Section A: Short Answers **60 Marks**

Attempt **all** 15 questions in this section. Each question is worth 4 marks. Answers are to be written in the space provided.

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1. $f_b = |f_1 - f_2|$ Must show working (2 marks)

$f_2 = 256 - 6$

$f_2 = 250\ \text{Hz}$ ← 2 marks only. (2 marks)

2. (a) 2 (2 marks)

(b) Positive (2 marks)

3.

$$60 = 10\log_{10}\frac{I}{I_o}$$

$$I_{1fp} = 10^6 \times 10^{-12}$$

$$I_{5fp} = 5 \times 10^6 \times 10^{-12}$$ (2 marks)

$$\text{sound level} = 10\log_{10}\frac{5\times10^6\times10^{-12}}{10^{-12}}$$ (1 mark)

$$\text{sound level} = 67\ \text{dB}$$ (1 mark)

4. (a) Orbital height above surface = 790 km = 7.90 x 10^5 m

$$\frac{m_s v^2}{r} = G\frac{m_s m_e}{r^2}$$ (1 mark)

$$v^2 = G\frac{m_e}{r}$$

$$v = \sqrt{\frac{6.67\text{x}10^{-11}\text{x}5.98\text{x}10^{24}}{[6.37\text{x}10^6 + 7.90\text{x}10^5]}}$$

$$v = 7.46\text{x}10^3\ \text{m s}^{-1}$$ (1 mark)

(b)

$$v = \frac{2\pi r}{T}$$ (1 mark)

$$T = \frac{2\pi r}{v}$$

$$= \frac{2\pi[6.37\text{x}10^6 + 7.90\text{x}10^5]}{7.46\text{x}10^3}$$

$$= 6.03\text{x}10^3\ \text{s}$$ (1·67 hrs) (1 mark)

Wrong trig sign - take 2 marks off.

5.

resolving vertically $2T\sin 15° = mg$ (2 marks)

$2T\sin 15° = 65 \times 9.8$ (1 mark)

$T = 1231\,N$ (1 mark)

6. (a) Centripetal force F_c is required for water to move in a circular path.
At the top of swing the F_c is provided by mg + N (2 marks)
As the velocity is decreased the N force becomes smaller and smaller, until at a critical velocity, N = 0

(b) If angular velocity becomes less than the critical velocity, the water will come out of bucket and follow a projectile path.

$$N + mg = \frac{mv^2}{r}$$

$$v_c = \sqrt{rg}$$

$$v_c = \sqrt{1.1 \times 9.8} = 3.28\ m\ s^{-1}$$ (2 marks)

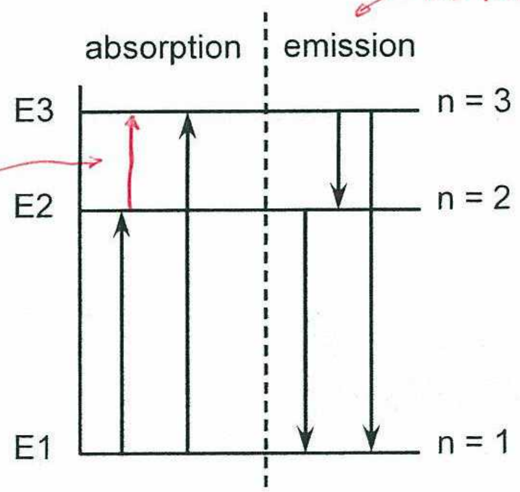
7. Stress = F/A, So force = stress × area (1 mark)
force = $214 \times 10^6 \times (8.5 \times 10^{-3} \times 10^{-2} \times 2 \times 10^{-2})$ (2 marks)
force = 364 N (1 mark)

8.

No labels - 1 mark off.

Assume the atom is in the excited state (statement) then full marks for this transition.

Students must give this explanation



1 mark for absorption and emission correctly labelled
-1 mark for every transition missing or incorrect

9. (a) $1.0mW = 1 \times 10^{-3}\ J\ s^{-1}$

$$E_{photon} = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34})(3.00 \times 10^8)}{633 \times 10^{-9}} = 3.14 \times 10^{-19}\ J$$

$$photons/second = \frac{E_{light}}{E_{photon}} = \frac{1 \times 10^{-3} \times 633 \times 10^{-9}}{6.63 \times 10^{-34} \times 3 \times 10^8}$$ (2 marks)

3.18×10^{15} photons hit the screen every second (1 mark)

(b) **C.** More photons hit the screen every second. (1 mark)

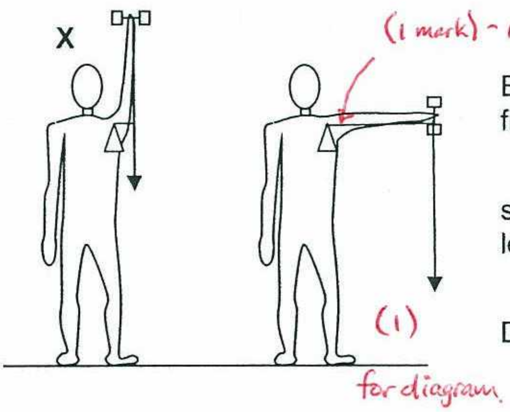
10. (a) Fluorescence or phosphorescence. (1 mark)

(b) Incident ultraviolet light excites electrons to a higher energy level in one transition. (1 mark)
The electrons then return to the lower energy level via a series of transitions (1 mark)
which emit photons of visible light (1 mark).
The frequency of the emitted photons depends on the size of the transition.

Appropriate diagram should be given credit. – to 3 marks if fully labelled and explains fluorescence correctly

11. (b) Right angles to body (1) (1 mark)

(1 mark) - refer to large force in muscle acting close to pivot.



Because in position **X** the perpendicular distance from the dumbbell to the pivot point is less (1 mark)

so the moment is less so the arm needs to provide less moment in the opposite direction (1 mark)

Diagram must have appropriate annotations(1 mark)

12. Estimate child has mass 10 kg to 50 kg
Length of gate 1 m to 3 m
Time to swing on gate 1 s to 5 s Can be a speed $(1-3\ ms^{-1})$ (2 marks for appropriate estimates)

$v = \frac{d}{t}$ where $d = \frac{1}{4} \times 2\pi r$ (1 mark)

then use $F = \frac{mv^2}{r}$

which should give F in range 1.0 N to 370 N (1 mark)

13. For a voltage to be induced in the secondary coil, a changing magnetic field must cut the secondary coil. (2 marks)

The input current is DC so there is no change in the magnetic field and hence no induced voltage in the secondary. (2 marks)

14.

$\sum F_y = N\cos\theta - mg = ma$ (1 mark)

$N = \dfrac{mg}{\cos\theta}$

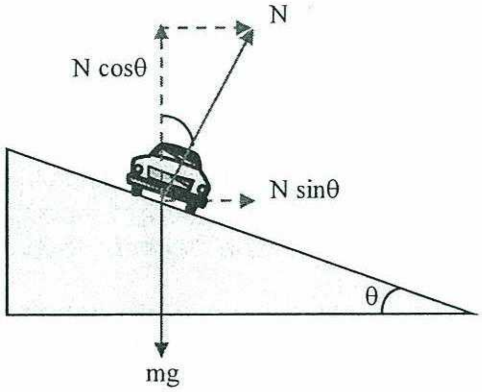
$\sum F_x = N\sin\theta = ma$ (1 mark)

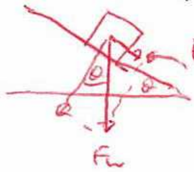
$N\sin\theta = m\dfrac{v^2}{r}$

$\dfrac{mg}{\cos\theta}\sin\theta = m\dfrac{v^2}{r}$

$v^2 = grtan\theta$ (2) (1 mark)

$\underline{v = 37.6 \text{ m s}^{-1}}$ (2)





$F_w \sin\theta = F_c = \frac{mv^2}{r}$ (1 mark)

Appropriate diagram 1 mark

15. use sum of clockwise moments = sum of anticlockwise moment
pan, handle and water are all causing a clockwise moment, so arm has to create an CLOCKWISE MOMENT. (1 mark)

Total ACW moment = $moment_{pan}$ + $moment_{handle}$ + $moment_{water}$ (1 mark)

ACW moment = (0.225 × 0.45 × 9.8) + (0.075 × 0.05 × 9.8) + (0.225 × 2 × 9.8)
(1 mark)

ACW moment = 5.44 N m (1 mark)

So arm must supply moment of $\underbrace{\text{5.44 N m}}_{\text{3 marks}}$ in an $\underbrace{\text{clockwise}}_{\text{1 mark}}$ direction

Explanation of 2 forces acting at the hand, give full marks (even with no calculation).

$\Sigma ACM = (24.0)(0.225) + (0.49)(0.075)$

$= 5.44$ Nm.

$\therefore \Sigma CM = 5.44$ Nm clockwise.

Section B: Problem Solving **100 Marks**

Attempt **all** 7 questions in this section.

1.

(a) Answer: **B** A : 2 marks C : 1 mark (4 marks)

(b)

$f_n = \frac{nv}{2L}$ (1 mark)

$L = \frac{nv}{2f_n} = \frac{1 \times 346}{2 \times 300}$ (1 mark)

$= 0.58\ \text{m}$ (1 mark)

(c) An open end of an air column reflects a sound wave with a change of phase – creating a pressure node (displacement antinode). (1 mark)
A closed end reflects with no change of phase creating a pressure antinode (displacement node). (1 mark)
So standing waves in a closed pipe have a node at one end and an antinode at the other. So in this situation only odd numbered harmonics are possible. (1 mark)

Labelled diagram (1)

(d)

$f_{Yn} = \frac{nv}{4L_Y}$

$f_{Xn} = \frac{nv}{2L_X}$

for pipe X, $n = 2$ for pipe Y, $n = 3$

$\frac{2v}{2L_X} = \frac{3v}{4L_Y}$ (2 marks)

$L_Y = \frac{3L_X}{4} = \frac{3 \times 0.58}{4}$ (1 mark)

$= 0.43\ \text{m}$ (1 mark)

For X: $f = 600$ Hz (2nd harmonic)

For Y: $f = \frac{nV}{4L}$

$\Rightarrow L = \frac{nV}{4f}$

$= \frac{3(346)}{4(600)}$

$= 0.432$ m.

2. Must show working.

(a) max height occurs when vertical velocity = 0. Vertically u = 47 sin30°

use

$$v^2 = u^2 + 2as \Rightarrow s = \frac{v^2 - u^2}{2a}$$ (1 mark)

$u = -23.5 \text{ ms}^{-1}$

$$s = \frac{(47 \times \sin 30°)^2}{2 \times 9.8}$$ (1 mark)

$s = 28.2\text{ m} + 1.2\text{ m}$ (1 mark)

$= 29.4\text{ m}$ (1 mark)

(b)

$v = \sqrt{2as}$ (1 mark)

$v = \sqrt{2 \times 9.8 \times 29.4}$ (1 mark)

$v = 24.0\text{ m s}^{-1}$ (1 mark)

Alternative answer 23 m s^{-1}

(c)

$$t = \frac{v - u}{a}$$ (1 mark)

$$t = \frac{-24 - (47 \sin 30°)}{-9.8}$$ (2 marks)

$t = 4.85\text{ s}$ (1 mark)

Alternative answer 4.74 s (use 23m)

4.44 s (use 20m)

(d)

$s = u_h t = 47\cos 30° \times 4.85$ (2 marks)
$s = 197\text{ m}$ (1 mark)

Alternative answer 122 m (3.0s) 193m (4.74s) 181m (4.44s).

If a student has used the alternative value in part (b) and then carried this through then c = 4.74 s, d = 193 m

If a student has used the alternative value in part (c) and then carried this through then d = 193 m

3.

(a) the piece of iron would be attracted to the first magnet it crossed (1 mark)
and stay there (1) (1 mark)

(b) Non-magnetic metals have a current induced in them (1 mark)
when they pass over changing magnetic fields (N to S to N) (2 marks)
this induced current produces a field opposite in direction to that inducing it (1 mark)
and therefore the metal experiences a repulsive force. (1 mark)

Lenz's law statement - (1)

(c) X glass – it is non-conducting and therefore unaffected by the magnets (2 marks)

Y copper - this has the lower value of conductivity/ density so is affected by the magnets but not as much as the material with the greatest value (2 marks)

Z aluminium – this has the greatest value of conductivity/density so will be the most affected (2 marks)

Wrong order but concepts right - 2 marks off.

1 mark each material correctly identified
1 mark each reason

4.

(a) Heated filament emits electrons (1 mark)
Electrons accelerate towards the anode target (1 mark)
due to the high potential difference applied across the cathode and the anode. (1 marks)
When these high energy electrons hit the target, their energy is converted into X-rays.

Decelerated rapidly (1)

Most of the energy goes into heat and less than 1% is converted into X-rays.

Ionising K+L shells (spikes) – (1)

(b) Maximum kinetic energy of electron = 100 keV (1 mark)
Therefore maximum energy of X-ray photon in the beam is also 100 keV (1 mark)

(c) (i) Wavelength of x-ray is shorter than UV, deeper penetration. (1 mark)
Thus X-ray photons have higher energy than UV photons (1 mark)

(ii) Any 2 of:
Operator stays behind a shield when X-ray machine is on; shield absorbs X-rays. (1+1)
Stay at a distance from the X-ray tube; attenuation increases with distance. (1+1)
Spend less time in the radiation area; radiation damage is cumulative. (1+1)
Wear lead clothing; lead absorbs X-rays (1+1)

5. (a)

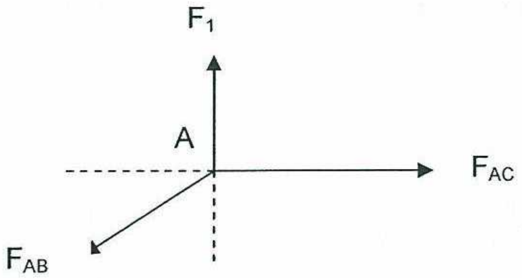
$$\Sigma\tau = F_2 \times L \quad Mg \times \frac{L}{2} = 0$$ (2 marks)

$$F_2 = \frac{Mg}{2}$$ (2 marks)

$$F_1 = F_2 = (6.0 \times 10^5)9.8 = 5.88 \times 10^6 \text{N}$$ upwards 1 mark (1 mark)

maybe shown on diagram.

(b) Forces acting on pin A.



$\Sigma F_y = F_1 - F_{AB} \sin 60° = 0$ (2 marks)

$F_{AB} = \dfrac{F_1}{\sin 60°} = 6.79 \times 10^6$ N (2 marks)

Compressive (1mark)

$F_{AB} = \dfrac{5.88 \times 10^6}{\sin 60°} = 6.79 \times 10^6$ N.

(c)

Allowing for a safety factor of 5, the breaking stress will be $\frac{1}{5}^{\text{th}}$ of the value given in the data table.

$\dfrac{1}{5}(\text{Breaking stress}) = \dfrac{F}{A}$ (2 marks)

$A = \dfrac{(6.79 \times 10^6)}{\frac{1}{5}(11 \times 10^8)}$ (2 marks)

$= 0.03\ \text{m}^2 = 3.0 \times 10^{-2}\ \text{m}^2$ (1 mark)

Alternative answer: 1.59×10^{-2} m^2

6.

(a)

use emf $= \ell vB$ (1 mark)

$= 0.3 \times 6 \times 0.5$ (1 mark)

$= 0.9$ V (1 mark)

(b) Use $I = \dfrac{V}{R} = \dfrac{0.9}{2} = 0.45$ A (2 marks)

in direction S to R (2 marks)

Size of current: 0.45 A Direction: S to R

(c) use $F = I\ell B = 0.5 \times 0.45 \times 0.3 = 0.0675$ N (2 marks)

to the right (2 marks)

Directions in (d) opposite to (c)

(d) 0.0675 N (2 marks)

to the left (1 mark)

$\leftarrow \Rightarrow$ 1 mark given.

7.

(a)

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.672\times10^{-11}\times1.305\times10^{22}\times1.52\times10^{21}}{(19570\times10^3)^2}$$ (3 marks)

$$F = 3.46\times10^{18}\,N$$ (1 mark)

(b)

$$v^2 = \frac{Fr}{m}$$ (1 mark)

$v = \sqrt{\frac{GM}{r}}$ - 1 mark

$$v = \sqrt{\frac{Fr}{m}} = \sqrt{\frac{3.46\times10^{18}\times2034\times10^3}{1.305\times10^{22}}}$$ (2 marks)

wrong formula for this problem.

$$v = 23.2\,m\,s^{-1}$$ (1 mark)

(c) (i)

$$t = \frac{2\pi r}{v}$$ (2 marks)

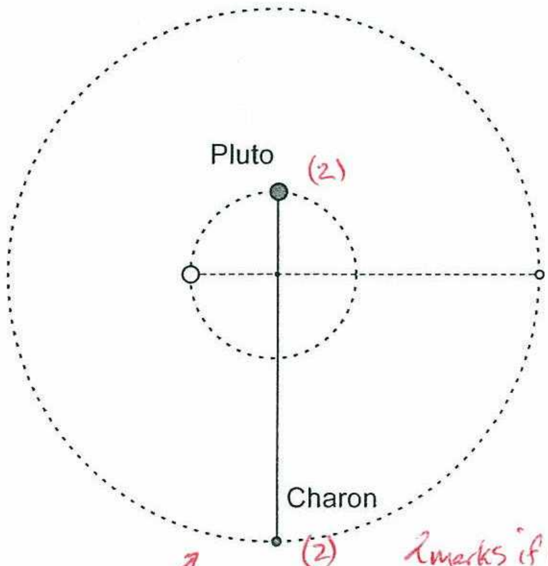
$$= \frac{2\pi\times2034\times10^3}{23.2}$$ (1 mark)

$$= 550\times10^3\,s$$ (1 mark)

$$t = 6.4\text{ days}$$

6·16 days ($v = 24\,ms^{-1}$)

(ii)



2 marks for calculation

2 marks if in a straight line.

2 marks each planet.

For 6·16 days, Pluto-Charon is just past 90°.

Section C: Comprehension and Interpretation

1.

(a) The string vibrating on its own will not displace much air so it would be difficult to hear the note. (1 marks)

The hollow box is a resonant cavity, the air resonates when the string is plucked and so the volume is increased (1) (2 marks)

Strings cause the wood to vibrate. (1) Large area (1) Large amplitude (1)

(b) A current in a conductor generates a magnetic field around it.
An alternating current generates a magnetic field which changes direction. (1 mark)

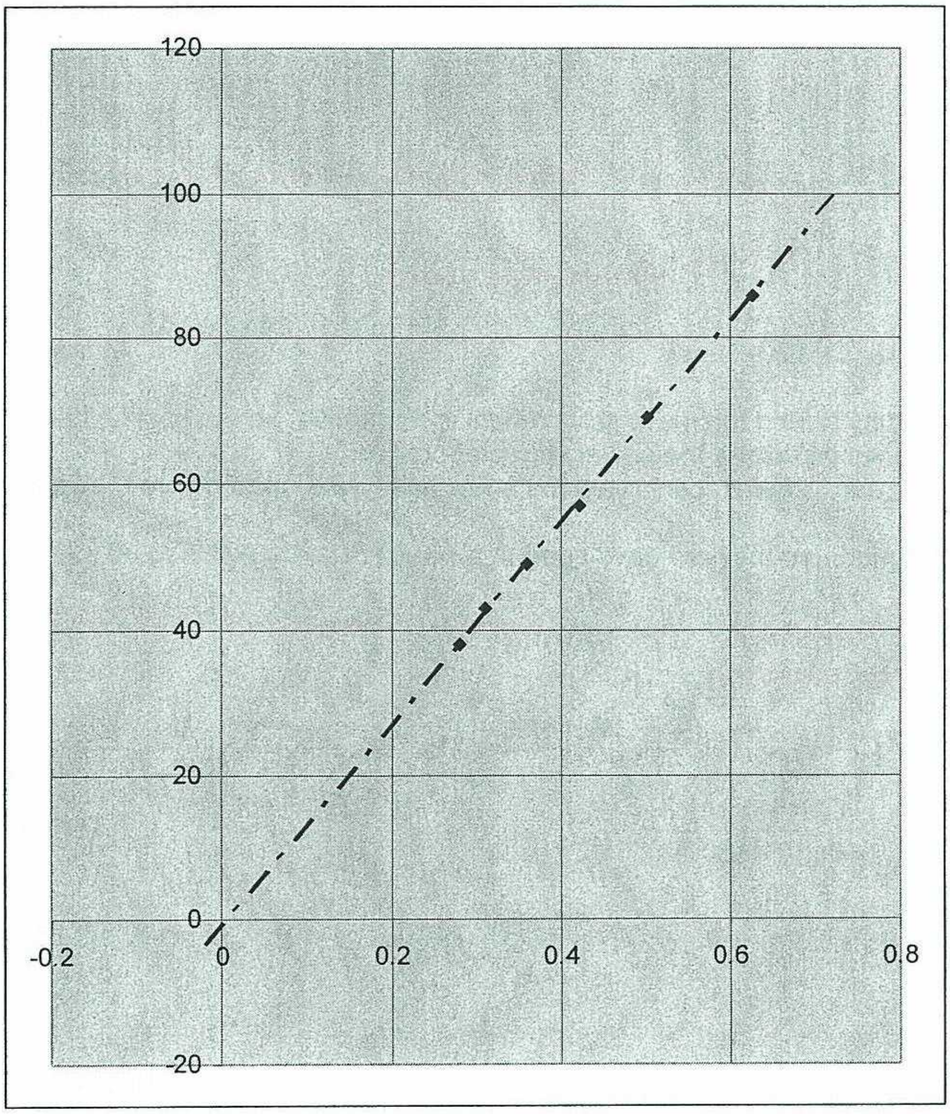
When the conductor is placed in a permanent magnetic field the two field repel and attract. (1 mark)
Since there is an alternating current in the wire the wire is being continually repelled and attracted to the permanent field, (1 mark)
the AC has a definite frequency – so the wire oscillates (1 mark)

(c)

Length (m)	Tension (N)	Resonant frequency (Hz)	$\frac{1}{2L}$
0.8	7.6	86	**0.625**
1.0	7.6	69	**0.5**
1.2	7.6	57	**0.42**
1.4	7.6	49	**0.36**
1.6	7.6	43	**0.31**
1.8	7.6	38	**0.28**

2 sig. figs

Table completed 1 mark
Graph: axes set out correctly 1 mark
Axes labelled appropriately 1 mark
points plotted correctly 1 mark
line of best fit 1 mark



working (1) slope = $\frac{80}{0.59}$ = 138 Hz m.

(d) gradient = 138 (1 marks) Unit quoted: Hz m (1 mark)

Inverse: grad = 7.25×10^{-3} $Hz^{-1} m^{-1}$. ms^{-1} OK.

(e)

$$\text{gradient} = f2L = \sqrt{\frac{T}{\mu}}$$ (1 mark)

$$\text{gradient}^2 = \frac{T}{\mu}$$ (1 mark)

$$\mu = \frac{T}{\text{gradient}^2} = \frac{7.6}{138^2} = 4 \times 10^{-4}\ \text{kg m}^{-1}$$ (1 mark)

2.3×10^{-3} $kg m^{-1}$ (alternative)

so string is an E. (1 mark)

Alternative value gives a D

2.

$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{1}{20}$ (3 marks)

(a) (3 marks)

$$\text{turns ratio} = \frac{V_s}{V_p} = \frac{20 \times 10^3}{1000} \quad (2)$$

$= 20$ (1) ← Answer only - 1 mark.

Wrong way around (calc area) = 1 mark

(b) Any reasonable response, for example: (4 marks)

Must have some Physics!

The power extracted by a wind turbine is proportional to the radius^2 so increasing the diameter of the turbines increases the power extracted; or (2 marks)
Large scale turbines may require specialised materials to be developed before they can be viable; or
Large turbines cost more, so they are developed at a small scale, then scaled up for sale

Demand for green technology.
Greater demand for electricity.

Improved technology ⇒ larger blades. (2 marks)

(c)

$$P = \frac{1}{2} C_p A \rho v^3 = \frac{\pi}{8} C_p \rho D^2 v^3$$

$$C_p = \frac{8P}{\pi \rho D^2 v^3} = \frac{8 \times 15 \times 10^3}{\pi \times 1.22 \times (10)^2 (10)^3}$$ (2 marks)

$= 0.313$ (31.3%) (1 mark)

$$\Rightarrow C_p = \frac{2P}{\rho A v^3} = \frac{2(15 \times 10^3)}{(1.22)(25\pi)(10)^3} = 0.313$$

(d)

$$V_G = \frac{XP_{em}}{3V_T}$$ (1 mark)

$$= \frac{10 \times 3000 \times 10^3}{3 \times 1000}$$ (1 mark)

$= 10\text{ kV}$ (1mark)

(e) generator solenoid has frequency 50Hz, (1 mark)
rotor has frequency 16 rpm = 0.26 Hz } 2 marks. Statement!

$\frac{16}{60}$ gives 188.

so ratio is $\frac{50}{0.26}$ (1 mark)

$= 185$ (1) (1 mark)

Can't find ratio of velocities - 3 marks

(f)

$$B = \frac{V_G}{2\pi f \quad NA}$$ (2 marks)

$$= \frac{10 \times 10^3}{2\pi \times 50 \times 10000 \times \pi(0.2)^2}$$ (1 mark)

0.126

$= 0.025\text{ T}$ (1mark)