U	8	4	III A7
	3.	13	U	8	5	III A9, A2

or

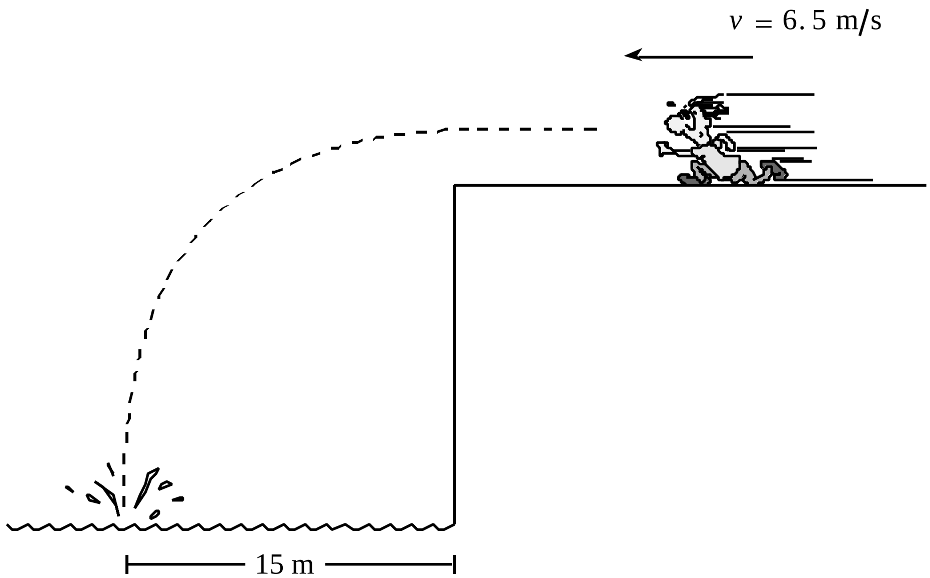
	Q	**B**	**C**	**T**	**S**	**CGR**
Section III	1.	14	U	9	3	I E8
	2.	15	U	9	4	I C2, A10, B3
	3.	16	U	9	5	I A5, A3

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

LEGEND:

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

1. Mike runs horizontally off a cliff at 6.5 m/s and lands in the water 15 m from the base of the cliff.



a) How long does it take Mike to hit the water? **(3 marks)**

$d_H = v_H t$ ← **1 mark**

$t = \frac{d_H}{v_H}$

$= \frac{15}{6.5}$ ← **1 mark**

$= 2.3\text{s}$ ← **1 mark**

b) How high is the cliff? **(4 marks)**

$d = v_0 t + \frac{1}{2}at^2$ ← **1 mark**

$d = \frac{1}{2}(9.8)(2.3)^2$ ← **2 marks**

$= 26$ m ← **1 mark**

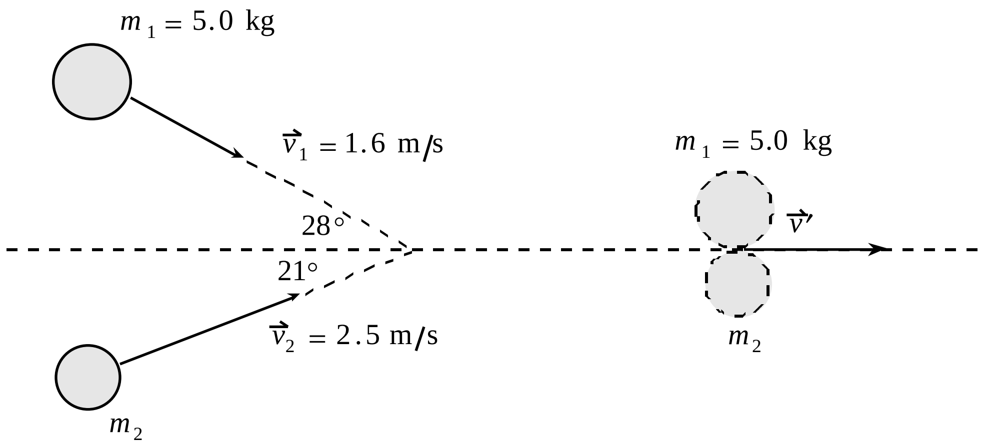
OR

$v_y = v_0 + at = 0 + (9.8)(2.31) = 22.6$ m/s

$v^2 = v_0{}^2 + 2ad$

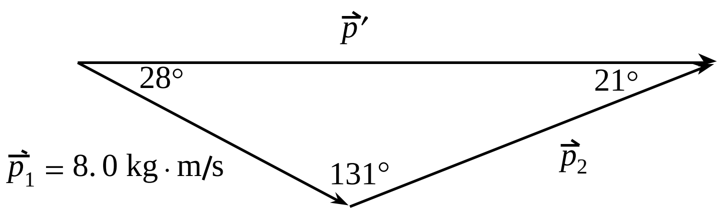
$d = \frac{v^2 - v_0{}^2}{2a} = \frac{22.6^2 - 0}{2(9.8)} = 26.1$

2. A 5.0 kg object travelling at 1.6 m/s collides with an object of unknown mass m_2 travelling at 2.5 m/s. The two objects stick together and move towards the right as shown in the diagram.



Find the mass of object m_2. **(7 marks)**

$p_1 = m_1 v_1 = 5.0(1.6) = 8.0 \text{ kg} \cdot \text{m/s}$ ← **1 mark**



← **3 marks**

$\dfrac{p_2}{\sin 28°} = \dfrac{8.0}{\sin 21°}$ ← **1 mark**

$p_2 = 10.5 \text{ kg} \cdot \text{m/s}$ ← **1 mark**

$m_2 = \dfrac{10.5}{2.5} = 4.19 \text{ kg}$ ← **1 mark**

OR the Component Method

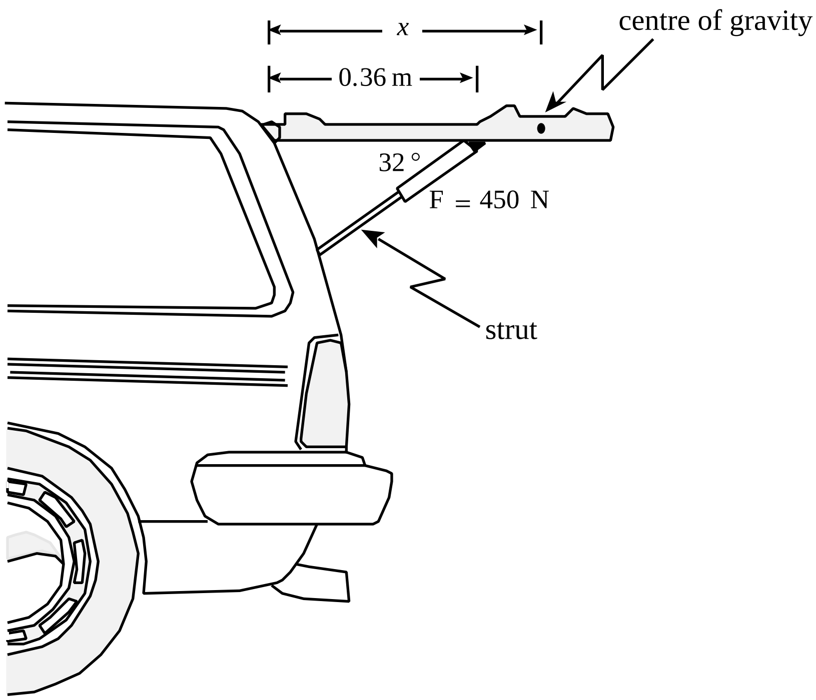
$\tau_{cc} = -5(1.6)\sin 28°$ ← **2 marks**

$\tau_c = m(2.5)\sin 21°$ ← **2 marks**

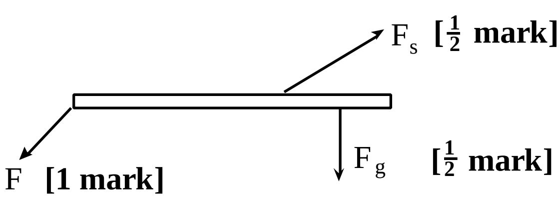
$\sum \tau_y = 0 \quad \therefore m(2.5)(\sin 21°) + -5(1.6)\sin 28° = 0$ ← **1 mark**

$m = 4.2 \text{ kg}$ ← **2 marks**

3. The diagram shows the rear door of a station wagon supported horizontally by a strut. The mass of the door is 18 kg and the compression force in the strut is 450 N.



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



b) At what distance, x, from the hinge is the centre of gravity of the door located? **(5 marks)**

$$\tau_c = \tau_{cc}$$

$$mgx = F_s(d)\sin\theta \qquad \leftarrow \textbf{2 marks}$$

$$18(9.8)x = 450(0.36)\sin 32° \qquad \leftarrow \textbf{2 marks}$$

$$x = 0.49 \text{ m} \qquad \leftarrow \textbf{1 mark}$$

4. a) The space shuttle orbits the Earth in a circular path where the gravitational field strength is $8.68\ \text{N/kg}$. What is the shuttle's orbital radius? **(5 marks)**

$$F_g = mg = \frac{GMm}{r^2}$$ ← **2 marks**

$$g = \frac{GM}{r^2}$$ ← **1 mark**

$$r = \sqrt{\frac{GM}{g}}$$

$$= \sqrt{\frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{8.68}}$$ ← **1 mark**

$$= 6.78 \times 10^6\ \text{m}$$ ← **1 mark**

b) A space station that has 10 times the mass of the shuttle in a) orbits Earth at the same altitude. How does the orbital speed of the space station compare to that of the shuttle? (Check one response.) **(1 mark)**

- ☐ The space station's speed is less than the shuttle's speed.
- ☑ The space station's speed is the same as the shuttle's speed.
- ☐ The space station's speed is greater than the shuttle's speed.

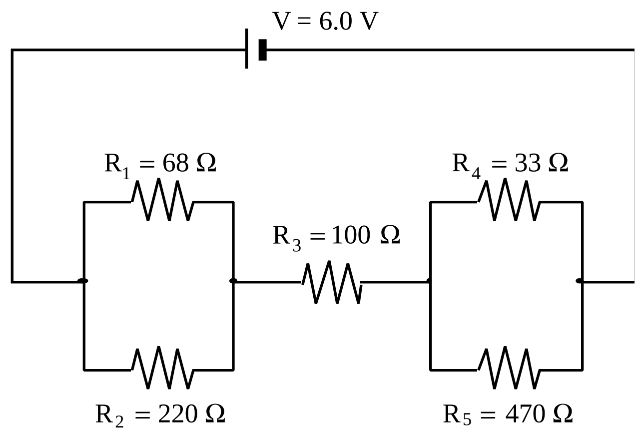
c) Using principles of physics, explain your answer to b). **(3 marks)**

The force of gravity is the only force that provides the centripetal acceleration. Since both the gravitational force and the centripetal force are proportional to mass, the acceleration remains the same, therefore the speeds must be the same. $\left(\frac{v^2}{r}\right)$ ← **3 marks**

OR

Since $F_g = F_c$, $\frac{m_1 v^2}{r} = \frac{G m_1 m_{earth}}{r^2}$ **when you solve for *v*, the mass of the orbiting body cancels out. Speed is independent of the size of the orbiting mass.**

5. Consider the circuit shown in the diagram below.



a) What is the total resistance of the circuit? **(3 marks)**

$$\frac{1}{R_1^{||}} = \frac{1}{68\ \Omega} + \frac{1}{220\ \Omega}$$

$$R_1^{||} = 51.9\ \Omega$$

$$\frac{1}{R_2^{||}} = \frac{1}{33\ \Omega} + \frac{1}{470\ \Omega}$$

$$R_2^{||} = 30.8\ \Omega$$

$$\therefore R_T = R_1^{||} + 100\ \Omega + R_2^{||}$$

$$= 51.9\ \Omega + 100\ \Omega + 30.8\ \Omega$$

$$= 182.7\ \Omega \rightarrow 1.8 \times 10^2\ \Omega$$

← **3 marks**

b) What is the current through the $100\ \Omega$ resistor? **(2 marks)**

$$I_{circuit} = I_{100} = \frac{V}{R_T}$$

$$= \frac{6.0\ V}{182.7\ \Omega}$$

$$= 3.3 \times 10^{-2}\ \text{A}$$

← **2 marks**

c) What is the power dissipated in the $100\ \Omega$ resistor? **(2 marks)**

$P_{100} = I^2R$

$= (0.0328\ A)^2 \cdot 100\ \Omega$

$= 0.11\ \text{W}$ ← **2 marks**

6. A proton enters a magnetic field of magnitude 2.4×10^{-2} T at a speed of 5.0×10^{5} m/s perpendicular to the field.

   a) What magnetic force acts on the proton? **(3 marks)**

$F = qvB$ ← **1 mark**

$= 1.6 \times 10^{-19} \times 5.0 \times 10^{5} \times 2.4 \times 10^{-2}$ ← **1 ½ marks**

$= 1.9 \times 10^{-15}$ N ← **½ mark**

   b) What is the radius of the proton's circular path? **(4 marks)**

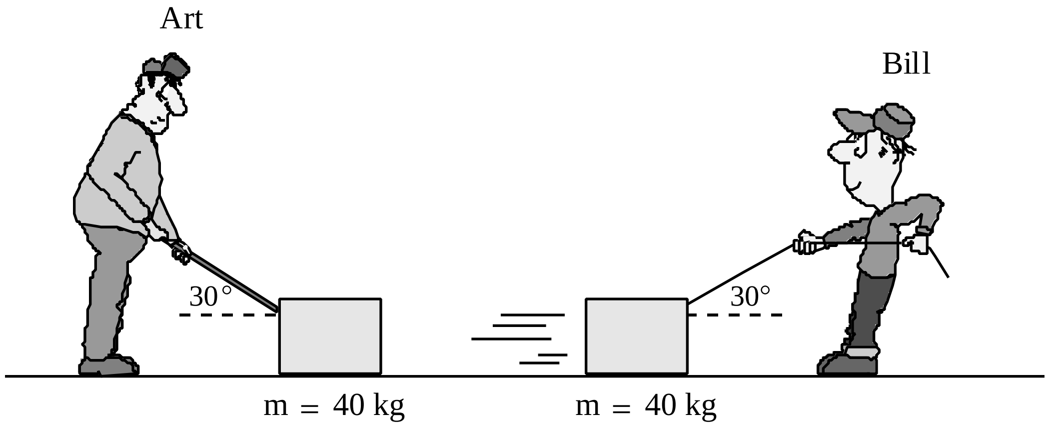
$F_c = F_B$ ← **1 mark**

$\frac{mv^2}{r} = qvB$ ← **1 mark**

$r = \frac{mv}{qB}$

$= \frac{1.67 \times 10^{-27} \times 5.0 \times 10^{5}}{1.6 \times 10^{-19} \times 2.4 \times 10^{-2}} = 0.22$ m ← **2 marks**

7. Art and Bill both attempt to move identical 40 kg crates across identical rough surfaces. Art exerts an 80 N force by pushing with a stick. Bill exerts an 80 N force by pulling on a cord. Bill's crate slides across the ground, but Art's will not move.



Explain this observation, using principles of physics. **(4 marks)**

When Art exerts a force on the crate there is a downward component which must be opposed; there is therefore a large normal reaction force.

When Bill exerts a force there is an upward component which means the normal reaction force will be small.

As the force of friction depends on the normal reaction force $(F_F = \mu F_N)$, Art encounters a large friction force and he is unable to move the crate.

Bill, however, is able to move his crate because the friction force is small.

PART C: ELECTED TOPICS

SECTION I: Quantum Mechanics

1. What is the threshold frequency for a metal with a work function of 2.3 eV? **(3 marks)**

$$\left.\begin{aligned} E_k &= hf - W \\ hf_0 &= W \end{aligned}\right\} \leftarrow \textbf{1 mark}$$

$$f_0 = \frac{W}{h} \qquad \leftarrow \textbf{1 mark}$$

$$= \frac{2.3}{4.14 \times 10^{-15}}$$

$$= 5.6 \times 10^{14}\ Hz \qquad \leftarrow \textbf{1 mark}$$

2. Light of wavelength 1.35×10^{-8} m is emitted from a doubly ionized Lithium ion (3 protons) when the electron jumps from quantum level n to ground state $(n = 1)$. What is the value of n? **(4 marks)**

$$E = \frac{hc}{\lambda} = \frac{(4.14 \times 10^{-15})(3.0 \times 10^{8})}{1.35 \times 10^{-8}} = 92.1\ eV \qquad \leftarrow \textbf{1 mark}$$

$$E_1 = \frac{-13.6(3^2)}{1^2} = -122.4\ eV \qquad \leftarrow \textbf{1 mark}$$

$$E_n - E_1 = 92.1$$

$$E_n - (-122) = 92.1$$

$$E_n = -30.3\ eV \qquad \leftarrow \textbf{1 mark}$$

$$-30.3 = \frac{-13.6(3^2)}{n^2}$$

$$n = 2 \qquad \leftarrow \textbf{1 mark}$$

3. An electron has a de Broglie wavelength of 1.7×10^{-11} m.

a) What is the speed of the electron? **(3 marks)**

$$\lambda = \frac{h}{p} \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$\lambda = \frac{h}{mv} \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$\textbf{1 mark} \rightarrow \left\{ v = \frac{h}{m\lambda} = \frac{6.63 \times 10^{-34} \quad \leftarrow \tfrac{1}{2} \textbf{ mark}}{\left(9.11 \times 10^{-31}\right)\left(1.7 \times 10^{-11}\right)} \right.$$

$$v = 4.3 \times 10^{7} \text{ m/s} \leftarrow \tfrac{1}{2} \textbf{ mark}$$

b) To acquire this speed, through what potential difference was this electron accelerated from rest? **(2 marks)**

$$\Delta Ep = E_k \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$QV = \tfrac{1}{2} mv^2 \quad \leftarrow \tfrac{1}{2} \textbf{ mark}$$

$$\tfrac{1}{2} \textbf{ mark} \rightarrow \left\{ V = \frac{\left(9.11 \times 10^{-31}\right)\left(4.3 \times 10^{7}\right)^2}{2\left(1.6 \times 10^{-19}\right)} \right. = 5.2 \times 10^{3} \text{ V} \leftarrow \tfrac{1}{2} \textbf{ mark}$$

END OF SECTION I: Quantum Mechanics

SECTION II: Fluid Theory

1. What is the average kinetic energy per molecule of an ideal gas at a temperature of 310 K?

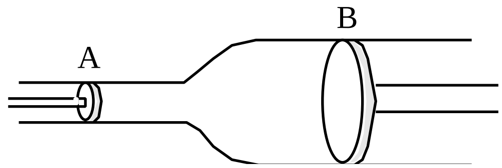
(3 marks)

$$E_k = \frac{3}{2}kT$$ ← **1 mark**

$$= \frac{3}{2}\left(1.38\times10^{-23}\right)(310)$$ ← **1 mark**

$$= 6.4\times10^{-21}\text{ J}$$ ← **1 mark**

2. In the hydraulic brake system shown below, a force of 25 N is exerted on piston A of area $5.0\times10^{-4}\text{ m}^2$.



What resulting force would be exerted on the larger piston B if it has an area of $1.1\times10^{-2}\text{ m}^2$?

(4 marks)

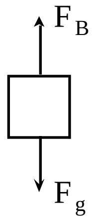
$$P_A = P_B$$ ← **1 mark**

$$\frac{F_A}{A_A} = \frac{F_B}{A_B}$$

$$F_B = F_A\left(\frac{A_B}{A_A}\right)$$ ← **2 marks**

$$= (25)\left(\frac{1.1\times10^{-2}}{5.0\times10^{-4}}\right) = 550\text{ N}$$ ← **1 mark**

3. An object of unknown material has a mass of 4.30 kg. When the object is submerged in fresh water, it has a weight of 39.0 N. What is the density of the object? **(5 marks)**



$$F_{net} = F_g - F_B$$

$$39.0 = (4.30)(9.8) - F_B$$

$$F_B = 3.1 \text{ N}$$ ← **2 marks**

$$F_B = \rho V g$$

$$3.1 = (1000)(V)(9.8)$$

$$V = 3.2 \times 10^{-4} \text{ m}^3$$ ← **2 marks**

$$\rho = \frac{m}{V} = \frac{4.3}{3.2 \times 10^{-4}}$$

$$= 1.3 \times 10^{4} \text{ kg/m}^3$$ ← **1 mark**

END OF SECTION II: Fluid Theory

SECTION III: AC Circuitry and Electronics

1. Without feedback, the gain of an amplifier is 85. With feedback, the gain of the amplifier is 65. What is the feedback ratio? **(3 marks)**

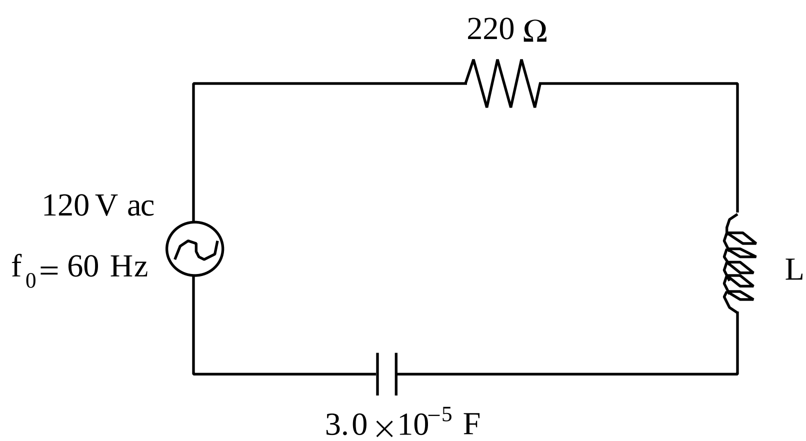
$$A_f = \frac{A}{1-\beta A} \quad \leftarrow \textbf{1 mark}$$

$$65 = \frac{85}{1-\beta(85)} \quad \leftarrow \textbf{1 mark}$$

$$1-\beta(85) = \frac{85}{65}$$

$$\beta = -3.6\times 10^{-3} \quad \leftarrow \textbf{1 mark}$$

2. The following circuit has a resonant frequency of 60 Hz. **(4 marks)**



What is the inductive reactance at resonance?

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

$$L = \frac{1}{4\pi^2 f_0^2 C} = 0.235\text{ H} \quad \leftarrow \textbf{2 marks}$$

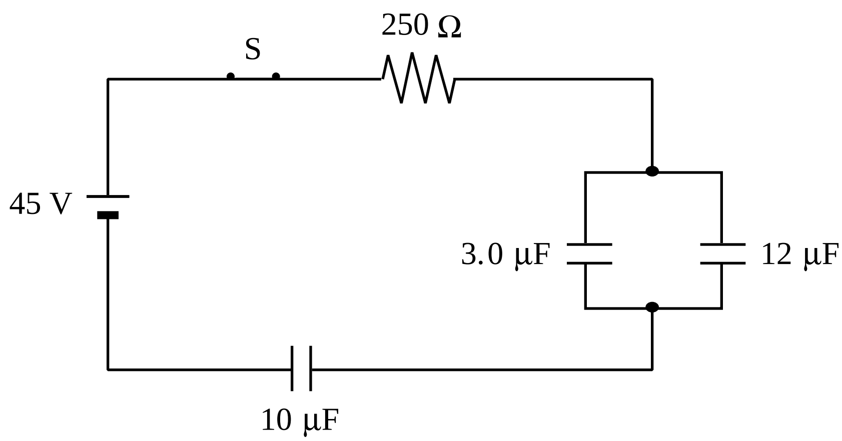
$$X_L = 2\pi f L = 2\pi(60)(0.235) = 88\ \Omega \quad \leftarrow \textbf{2 marks}$$

OR

At resonance $X_L = X_C$ ← **2 marks**

$$X_C = \frac{1}{2\pi f c} = \frac{1}{2\pi(60)(3\times10^{-5})} = 88\ \Omega \quad \leftarrow \textbf{2 marks}$$

3. Switch S in the circuit below has been closed for a long time.



What is the charge on the 3.0 μF capacitor? **(5 marks)**

$$C_{\|} = 15\mu F$$ ← **1 mark**

$$\frac{1}{C_T} = \frac{1}{10\mu F} + \frac{1}{15\mu F}$$

$$C_T = 6.0\mu F$$ ← **1 mark**

$$Q_T = C_T V$$

$$= \left(6.0 \times 10^{-6}\right)(45)$$

$$= 2.7 \times 10^{-4} \text{ C}$$ ← **1 mark**

$$V_{\|} = \frac{Q_T}{C_{\|}} = \frac{2.7 \times 10^{-4}}{15 \times 10^{-6}} = 18 \text{ V}$$ ← **1 mark**

$$Q = CV = \left(3.0 \times 10^{-6}\right)(18) = 5.4 \times 10^{-5} \text{ C}$$ ← **1 mark**

END OF SECTION III: AC Circuitry and Electronics

END OF KEY