Queen's College
S6 Mock Examination 2019-2020

PHYSICS PAPER 2
Section B & C
Question-Answer Book

Date: 6 February 2020
Time: 11:45 am – 12:45 pm (1 hour)

This paper must be answered in English

Class: _____

Class No.: _____

Block: _____

INSTRUCTIONS

(1) Write your Class, Class No. and Subject Block in the spaces provided on Page 1.

(2) This paper consists of **TWO** sections, Sections B and C. Each section contains eight multiple-choice questions and one structured question which carries 10 marks. Answer **ALL** questions.

(3) Write your answers to the structured questions in the **ANSWER BOOK** provided. For multiple-choice questions, blacken the appropriate circle with an HB pencil. You should mark only **ONE** answer for each question. If you mark more than one answer, you will receive **no marks** for that question.

(4) Supplementary answer sheets will be provided on request. Write your Class and Class No. on each sheet.

(5) The diagrams in this paper are **NOT** necessarily drawn to scale.

(6) The last two pages of this Question-Answer Book contain a list of data, formulae and relationships which you may find useful.

Question No.	Marks
Section B 2.1 – 2.8	
Section B SQ	
Section C 3.1 – 3.8	
Section C SQ	
TOTAL:	

Section B: Atomic World

Q. 2: Multiple-choice questions

2.1. The Rutherford's atomic model needed to be improved so that is could explain

(1) why a gold atom could deflect an α particle.

(2) why an atom could exist in a stable state without emitting electromagnetic wave.

(3) why the electromagnetic waves emitted by an atom have particular frequencies only.

A. (1) only

B. (2) only

C. (1) and (3) only

D. (2) and (3) only

A	B	C	D
○	○	○	○

2.2. Some photocells made of different metals are shone with radiation beams of different wavelengths. Which of the following gives the largest magnitude of stopping potential?

	work function of metal	**wavelength of radiation**
A.	5.93 eV	80 nm
B.	4.26 eV	125 nm
C.	2.87 eV	350 nm
D.	2.14 eV	420 nm

A	B	C	D
○	○	○	○

2.3. Figure (a) shows a set-up for studying photoelectric effect. Green light is directed onto the metal plate. The ammeter detects the current I passing through the circuit as the voltage V of the power supply changes. Graph X in Figure (b) is obtained from the results.

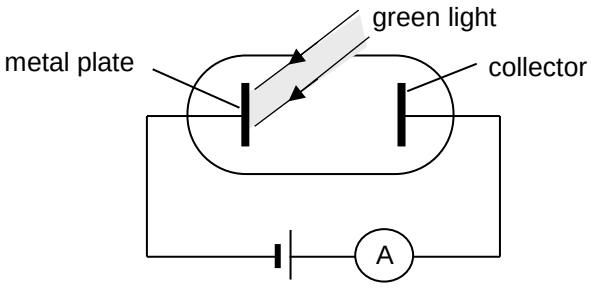


Figure (a)

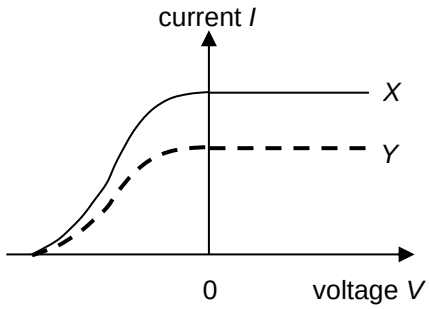


Figure (b)

Which of the following light sources should be used in order to obtain graph Y instead?

A. A source emitting green light with higher intensity

B. A source emitting green light with lower intensity

C. A source emitting red light with higher intensity

D. A source emitting violet light with lower intensity

A	B	C	D
○	○	○	○

2.4. According to Bohr's model of the hydrogen atom, what is ratio of the orbital radius of an electron at the 2nd excited state to that at the 4th excited state?

A. 3 : 5
B. 9 : 25
C. 1 : 2
D. 2 : 3

A B C D
○ ○ ○ ○

2.5. A space telescope has a 'lens' of diameter 6.5 m and will be used to observe electromagnetic waves of wavelengths between 0.6 μm and 28 μm. Estimate the minimum angular separation that the telescope can resolve.

A. 1.13×10^{-7} rad
B. 5.26×10^{-6} rad
C. 1.13×10^{-4} rad
D. 5.26×10^{-3} rad

A B C D
○ ○ ○ ○

2.6. What is the de Broglie wavelength associated with an electron with kinetic energy of 13.6 eV?

A. 2.1×10^{-9} m
B. 8.5×10^{-10} m
C. 3.3×10^{-10} m
D. 9.7×10^{-11} m

A B C D
○ ○ ○ ○

2.7. Which of the following is **not** the limitation of transmission electron microscope (TEM)?

A. The specimens must be very thin.
B. The specimens may be damaged.
C. It can only be used to observe the surface structure.
D. It can only produce 2D images.

A B C D
○ ○ ○ ○

2.8. Two samples, *X* and *Y*, are made of the same material. Sample *X* contains material in nano-form while sample *Y* contain material in bulk form. Which of the following may be possible?

(1) *X* is transparent while *Y* is opaque.
(2) *X* has a much lower melting point than *Y*.
(3) *X* is 10^4 times harder than *Y*.

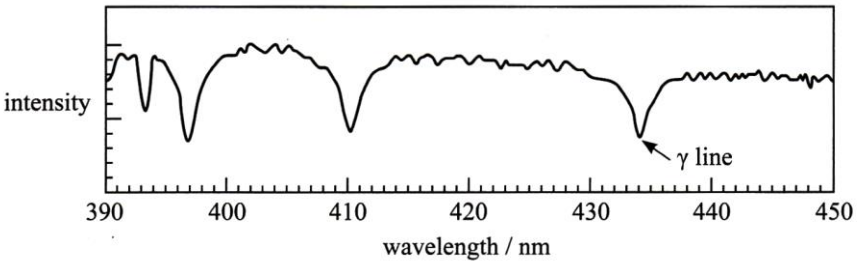
A. (1) and (2) only
B. (1) and (3) only
C. (2) and (3) only
D. (1), (2) and (3)

A B C D
○ ○ ○ ○

Q. 2: Structured question

The light emitted from a distant star passes through the star's atmosphere and produces an absorption spectrum. Figure 2.1 shows part of the spectrum which corresponds to the Balmer series *(transitions which involve the first excited state)* of hydrogen atoms. There are discrete sharp drops of the intensity of some particular wavelengths of light.

Figure 2.1



(a) Explain

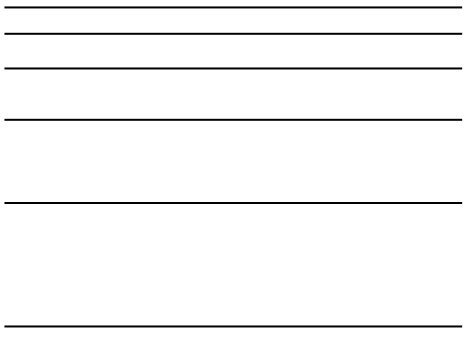
(i) why there are discrete sharp drops of intensity, and (2 marks)

(ii) why the intensity does not fall to zero for those particular wavelengths. (1 mark)

(b) The γ line in Figure 2.1 corresponds to a sharp drop at wavelength 434 nm. There are only two more sharp drops (not shown in the figure) on the right hand side of the γ line that also belong to the Balmer series.

(i) Calculate the energy (in eV) of a photon with wavelength 434 nm. (2 marks)

(ii) In the energy level diagram below, draw an arrow to illustrate the transition of energy levels which leads to the formation of the γ line. (1 mark)

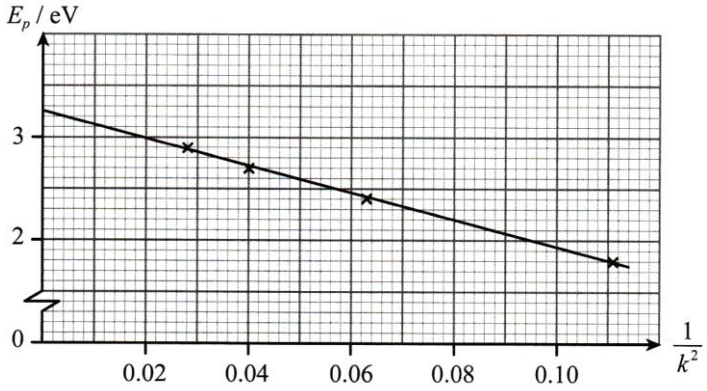


not to scale

(c) From the Bohr model, the energy levels E_n of an electron in a hydrogen atom is given by $E_n = \frac{-E_0}{n^2}$, where $-E_0$ is the ground state energy.

For a transition of energy levels between $n = 2$ and $n = k$, the energy of photon involved = E_p. Figure 2.2 shows how E_p varies with k.

Figure 2.2



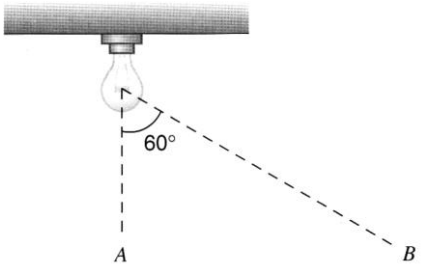
(i) State ONE postulate of Bohr model which is **not** 'classical'. (1 mark)

(ii) By using the graph, find the value of E_0. Show your calculations. (3 marks)

Section C : Energy and Use of Energy

Q. 3: Multiple-choice questions

3.1. An illuminance meter is placed at a certain height below a point light source. The reading of the meter is taken at positions *A* and *B* as shown. What should the ratio of the reading be at *A* to that at *B*? Given that *A* and *B* are at the same horizontal level.



A. 8 : 1
B. 4 : 1
C. 2 : 1
D. Cannot be determined.

A	B	C	D
○	○	○	○

3.2. The following table shows the power input and power output of four monochromatic light sources, *P*, *Q*, *R* and *S*.

	P	***Q***	***R***	***S***
Color of light emitted	red	red	green	green
Power input / W	15	20	15	20
Power output / W	10	10	10	10

Which of the light sources has/have the highest efficacy?

A. *P* and *R*
B. *Q* and *S*
C. *R*
D. *S*

A	B	C	D
○	○	○	○

3.3. The top of a solar cell is usually added with a transparent thin film, which makes the solar cell appears dull in colour. This film can increase the efficiency of the solar cell by

A. increasing the heat gained from the sunlight.
B. improving heat insulation between the solar cell and the surroundings.
C. reducing the amount of sunlight reflected from the solar cell.
D. absorbing the ultra-violet radiation in the sunlight.

A	B	C	D
○	○	○	○

3.4. Two rods, *P* and *Q*, are joined end-to-end as shown in the diagram. Both rods are of the same dimension, but the thermal conductivity of *Q* is twice that of *P*. The free ends *P* and *Q* are maintained at 100°C and 0°C respectively.

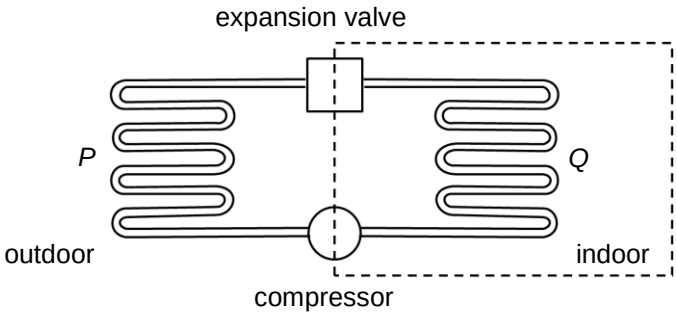
Assume that there is no energy loss to the surroundings. Which of the following statements is/are correct?

(1) The rate of heat conduction through *P* is half of that through *Q*.
(2) The temperature at the junction is lower than 50°C.
(3) The U-value of *P* is half of that of *Q*.

A. (1) only
B. (3) only
C. (1) and (3) only
D. (2) and (3) only

A ○ B ○ C ○ D ○

3.5. The figure shows a schematic diagram of an air conditioner which is used to cool down a room.



Which of the following combinations is correct?

	Process carried out at *P*	**Process carried out at *Q***	**Flowing direction of refrigerant through expansion valve**
A.	Condensation	Evaporation	From outdoor to indoor
B.	Condensation	Evaporation	From indoor to outdoor
C.	Evaporation	Condensation	From outdoor to indoor
D.	Evaporation	Condensation	From indoor to outdoor

A ○ B ○ C ○ D ○

3.6. A hybrid car is environmental friendly. Which of the following may provide a reason for this?

(1) A hybrid car does not emit carbon dioxide at all.

(2) The engine of a hybrid car is smaller.

(3) A hybrid car has a regenerative braking system.

A. (1) only

B. (3) only

C. (1) and (2) only

D. (2) and (3) only

A	B	C	D
○	○	○	○

3.7. A space telescope is powered by two solar panels, each of size 1.1 m × 0.9 m. The orientation of the solar panels can be adjusted automatically so that the panels always face the Sun. Given that the solar intensity received by the panels is 1360 W m^{-2}. If the efficiency of the solar panels is 15%, find the electrical power generated by the panels.

A. 202 W

B. 404 W

C. 1140 W

D. 2290 W

A	B	C	D
○	○	○	○

3.8. A helium 3 nucleus consists of two protons and one neutron. Estimate the binding energy of one helium 3 nucleus.

Given: mass of one proton = 1.0073 u
mass of one neutron = 1.0087 u
mass of one helium 3 nucleus = 3.0149 u

A. 6.52 MeV

B. 7.82 MeV

C. 9.12 MeV

D. 10.4 MeV

A	B	C	D
○	○	○	○

Q. 3: Structured question

Figure 3.1 shows the schematic structure of the water dam of a hydroelectric power station. Figure 3.2 shows the monthly average of the power output of the power station in the year 2019.

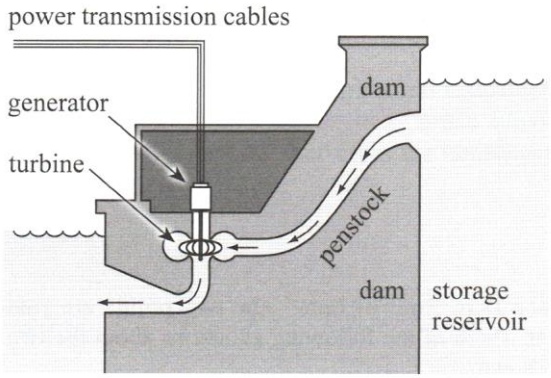


Figure 3.1

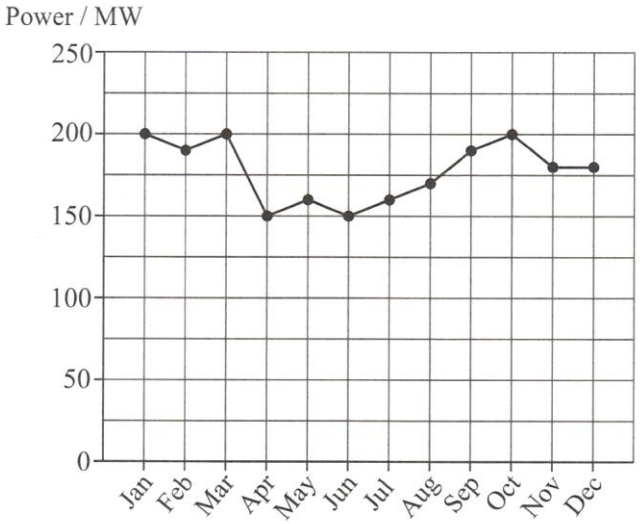


Figure 3.2

(a) Describe the energy conversions in the hydroelectric power station. (2 marks)

(b) (i) If the average volume flow rate of the water through the turbine is 13800 m^3 per minute, find the average height difference of the water on both sides of the water dam in Mar 2019. Given that the overall efficiency of the turbine and the generator of the power plant is 70%, and the density of water = 1000 kg m^{-3}. (3 marks)

(ii) In theory, the larger the height difference of the water on both sides of the water dam, the larger is the power generated by the power plant. In practice, this poses higher risks to the power station. Suggest one of the risks. (1 mark)

(iii) As shown in Figure 3.2, the power output dropped the most from Mar to Apr 2019. Suggest one reason to explain.
(1 mark)

(c) In order to maintain a steady output power to the city, the drop in power output of the hydroelectric power plant is compensated by a wind farm. In the wind farm, identical wind turbines of blade length 25 m and overall efficiency 30% is used. Assume that the wind always blows normally at a steady speed of 10 m s^{-1} towards the wind turbine. Find the minimum number of wind turbines required to compensate the drop in power output from Mar to Apr 2019. Given that the density of air = 1.3 kg m^{-3}.
(3 marks)

END OF PAPER

List of data, formulae and relationships

Data

molar gas constant	$R = 8.31$ J mol^{-1} K^{-1}	
Avogadro constant	$N_A = 6.02 \times 10^{23}$ mol^{-1}	
acceleration due to gravity	$g = 9.81$ m s^{-2} (close to the Earth)	
universal gravitational constant	$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}	
speed of light in vacuum	$c = 3.00 \times 10^8$ m s^{-1}	
charge of electron	$e = 1.60 \times 10^{-19}$ C	
electron rest mass	$m_e = 9.11 \times 10^{-31}$ kg	
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}$ C^2 N^{-1} m^{-2}	
permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H m^{-1}	
atomic mass unit	u = 1.661×10^{-27} kg	(1 u is equivalent to 931 MeV)
astronomical unit	AU = 1.50×10^{11} m	
light year	ly = 9.46×10^{15} m	
parsec	pc = 3.09×10^{16} m = 3.26 ly = 206265 AU	
Stefan constant	$\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}	
Planck constant	$h = 6.63 \times 10^{-34}$ J s	

Rectilinear motion

For uniformly accelerated motion :

$$v = u + at$$
$$s = ut + \frac{1}{2}at^2$$
$$v^2 = u^2 + 2as$$

Mathematics

Equation of a straight line	$y = mx + c$
Arc length	$= r\theta$
Surface area of cylinder	$= 2\pi rh + 2\pi r^2$
Volume of cylinder	$= \pi r^2 h$
Surface area of sphere	$= 4\pi r^2$
Volume of sphere	$= \frac{4}{3}\pi r^3$

For small angles, $\sin\theta \approx \tan\theta \approx \theta$ (in radians)

Astronomy and Space Science

$U = -\frac{GMm}{r}$	gravitational potential energy
$P = \sigma AT^4$	Stefan's law
$\left\|\frac{\Delta f}{f_0}\right\| \approx \frac{v}{c} \approx \left\|\frac{\Delta\lambda}{\lambda_0}\right\|$	Doppler effect

Energy and Use of Energy

$E = \frac{\Phi}{A}$	illuminance
$\frac{Q}{t} = \kappa\frac{A(T_H - T_C)}{d}$	rate of energy transfer by conduction
$U = \frac{\kappa}{d}$	thermal transmittance U-value
$P = \frac{1}{2}\rho A v^3$	maximum power by wind turbine

Atomic World

$\frac{1}{2}m_e v_{max}{}^2 = hf - \phi$	Einstein's photoelectric equation
$E_n = -\frac{1}{n^2}\left\{\frac{m_e e^4}{8h^2\varepsilon_0^2}\right\} = -\frac{13.6}{n^2}$ eV	energy level equation for hydrogen atom
$\lambda = \frac{h}{p} = \frac{h}{mv}$	de Broglie formula
$\theta \approx \frac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)

Medical Physics

$\theta \approx \frac{1.22\lambda}{d}$	Rayleigh criterion (resolving power)
power $= \frac{1}{f}$	power of a lens
$L = 10\log\frac{I}{I_0}$	intensity level (dB)
$Z = \rho c$	acoustic impedance
$\alpha = \frac{I_r}{I_0} = \frac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$	intensity reflection coefficient
$I = I_0 e^{-\mu x}$	transmitted intensity through a medium

A1.	$E = mc\,\Delta T$	energy transfer during heating and cooling
A2.	$E = l\,\Delta m$	energy transfer during change of state
A3.	$pV = nRT$	equation of state for an ideal gas
A4.	$pV = \frac{1}{3}Nm\overline{c^2}$	kinetic theory equation
A5.	$E_K = \frac{3RT}{2N_A}$	molecular kinetic energy

B1.	$F = m\frac{\Delta v}{\Delta t} = \frac{\Delta p}{\Delta t}$	force
B2.	moment $= F \times d$	moment of a force
B3.	$E_P = mgh$	gravitational potential energy
B4.	$E_K = \frac{1}{2}mv^2$	kinetic energy
B5.	$P = Fv$	mechanical power
B6.	$a = \frac{v^2}{r} = \omega^2 r$	centripetal acceleration
B7.	$F = \frac{Gm_1m_2}{r^2}$	Newton's law of gravitation

D1.	$F = \frac{Q_1Q_2}{4\pi\varepsilon_0 r^2}$	Coulomb's law
D2.	$E = \frac{Q}{4\pi\varepsilon_0 r^2}$	electric field strength due to a point charge
D3.	$E = \frac{V}{d}$	electric field between parallel plates (numerically)
D4.	$R = \frac{\rho l}{A}$	resistance and resistivity
D5.	$R = R_1 + R_2$	resistors in series
D6.	$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$	resistors in parallel
D7.	$P = IV = I^2R$	power in a circuit
D8.	$F = BQv\sin\theta$	force on a moving charge in a magnetic field
D9.	$F = BIl\sin\theta$	force on a current-carrying conductor in a magnetic field
D10.	$B = \frac{\mu_0 I}{2\pi r}$	magnetic field due to a long straight wire
D11.	$B = \frac{\mu_0 NI}{l}$	magnetic field inside a long solenoid
D12.	$\varepsilon = N\frac{\Delta\Phi}{\Delta t}$	induced e.m.f.
D13.	$\frac{V_s}{V_p} \approx \frac{N_s}{N_p}$	ratio of secondary voltage to primary voltage in a transformer

Solution to S6 Mock Examination Paper 2 2019-2020

Section B (Atomic world)

MC:

1-5: DABBA

6-8: CCD (1.25@, total = 10 marks)

SQ:

(a)

(i) When light of continuous wavelengths passes the atmosphere, photons of certain wavelengths are absorbed by the hydrogen atoms in the atmosphere.

Only photons of energy exactly equal to the difference between the energy levels of hydrogen are absorbed, so the intensity of those wavelengths drops. (2 A)

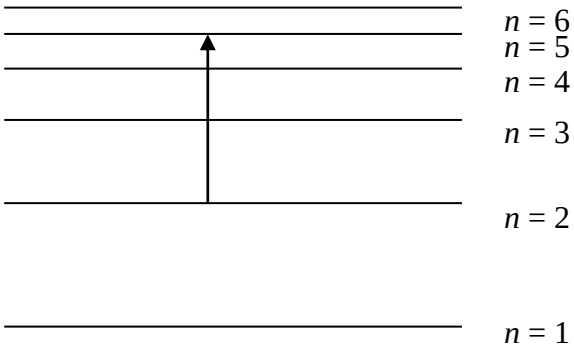
(ii) Once the photons are absorbed, they are re-emitted by the hydrogen atom in all directions.

Hence the intensity in the original direction is larger than zero. (1 A)

(b)

(i) $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3\times10^{8})}{434\times10^{-9}} = 4.58\times10^{-19}\ \text{J} = \underline{\underline{2.86\,\text{eV}}}$ (1M+1A)

(ii) From n = 2 to n = 5 (1A)



not to scale

(c)

(i) The angular momentum is quantized. (1A)

(ii) $E_p = E_k - E_2 = \frac{-E_0}{k^2} - (\frac{-E_0}{2^2}) = -E_0(\frac{1}{k^2}) + \frac{E_0}{4}$

Compare with straight line equation, we have y-intercept = $\frac{E_0}{4}$ (1M)

$E_0 = 4(3.25) = \underline{\underline{13\,\text{eV}}}$ (2A)

(Accept: since slope = $-E_0$, $E_0 = \frac{3-2}{0.095-0.02} = \underline{\underline{13{,}3\,\text{eV}}}$)

Section C (Energy and use of energy)

MC:

1-5: ACCDA

6-8: DBB (1.25@, total = 10 marks)

SQ:

(a) Gravitational potential energy of water → kinetic energy of turbine → electrical energy (2A)

(b)(i) $P = \frac{mgh}{t} \times \eta$ (1M)

$200 \times 10^6 = (\frac{13800}{60} \times 1000)(9.81)h \times 70\%$ (1M)

$h = 126.6 \approx \underline{\underline{127 \text{ m}}}$ (1A)

(ii) The dam may get damaged due to the huge water pressure behind the dam. (1A)
(The turbine may get damaged due to the high water speed.)

(iii) Insufficient rainfall (which causes the drop in water level in the upper reservoir). (1A)

(c) $\Delta P = N \times \frac{1}{2} \rho A v^3 \times \eta$ (1M)

$(200 - 150) \times 10^6 = N \times \frac{1}{2}(1.3)(\pi \times 25^2)(10)^3 \times 30\%$

$N = 130.6$ (1A)

$\therefore$ At least $\underline{\underline{131}}$ wind turbines are required. (1A)