Examination of the Effects of Basic Vehicle and Engine Operating Parameters on Particle Number Emissions of a City Bus

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Introduction

The effects of basic vehicle and engine operating parameters on the particle emissions of a city bus were examined under real-world urban driving conditions.
To perform the examinations, real time data for the parameters and solid Particle Number (PN) emissions were collected synchronously from the city bus on the routes of the Sakarya Municipality.

The real-world driving conditions were especially preferred, because laboratory tests may have not represented the real-world use of the busses. The PN measurement system was preferred, because it provided very high sensitivity to the engine transients and background emissions especially at the low particle emission levels typically found in modern diesel engines.

It was observed that the engine transient conditions, which commonly observed during the city bus accelerations, were the most favorable conditions for the particle emissions. During the acceleration periods, while the fuel rate, boost pressure, engine speed and engine power increase to their maximum, the lambda steeply decreases to its minimum due to the turbo-lag phenomenon. In this period, locally rich fuel-air mixture can be the reason for the dramatic increase of PN emissions. Once the engine operation is stabilized, the lambda rises up and the PN concentration decreases sharply.

Finally, it was concluded that, there is no linear relationship between the PN concentration and the basic engine operating parameters.

Test vehicle

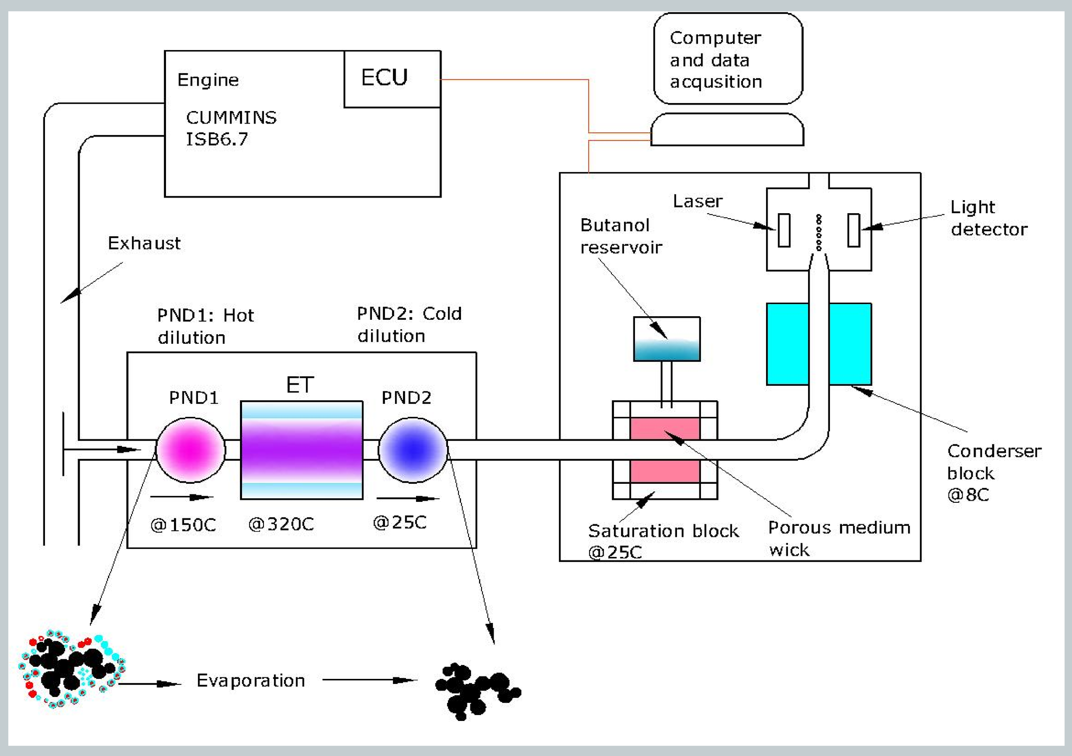
TEMSA Avenue Hybrid City Bus; 12 m long, 15 tons loaded weight
Engine: Cummins ISB6.7 Euro 5, 250 HP@2500 rpm
Hybrid system; SIEMENS ELFA with ultra-capacitors

Data sampling

SEMTECH DS for gaseous emissions and engine operating parameters

Rotating Disc Thermodilution System from Matter Engineering

TSI 3790 for PN measurement, TSI 3090 EEPS for Particle size distribution



Results

Figure 1 indicates a speed-distance profile of the route on which the bus was driven. As can be seen from this figure, the bus was driven mostly at constant speed, however, there are 5 major acceleration events. The following figures indicate effect of the constant speed driving and the acceleration events on the PN emissions of the bus.

Figure 2 indicates a typical acceleration event for the bus from zero to 70 km/h speed together with corresponding engine operating parameters and PN emissions. At this condition, while the engine speed and power start to rise up, the excess air ratio (lambda) decreases immediately from approximately 5.0 to 1.7. The turbo-charger lag is the main reason for such sharp decrease in lambda. Since the turbine of the turbo-charger is driven by kinetic energies of the hot exhaust gasses, the boost pressure cannot be increased immediately to its maximum during the acceleration period. Therefore, the rate of increase of the intake air flow lags behind that of the fuel flow. During this period, both density and turbulence of the air charge in the combustion chamber become insufficient to provide a perfect mixing of the fuel and air, therefore, the combustion becomes highly instable and PN emissions rise up immediately to the maximum. Once engine speed and power become stable at the maximum, the lambda rises up to 2.0 and PN emissions decrease sharply.

Diesel engines are very efficient power source to deliver power demands of heavy duty vehicles, but it comes together with excessive PN concentrations. Engine transients from zero to higher powers are the main reason for very high PN concentrations. As can be seen from the Figure, during this period while the engine delivers such a high power for this acceleration, PN emissions rise up to approximately 7.00E+6 $\#/cm^3$ of exhaust gas.

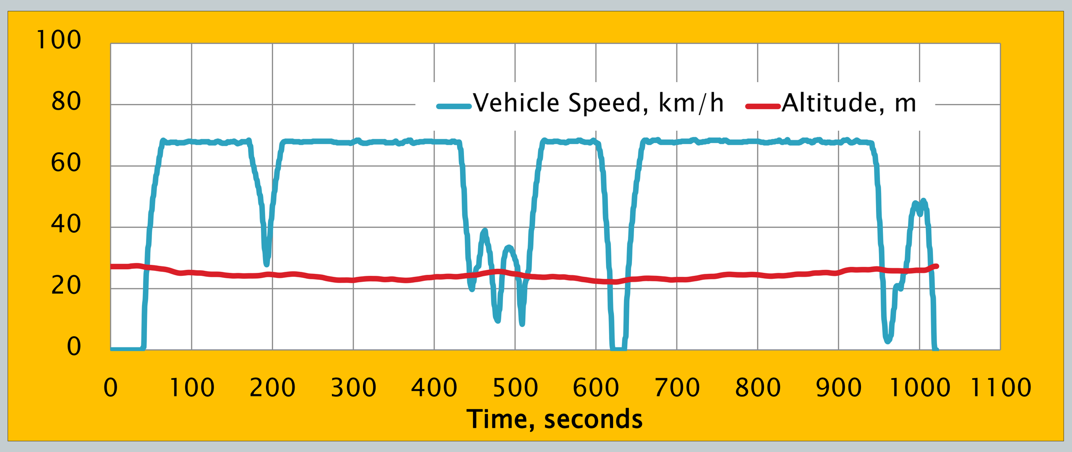


Figure 1. Speed – distance profile of the Karaman route

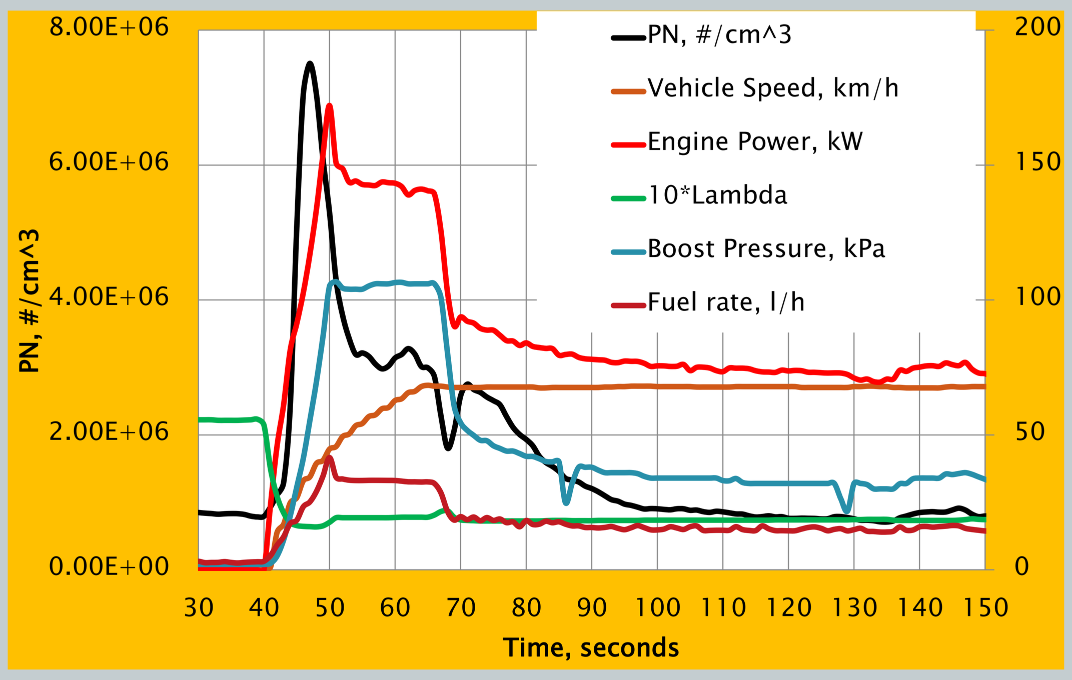


Figure 2. The basic engine operating parameters and PN emissions under the transient and constant speed operating conditions.

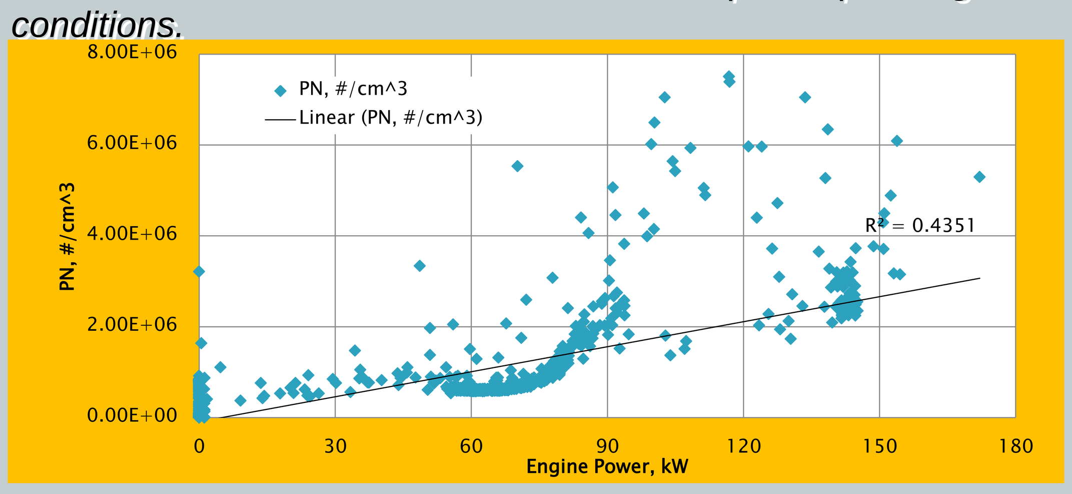


Figure 3. The effects of the engine power on PN emissions.

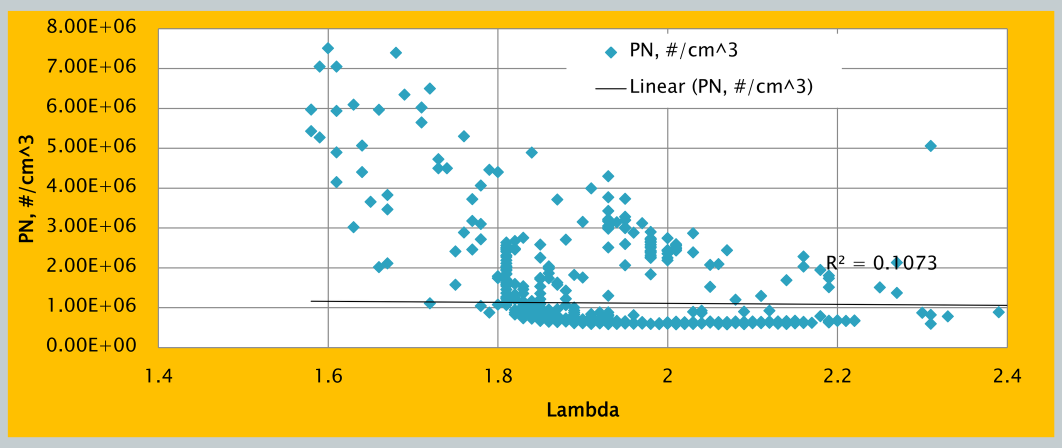


Figure 4. The effects of the lambda on PN emissions.

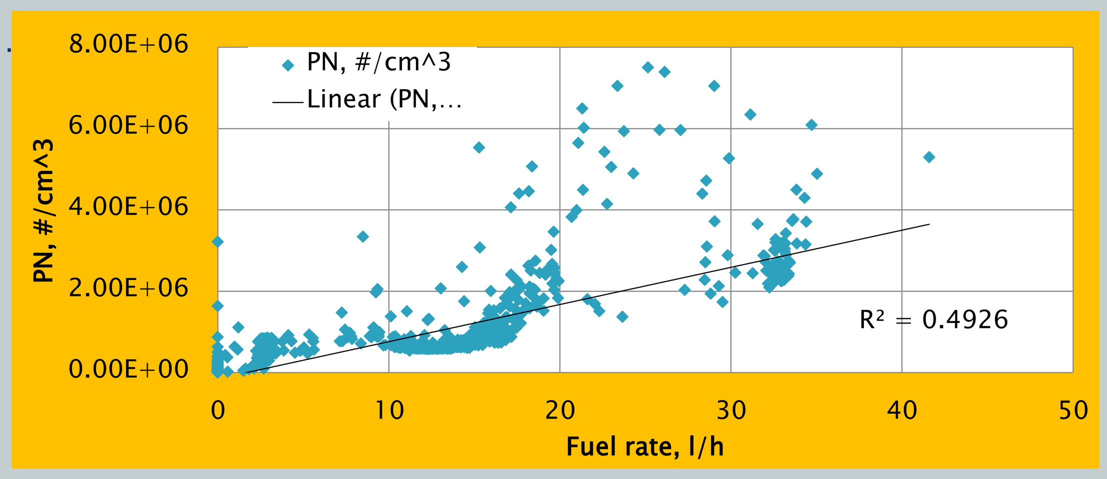


Figure 5. The effects of the fuel rate on PN emissions.

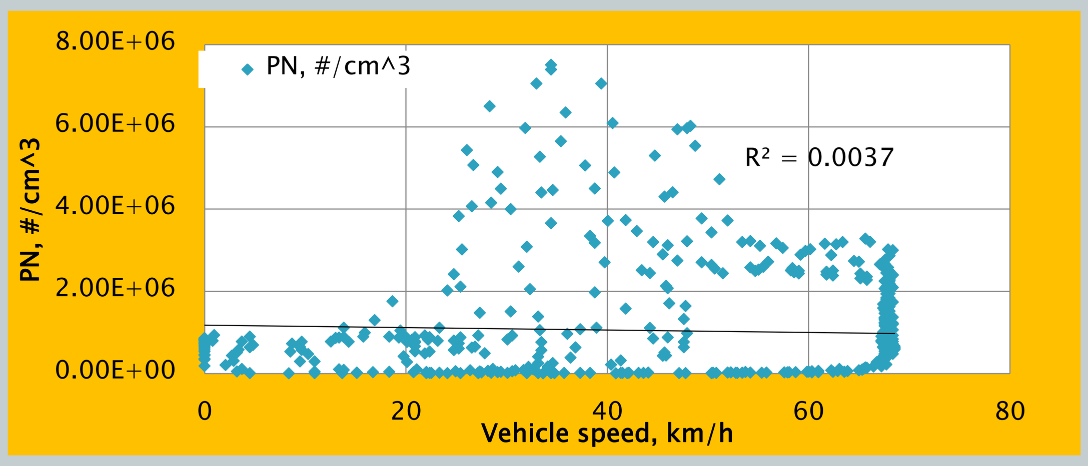


Figure 6. The effects of the vehicle speed on PN emissions

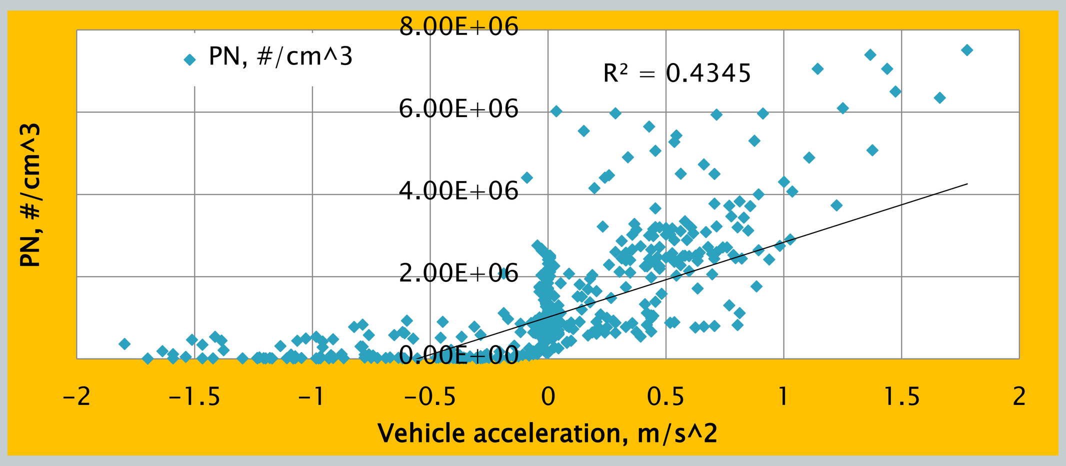


Figure 7. The effects of the vehicle acceleration on PN emissions.

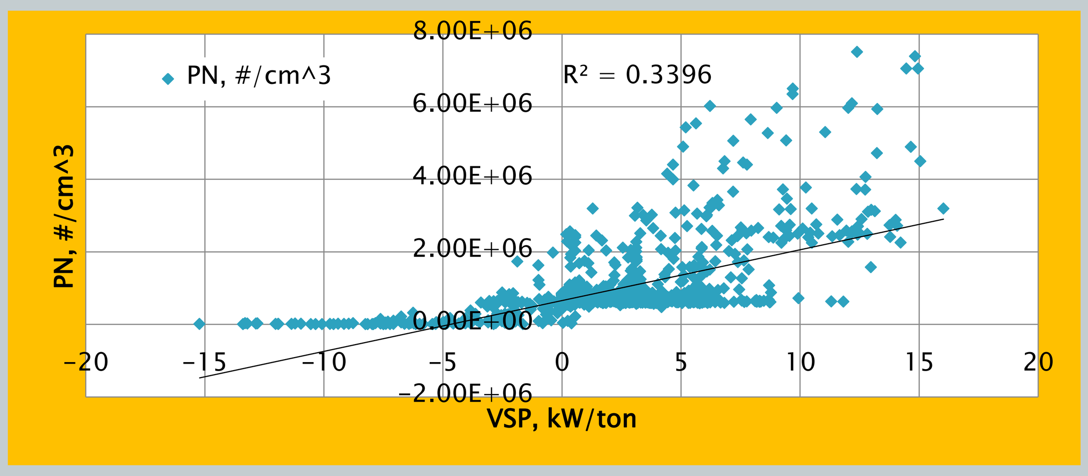


Figure 8. The effects of the VSP on PN emissions.

Conclusions

PN formation is dependent strongly on the fuel-air mixture enrichment rather than the basic engine operating parameters such as: engine speed, torque and power.

There is a linear relation between the PN emissions and the basic engine operating parameters under constant speed and load operations of the engine, which are relatively steady-state operations.

However, city bus operation in urban areas requires frequent accelerations, and every acceleration requires highly transient operation of the bus engine from idle to full power.

There is no a satisfying linear relationship between the basic engine operating parameters and PN emissions under urban driving conditions which involve frequent engine transients. These engine transients are the main reason for the excessive PN concentrations due to the turbo-charger lag.

The correlations between the PN concentrations and the vehicle operating parameters, such as speed, acceleration and vehicle specific power, were less than satisfactory, also.

Acknowledgment

Turkish Ministry of Science Industry and Technology and TEMSA R&D are acknowledged for their supports to this project.

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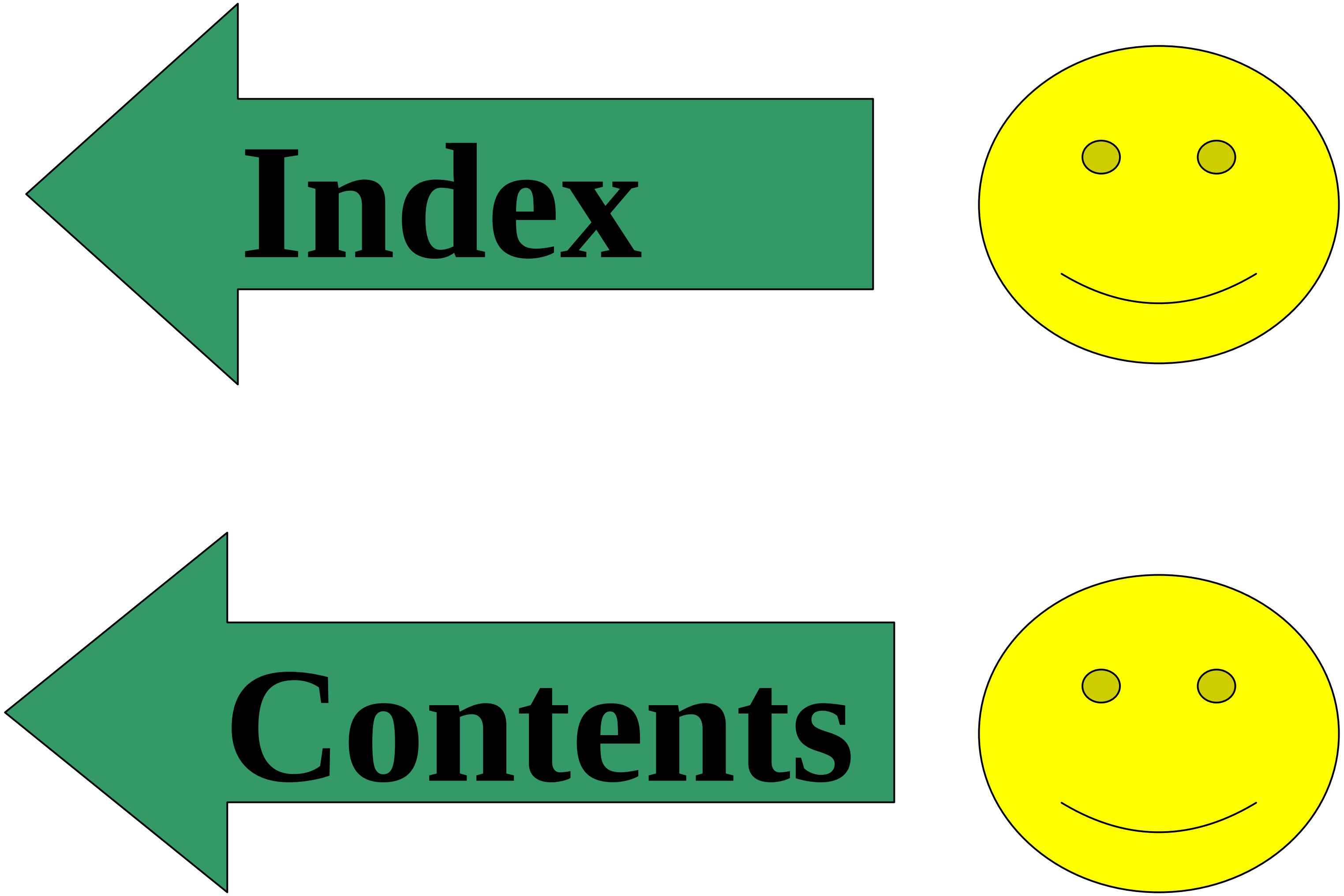
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