Name: _____

Date: _____

Class: _____

IB Environmental Systems and Societies

6.3 Photochemical Smog

Significant ideas:

The combustion of fossil fuels produces primary pollutants which may generate secondary pollutants and lead to photochemical smog, whose levels can vary by topography, population density and climate.

Photochemical smog has significant impacts on societies and living systems.

Photochemical smog can be reduced by decreasing human reliance on fossil fuels.

Urban air pollution

1. Define "pollution".

(Review chapter 1.5 – Humans and Pollution)

Addition of a substance or an agent to environment by human activity at a rate greater than that at which it can be rendered harmless by the env. and which has an appreciable effect on organisms within it.

2. a) Outline what is meant by "primary pollutant" and "secondary pollutant"

Primary - which are active on emission eg Carbon monoxide from incomplete combustion of fossil fuels.

Secondary - formed from primary pollutants when they undergo physical or chemical changes eg Sulphuric acid & Tropospheric Ozone

b) List 3 examples of primary pollutants

NOx

CO

PM

CO_2

Black carbon (SOOT)

SO_2

VOCs

c) List 3 examples of secondary pollutants

Sulphuric acid

Hydrogen peroxide

Nitric acid

SO_3

Tropospheric Ozone

Tropospheric ozone

1. Outline how photochemical reactions can form secondary pollutants

In the presence of Sunlight Primary pollutants undergo chemical reactions with chemicals already present in the atmosphere. eg Tropospheric O_3 is formed when Oxygen molecules react with Oxygen atoms released from NO_2 in the presence of sunlight.

2. With reference to fossil fuel use, describe what is meant by "incomplete combustion".

It happens due to poor mixing of fuel & air or due to low temperature.

Def: A process of partial burning of fuel. CO is produced as a byproduct.

3. Using a simple diagram (e.g. a flow diagram), summarize the formation of tropospheric ozone from nitric oxide.

(NO = Nitric Oxide)

(Nitirc oxide is a product of incomplete combustion of fossil fuels)

$$NO + O_2 \longrightarrow NO_2 \xrightarrow{S/l} NO + O$$

$$O + O_2 \longrightarrow O_3$$

4. Distinguish between "stratospheric ozone" and "tropospheric ozone". Include reference to sources and depletion, as well as consequences, in your answer.

	Stratospheric O_3	Tropospheric O_3
Source:	Natural when O_2 splits in presence of S/l	When NO_x react with VOC in S/l
Depletion	ODS eg CFC/CH_4/NO_x/Halons	
Effects	Ozone thinning; Crop damage/aquatic life death/skin cancer/eye irritation	Health: Acute effects (Eyes/lungs) Chronic effect (Damage to lung tissue.) Environment: Corrodes building/equipment Damages crop & plant leave

5. Complete the table to show the potential negative affects of tropospheric ozone.

Effect	Details
Oxidizing	Ozone is toxic gas & is a powerful oxidizing agent. (ability to give away the oxygen atom)
Damage to plants	Tropospheric O_3 absorbed by leaves where they degrade chlorophyll ∴ photosynthesis & productivity are reduced.
Damage to humans	Can reduce action of lungs causing breathing difficulties & may increase susceptibility to infection. & Eye / Nose / Throat irritation
Damage to materials	→ Attacks natural Rubber, cellulose, plastic → Reduces lifetime of car tyres → Bleaches fabrics.

Photochemical Smog

1. State the conditions in which photochemical smog is likely to form or become more pronounced

① Even though main primary pollutant concentration is high in morning & evening rush hours, smog is maximum in early afternoon as Smog formation is photochemical reaction

② Also low lying areas/valleys due to thermal inversion.

2. Outline the formation of photochemical smog. PS

Hint: in your answer you should include the words/phrases:

tropospheric ozone, nitrogen oxides, gaseous hydrocarbons, vehicle exhausts, volatile organic compounds, peroxyacyl nitrates, sunlight

PS - Is a mixture of 100 primary & secondary pollutants formed under influence of sunlight.

When fossil fuels are burnt, NO_x are released which react with other pollutants in the presence of S/l to produce Tropospheric O_3.

Since O_3 formation is slow, the pollutants may drift (transboundary) into surrounding areas. Smog is more likely under high pressure. Rain clears Smog & Wind disperses Smog

Urban climate also affects production of photochemical smog as have less vegetation & greater concentration of buildings & industries that generate heat.

3. Photochemical smog often peaks in the early afternoon, despite the fact that the amount of primary pollution release is at a maximum during rush house (early morning and late afternoon). Explain why this is.

See answer 1 on top.

4. Outline the way the following factors can influence the extent of photochemical smog.

Local Topography:

Low lying areas → more smog

Climate

High air pressure areas → more smog

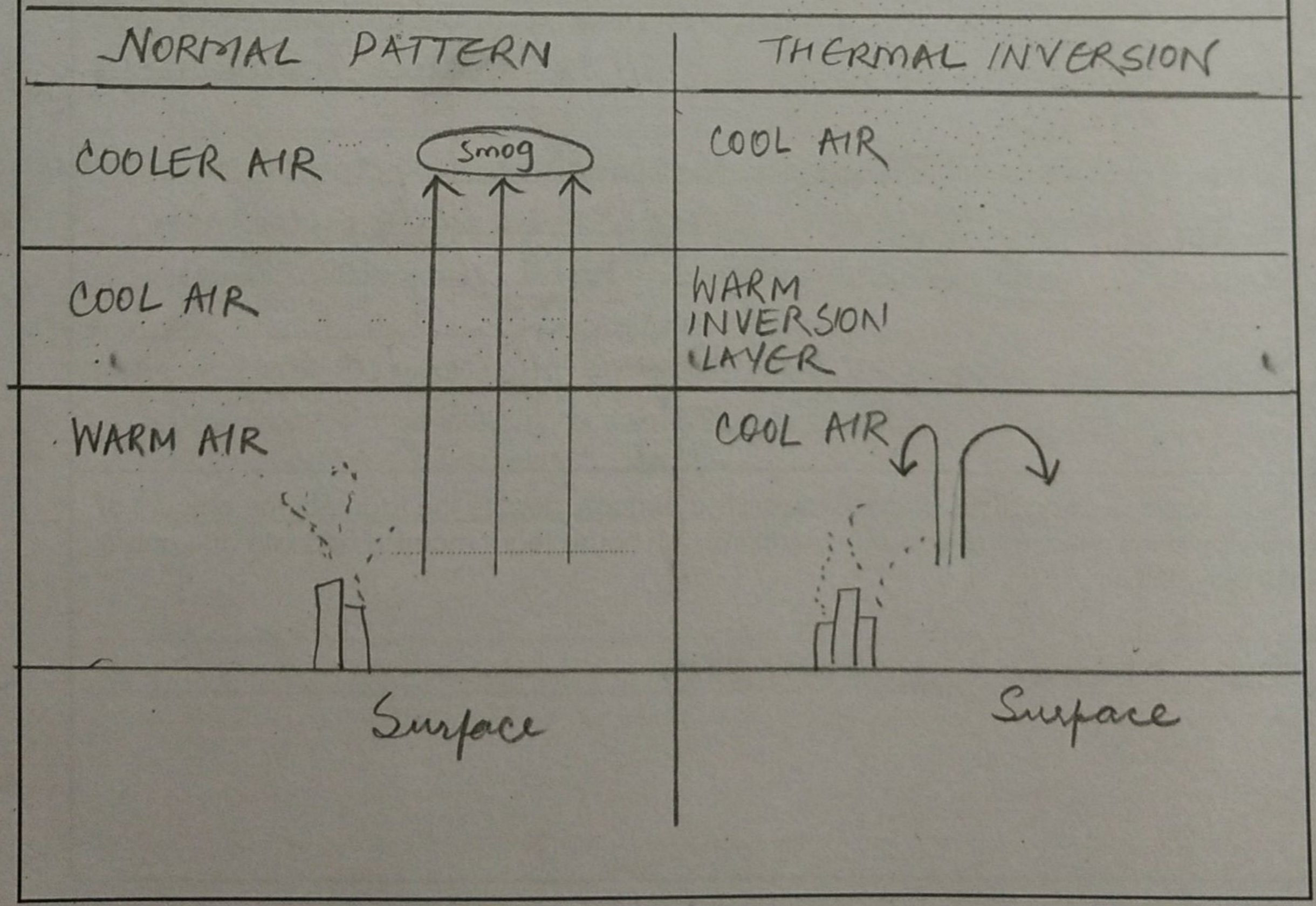
Population density

High number of vehicles → more smog

Fossil fuel use

Dependency on fossil fuel → More burning, more smog

5. Draw a diagram to explain how a thermal inversion can amplify the effect of photochemical smog.



ARC approach (Alter / Regulate / Clean-up)

Pollution Management Strategies for Photochemical Smog

1. Briefly summarize the three categories of the pollution management strategy model

Replace (A) Consume less fossil fuel / Energy efficient technology
Use renewable energy

Regulate (R) Govt. regulation / Taxation
Catalytic converters to clean exhaust
Regulate fuel quality

Restore (C) Afforestation to increase carbon sinks

2. Complete the table to list some suggestions for pollution management strategies to tackle photochemical smog.

Once you have your chosen list of strategies, **evaluate** each of them. Give one "for" and one "against" comment for each if possible

Strategy	Action	Evaluation
Altering human activities causing the pollution	(1) Consume less Burn less fossil fuel	(+) Will release less CO_2 Less dependence on natural resources
	(2) Be informed users. Buy Energy efficient technology (3) Use Renewable energy	(−) Technology costly MEDC can only afford − Depends on Topography
Regulate and reduce at point of emission	(1) Govt Regulation & Taxation (2) Catalytic converters	(+) Effective means to reinforce
	(3) Govt regulation of fuel quality	(−) LEDC may not be able to implement
Clean-up and restore	Afforestation to increase Carbon Sinks	(+) Will reduce atm CO_2 (−) We need land to support increasing population