Principles of Internal Combustion Engines

- Student Notes

Directions:
Fill in the blanks.

Engine Physics Segment

1. Physics

- Is the study of the properties and nature of matter and energy
  - matter is a general term for any _____ substance
- Analyzes natural events and processes to increase understanding of the universe
  - for example, force, motion, _____, heat

2. Physics

- Is often considered the most fundamental of the natural sciences
  - other branches of science apply concepts of physics in particular contexts
    - chemistry applies physics to _____ systems
    - _____ applies physics (and chemistry) to living things

3. Physics

- Is relevant to everyday life, as well as numerous careers
- Allows individuals to predict and _____ matter, energy and natural events and processes
  - for example, controlling and using _____

4. Physics

- Is applied in the engine industry in many ways, including understanding the following:
  - engine ignition
  - engine _____ systems
  - hydraulic brakes
  - drag force
  - _____
  - engine placement

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5. Fundamental Laws of Physics

- Act as "rules" for understanding the _____ among matter
  - over time, scientists have discovered patterns in nature which can be used to predict how nature will _____ in the future

6. Fundamental Laws of Physics

- Are not always fixed or comprehensive
  - many refer to idealized, _____ systems which are difficult to achieve in the real world
  - some are altered _____ depending on the circumstances

7. Thermodynamics

- Is a branch of physics including _____ principle laws concerned with heat and temperature and their relation to energy and work
- Describes how _____ energy is converted to and from other forms of energy
- Principles are particularly used in engine design

8. Zeroth Law of Thermodynamics

- States if two systems are in thermal equilibrium with a third body, then they are also in equilibrium with each other
  - thermal _____ is observed when a higher temperature product comes into contact with a lower temperature product and transfers heat
  - basically it means all _____ systems will reach and maintain the same temperature

9. First Law of Thermodynamics

- Is often called the "Law of Conservation of Energy"
- States heat is a form of energy
  - heat cannot be created or _____ but can be transferred from one location to another and _____ to and from other forms of energy

10. Second Law of Thermodynamics

- Is often called the "Law of Increased Entropy"
  - entropy is a measure of the_____ energy useful for work
    - also known as the degree of _____ or uncertainty in a system

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11. Second Law of Thermodynamics

- States that when energy is _____, there will be less energy available at the end of the transfer process than at the beginning
  - all of the available energy is not _____, therefore entropy increases an energy is transferred

12. Third Law of Thermodynamics

- Is often called the "Law of Absolute Zero"
  - absolute zero is the _____ temperature possible (zero degrees Kelvin)
- States that the _____ of a substance approaches zero as its temperature reaches absolute zero

13. Sir Isaac Newton

- Developed many of the basic laws of physics and introduced them in his 1687 book, Mathematical Principles of Natural Philosophy
  - generally referred to as the _____ (Principles in Latin)
- Built on observations and work of notable scientists before him, such as Copernicus, Kepler, _____, Aristotle and Descartes

14. Newton's Laws

- Developed by Sir Isaac Newton, are known as the laws of motion
- Include three laws explaining how motion _____ and the ways those changes in motion are related to _____ and mass

15. First Law of Motion

- States for the motion of an object to change, a force must act upon it
  - this concept is generally known as inertia
  - an object at rest will _____ at rest unless acted upon by a force
  - an object in motion will remain in motion, with the same direction and speed, unless acted upon by a force
  - examples of forces include gravity, _____, air resistance and applied force

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16. Second Law of Motion

- States acceleration produced by a force acting on an object is directly proportional to the magnitude of the force and _____ proportional to the mass of the object
  - the more force, the more acceleration
  - the _____ the object being acted upon, the less acceleration
  - force = mass x acceleration (F = ma)

17. Third Law of Motion

- States for every action (force) there is an _____ and opposite reaction (force)
  - the reaction is equal in _____, but opposite in direction

18. Daniel Bernoulli

- Was a Swiss physician, doctor and mathematician most known for his applications of _____ to mechanics
  - particularly _____ mechanics
- Created a physical principle known as Bernoulli's principle

19. Bernoulli's Principle

- Is an important principle involving the _____ of a fluid through a pressure difference
  - relating the pressure of a fluid to its _____ and its speed

20. Bernoulli's Principle

- States that an increase in the _____ of fluid occurs simultaneously with a decrease in pressure
  - on the other hand a _____ in the speed of a fluid produces an increase in pressure

21. Bernoulli's Principle

- Is an important aspect of a carburetors functioning
  - the faster air moves, the slower its static pressure, and the higher its _____ pressure
    - the speed of this flow, and its pressure, determines the amount of _____ drawn into the airstream

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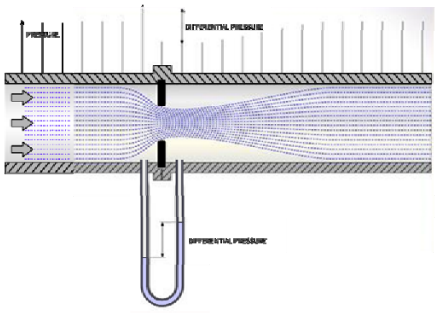
22. Giovanni Battista Venturi

- Was an Italian physicist most known for his works in _____
- Created a _____ principle based on Bernoulli's principle known as the "Venturi effect"

23. Venturi Effect

- Is the _____ in fluid pressure as a result of fluid flowing through a constricted section of pipe



24. Venturi Effect

- Applies to the use of a carburetor mixing air with fuel
  - air flows through the carburetor in a tube which contains a short section where the diameter _____ then widens again
    - this section is known as the "_____"

Designs, Components & Applications Segment

1. Internal Combustion Engines

- Are used in many different products, including automobiles, lawnmowers and large industrial machines
- Provide high _____ and more efficient and safe vehicles
- Are more _____ and accessible

2. Internal Combustion Engines

- Advantages include:
  - innovation of the car, _____ and other machines and vehicles
  - improved efficiency
- Disadvantages include:
  - releasing harmful _____ into the atmosphere

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3. Internal Combustion Engine

*See **Identification Activity** or **Engine Components Student Handout** for slide graphic*

4. Internal Combustion Engine Components

- Includes
  - cylinder block
  - cylinder head
  - piston
  - piston rings
  - connecting rod
  - crankshaft
  - engine bearings
  - crankcase
  - valves
  - _____
  - spark plug
  - manifold
  - camshaft
  - piston pin
  - pushrod
  - rocker arm
  - flywheel
  - oil sump
  - coolant
  - _____ gears

5. Cylinder Block

- Is the largest part of an internal combustion engine
- Is a part in which the intake, _____ and burning of fuel occurs
- Has the main function of _____ the piston

6. Cylinder Head

- Is found on the _____ portion of the cylinder block, acting as a seal
- Feeds air/fuel mixture to the cylinder, and allows exhaust to escape
- Has the main function of _____ the cylinder block
- Also helps keep the engine cool

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7. Piston

- Receives gas pressure and _____ the resulting force to the connecting rod
- Has the main function of tightly sealing the _____ end of the cylinder

8. Piston Rings

- Include the following types:
  - compression ring
    - has a main function of providing a seal between the piston and the _____ wall
    - transfers heat absorbed from the piston to the cylinder walls
  - wiper ring
    - helps to further seal the _____ chamber
    - aids in cleaning excess oil from the cylinder wall

9. Piston Rings

- Include the following types:
  - oil control ring
    - _____ and limits oil consumption
    - ensures piston and ring _____

10. Connecting Rod

- Connects the piston to the crankshaft
- Allows for fluid movement and _____ between the piston and the crankshaft
  - converts _____ motion of the piston into rotating motion of the crankshaft or vice versa

11. Crankshaft

- Is connected to the piston with the connecting _____
- Has the main function of taking the reciprocating motion of a piston and changing it into _____ motion

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12. Engine Bearings

- Are used to support moving parts of the engine, creating minimum power loss
- Include:
  - crankshaft bearings
  - connecting rod bearings
  - piston bearings
  - _____ bearings
- Have the main function of reducing _____ between moving parts

13. Crankcase

- Has the main function of housing and _____ the crankshaft and connecting rods
- Stores and _____ oil

14. Valves

- Are located at the _____ of the combustion chamber
- Have the main function of controlling _____ of air and exhaust of gases

15. Valve Timing

- Is the time it takes for the _____ to open and close before or after the piston is at top dead center (TDC) or bottom dead center (BDC)
- Is measured in _____ of crankshaft rotation

16. Valve Timing

- _____ can be calculated by adding the timing numbers together and then adding 180
  - for example:
    - a _____ with timing figures of 20 and 65

      = 20 + 65 = 85 + 180 = 275 degree duration

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17. Valve Train

- Is the mechanical system which controls the operation of the valves
- Includes the rotation of the _____ which results in the opening and closing of the valves
- Includes the following arrangements:
  - valve-in-block arrangement
  - overhead _____ arrangement
  - overhead cam design

18. Valve-In-Block Arrangement

- Is used when the camshaft is located in the _____ and the valves are located in the _____ block, which is right above the camshaft lobes

19. Overhead Valve Arrangement

- Is used when the camshaft is _____ in the crankcase and the valves are installed in the cylinder head

20. Overhead Cam Design

- Is used when the camshaft and valve _____ are located in the cylinder head

21. Tappets

- Are also called valve lifters
- Are located between the camshaft and the valve
- Have the main function of _____ or opening the valve in a vertical motion
- May be _____ or mechanical

22. Spark Plug

- Is used in a spark ignition engine
- _____ into the top of the cylinder head
- Has the main function of igniting the _____ air/fuel mixture in the combustion chamber

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23. Manifold

- Has the main function of evenly distributing air to all cylinders
  - in order for the right amount of air to _____ with the right amount of gas
  - called an intake _____
- Also collects the exhaust gases from all cylinders
  - called an exhaust manifold

24. Camshaft

- Regulates the opening and closing of valves during the proper piston stroke
  - the intake valve should open at the end of _____ stroke and close at the time of intake stroke
- May be placed at the top or _____ of the cylinder

25. Piston Pin

- Allows the connecting rods to _____
- Has the main function of connecting the _____ to the connecting rod

26. Pushrod

- Carries the camshaft _____ to the valves
  - allowing for fuel and air to enter and exhaust to exit the combustion _____

27. Rocker Arm

- Is connected to the pushrod
- Has the main function of helping the _____ convey movement from the camshaft to the _____
  - in order to open and close them

28. Flywheel

- Has the main function of rotating the shaft
- _____ the shaft when rotational force is applied
- _____ rotational energy

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29. Oil Sump

- Stores oil which is used to _____ all moving parts of an engine
- Is located at the bottom of the engine
- Is also known as the engine oil _____

30. Coolant

- Helps remove the waste heat from the engine
- Circulation improves heat transfer from _____ parts of the engine
- Is a mixture of water and _____

31. Timing Gears

- Rotate the crankshaft and the camshafts in order for the engine valves to open and close during _____ and exhaust
- Perform their functions at precise intervals _____ to the motion of the piston

Types of Engines Segment

1. Internal Combustion Engines

- Convert the energy contained in fuel into rotating power
- Are classified by _____ of ignition
  - spark ignition
  - _____ ignition

2. Spark Ignition Engines

- Work on the principle _____ of operation invented by Nicolaus A. Otto in 1876
- Are also known as _____ engines

3. Spark Ignition Engines

- Allow the burning of fuel to occur by a spark generated from the spark plug
  - air and fuel supplied by the _____ is compressed to high pressures and combustion takes place at a _____ volume

4. Internal Combustion Engines

- Operate based upon the principle of a cycle
  - _____-stroke cycle engines
  - two-stroke cycle engines

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5. Four-Stroke Cycle

- Operations are completed in four strokes of the piston inside the cylinder
- Involves two full crankshaft _____
- Include the following events:
  - intake
  - _____
  - power
  - exhaust

6. Intake

- Is the process of getting the fuel and air required for _____
  - a mixture of fuel and air is forced into the cylinder through the intake valve
  - the exhaust valve remains _____

7. Intake

- Is when the piston _____ from the top dead center (TDC) to the bottom dead center (BDC) of the cylinder
  - increasing the _____ of the cylinder

8. Compression

- Is the reduction in volume and increase of air pressure within the cylinder _____ to ignition
  - the intake valve closes
- Allows the piston to return to the _____ of the cylinder
  - compressing the air/fuel mixture into the cylinder head

9. Power

- Allows for the compressed air/fuel mixture in a _____ engine to be ignited by a spark plug
  - forcing the piston back down
- Allows for the compressed air/fuel mixture in a _____ engine to be ignited due to the generation of heat
  - forcing the piston back down

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10. Exhaust

- Is the process of _____ the used air/fuel mixture
  - the exhaust valve opens
  - the intake valve remains _____
- Allows the piston to once again return to top dead center (TDC)

11. Two-Stroke Cycle

- Operations are completed in two _____ of the piston inside the cylinder
- Involves one full crankshaft revolution
- Include the following events:
  - power stroke
  - _____ stroke

12. Power Stroke

- Operates when the piston is at top dead center (TDC) of the cylinder
- Ignites the air/fuel mixture
  - from a spark in spark ignition engines
  - from high _____ and pressure in a compression ignition engine
- Creates _____ from combustion, which then drives the piston downward

13. Compression Stroke

- Occurs when the piston is at bottom dead center (BDC) of the cylinder
- Causes pressurized air to _____ the cylinder, which forces out the exhaust gases
- Allows for the compression of the air/fuel mixture as the piston moves toward the top, _____ the upper cylinder

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14. Two-Stroke vs. Four-Stroke

Two-Stroke Cycle Engines	Four-Stroke Cycle Engines
• Lower costs	• More costs
• Lighter weight	• Heavier weight
• Operates in many positions	• Operates in limited positions
• High power to weight ratio	• Lower power to weight ratio
• Engine oil mixed with fuel	•
• Louder operation	• Quieter operation
• Higher engine speeds	• Slower engine speeds
• More vibration	• Smoother operation
• Rough idling operation	• Smoother idling operation
• Shorter life	• Longer life
•	• Less pollution

15. Internal Combustion Engines

- Include:
  - _____ engines
  - multi-cylinder engines

16. Single-Cylinder Engines

- Have one chamber in which a piston moves to engage combustion
- Are primarily used on smaller _____ and equipment
- Are _____ and compact

17. Multi-Cylinder Engines

- May have two, three, four, five, six, _____ or more cylinders
- Have _____ power when compared to single-cylinder engines

18. Internal Combustion Engines

- May be classified by their engine power
  - small engines
    - produce _____ than 25 horsepower
  - large engines
    - produce _____ than 25 horsepower

Horsepower – the rate at which work is done

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19. Internal Combustion Engines

- May be classified according to the location and _____ of valve system used
  - L-head
  - I-head
  - T-head
  - _____

20. L-Head

- Is a type of valve system in which both intake and exhaust valves are located on the _____ side of the cylinder
- Valves are operated by a _____ camshaft

21. I-Head

- Is a type of valve system in which both intake and exhaust valves are mounted directly _____ the cylinder
- Valves are operated by a _____ camshaft

22. T-Head

- Is a type of valve system in which the intake and exhaust valves are located on _____ sides of the cylinder block
- Valves are operated by _____ camshafts

23. F-Head

- Is a type of valve system in which one valve is in the cylinder head and the other valve is in the cylinder _____
- Valves are operated by a _____ camshaft

Engine Calculations Segment

1. Calculations

- Commonly used in the engine industry include:
  - speed
  - momentum
  - acceleration
  - _____
  - power
  - torque

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2. Speed

- Is a ratio of the distance traveled and the _____ it took to reach a certain point
- Is measured in:
  - _____ per minute (rpm)
  - miles per hour (mph)

3. Engine Speed

- Refers to revolutions per minute
  - distance refers to the distance traveled _____ a fixed axis
- Is _____ by the following equation:

rpm = (mph•g•f•88) / C

rpm = revolutions per minute
mph = miles per hour
g = gear ratio
f = final drive ratio
C = circumference

4. Momentum

- Refers to the quantity of motion an object has
  - how much an object moves
- Depends on two variables:
  - mass
    - how _____ is moving
  - velocity
    - how _____ it is moving

5. Engine Momentum

- Is calculated by the following equation:

p = m•v

p = _____
m = mass
v = _____

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6. Acceleration

- Is the rate of change of _____ or speed of an object with respect to time
  - as a result of any and all _____ acting on the object

7. Engine Acceleration

- Is calculated by the following equation:

$$a = \frac{dv}{dt}$$

a = acceleration

dv = _____ in velocity

dt = time _____

8. Work

- Is when a force acts upon an object, _____ it from its place or position
- Is also known as force _____

9. Engine Work

- Is calculated by the following equation:

$$w = F \cdot d$$

w = _____

F = force

d = _____

10. Power

- Is the measure of how much _____ can be done in a specified time
  - used to measure the power of engines
- Is also known as _____

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11. Engine Power

- Is calculated by the following equation:

$$hp = \frac{rpm \times t}{5252}$$

hp = _____

rpm = revolutions per minute

t = _____

12. Torque

- Is the rotational or twisting effect of a force around an _____
- Is the force the pistons put on the crankshaft, causing it and the wheels to _____

13. Engine Torque

- Is calculated by the following equation:

$$T = F \cdot d$$

T = torque

F = force applied

d = _____ distance of force from the axis of rotation