

Model Answers May 2018

Question 1

Question 1 answer

The Post Office have decided to investigate the advantages of employing hybrid technology on their urban delivery and collection vans. They hope to gain the following improvements:

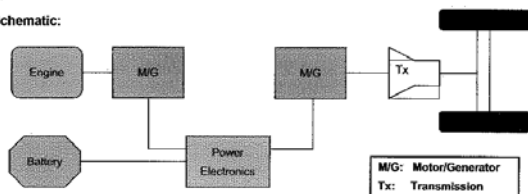
- Reduced fuel consumption
- Lower emissions
- Reduced running costs
- A greener image

- a) Analyse alternative hybrid vehicle architectures
(2 marks)

The student should explain and contrast series hybrid

Series Hybrid

Schematic:



• Defining Features

- Genset and motor
- EV operation or electric drive with engine as 'range extender'
- Electric machine drives wheels

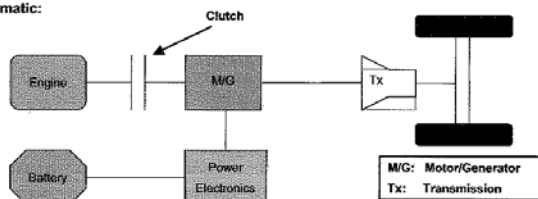
• Examples

- Many PSVs
 - A-D Enviro 200H
 - Eneco Epack
- Many initial concepts
 - GM Series EV1, Kia KEV4

And parallel hybrid

Full Parallel Hybrid

Schematic:



• Defining Features

- Engine only, EV only and motor-assist modes of operation possible
- Regenerative braking
- Motive charging

• Examples

- Audi Duo
- Hino HIMR system (PSV)

b) Investigate and contrast alternative technologies for

1Combustion engine

ICE diesel or petrol, possible hydrogen??

Gas turbine, fuel cell

2Energy storage

Battery technologies

LiON, NiMHyd, Pb acid, hot Zebra

Super Caps

Possible flywheel

Student should discuss, energy density, power density, number of cycles, acceptable

SOC's, any memory effects

3Transmission and driveline

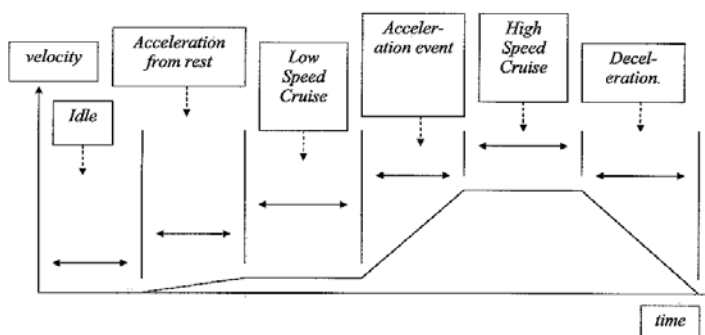
CVT/IVT,

4Drive / electrical machine

(6marks)

c) Develop a brief typical drive cycle

(2 marks)



The student should note

- Fairly constant running, low speeds
- Lots of regular stops/starts for collection and delivery
- Higher speed runs to and from the sorting office
- Low average power demand
- Fairly consistent vehicle mass

a) Recommend an urban PO van hybrid solution and demonstrate how it may meet the requirements

(10 marks)

Students should (hopefully) use information above.

Very low average speeds = low average power

Series hybrid a good option. (but not the only solution, esp longer journeys to sorting office)

Silent operation may be an advantage

Low speed and power, could use larger battery capacity to support silent running.

Low power, high efficiency ICE unit, turbo diesel, turbo petrol,

Could also consider gas turbine technology (size, efficiency, kerosene) but not start/stop function

Engine could be off when stationary, all peripherals should be electric eg aircon, cooling

For long term low energy 'start-stop' running.

Possible plug-in battery charge for initial journey support.
 Battery needs high efficiency ICE engine support to recharge.
 Students could discuss ICE as APU alternative power unit.

Question 2 answer

- a) How much energy is stored by the flywheel at the bottom of the hill?

$$\text{Potential energy} = m \cdot g \cdot h = 2000 \times 9.81 \times 30 = 588.6 \text{ Kj}$$

$$\text{Rolling resistance} = 0.016 \times 2000 \times 9.81 = 313.9 \text{ N}$$

$$\text{Road speed } 40\text{kph} = 11.111 \text{ m/s}$$

$$\text{Aero resistance} = 0.5 \times \text{density of air} \times C_d \times \text{frontal area} \times \text{velocity squared}$$

$$AR = 0.5 \times 1.2 \times 0.5 \times 3 \times 123.5 = 111.15 \text{ N}$$

$$\text{Total resistance force } R_F = 313.9 + 111.15 = 425.05 \text{ N}$$

$$\text{Total resistive power } R_P = R_F \times \text{Velocity} = 425.05 \times 11.111 = 4722.7 \text{ watts}$$

$$400\text{m at } 11.11 \text{ m/s takes } 36 \text{ secs}$$

$$4722.7 \text{ watts over } 36 \text{ secs uses } 7774.9 \times 36 = 170 \text{ Kj}$$

$$\text{Available energy after decent} = \text{PE-used energy} = 588.6 - 170 = 419 \text{ Kj}$$

- b) If the vehicle turns left and continues at the same speed along level ground how far will it travel before the energy in the flywheel has been exhausted?

$$\text{Resistive power is } 4723 \text{ watts}$$

$$\text{Secs} = \text{joules/watts} = 419 \text{ Kj} / 4.723 \text{ Kw} = 88.6 \text{ secs}$$

$$88.6 \text{ secs @ } 11.11\text{m/s} = 985\text{m}$$

- c) A similar vehicle is equipped with a similar KERS device. The flywheel has been specified to store 400Kj of energy.

$$\text{The device has a maximum rotational speed of } 10,000\text{rpm}$$

$$\text{Packaging dictates that the disc can be no larger than } 0.4 \text{ m outer diameter}$$

$$\text{Calculate the dimensions and mass for a suitable solid (plain section) flywheel?}$$

$$\text{Density of steel} = 7820 \text{ kg/m}^3$$

$$10000 \text{ rpm} = 166.67 \text{ rps} = 1047 \text{ rads/sec}$$

$$KE = 0.5 \text{ Rot In} \times 1047^2$$

$$\text{Rot In} = 2 \times KE / 1047^2 = 800000 / (1047 \times 1047) = 0.730 \text{ kgm}^2$$

$$\text{Rot In} = M \cdot K^2$$

$$K = \text{rad} \times 0.707 = 0.2 \times 0.707 = 0.1414\text{m}$$

$$M = 0.730 \text{ kg} / (0.1414 \times 0.1414) = 36.5 \text{ Kg}$$

$$\text{Flywheel mass} = \text{area} \times \text{thickness} \times \text{density}$$

$$\text{Thickness} = \text{mass} / (\text{area} \times \text{density}) = 36.5 / (\text{Pi} \times 0.2 \times 0.2 \times 7820) = 0.037\text{m}$$

- d) The student should identify the problem that as the vehicle slows down the flywheel must pick up speed. Therefore there is an energy transmission problem esp for a mechanical solution, which should be efficient. A graph would be expected.
Ideally the student will assume a max vehicle speed and calc the speed ratio range that would be appropriate.

The student should discuss the application of:

IVT (torotrack)

CVT

Fixed speeds with slipping clutches (flybrid)

The flywheel battery concept with an 'electrical transmission' and possible magnetic coupling within a permanent vacuum (Ricardo).

Question 3

1. Explain why the specific fuel consumption increases when moving away from the best specific fuel consumption point by:

Ideally the student should draw a map and indicate the best specific fuel consumption point, the explain

- a) Increasing the power/load required at the same rpm value

Generally in this area the ICE is running at its thermal limit and overfuelling occurs to control cylinder temps and reduce the likelihood of detonation.

- b) Increasing the rpm at the same power/load value

The friction of the ICE increases with rpm, using power. This is why WRC and probably F1 from 2014, endeavour to keep engine speed low.

- c) Reducing the power/load required at the same rpm value

The inlet throttle is nearly closed and cylinder pumping losses occur due to the low pressure in the plenum.

- d) Reducing the rpm at the same power/load value

In slowing up the ICE the time for combustion increases and more heat is lost through the piston crown and into the cylinder and head

(4 marks)

2. Explain how exhaust gas recirculation can be used to improve internal combustion engine efficiency at low load. Use diagrams and graphs (pressure-volume and pressure crank angle) to explain:
- a) The the lack of efficiency at low power/load conditions.

The student should draw a plenum and throttle. I ideally an additional sketches would show: area change with throttle opening (area of a circle – area of an ellipse)

and C_d variation against throttle angle

The student will explain

that a throttle is a restrictor

mass air flow will need to be maintained

There is a delta pressure difference across the throttle

There will be a depression in the plenum as the pistons pull in fresh air

The descending pistons in the inlet stroke has to do work to overcome the pressure loss through the throttle which reduces efficiency.

The student should draw a P-V diagram with both power and pumping loss loop/areas.

b) How EGR can help to improve efficiency?

The incoming fuel air mass can be diluted by about 20 – 30% EGR

To maintain the same power the engine requires the same amount of fuel and air, therefore, the throttle must be open more to pull in the required fuel and air as the plenum pressure has been increased.

Pumping losses are reduced, efficiency improved

The student should draw a P-V diagram with both power and pumping loss loop/areas.

c) What advantages or disadvantages are associated with EGR systems?

Advantage. Obviously the reduced pumping losses at low load. Also as the incoming fuel and air has been diluted, combustion flame speed is slower and cooler reducing the NO_x products.

Disadvantages. Expense and complexity. More importantly due to the slower combustion there is a requirement to advance the ignition BTDC, increasing the amount of –ve work. (however it is not as bad as the advantages from reduced pumping losses.

(8 marks)

Explain how power-stroke over expansion can be used to improve engine efficiency

Use diagrams and graphs to explain:

a) Limitations of the otto cycle and the lack of efficiency.

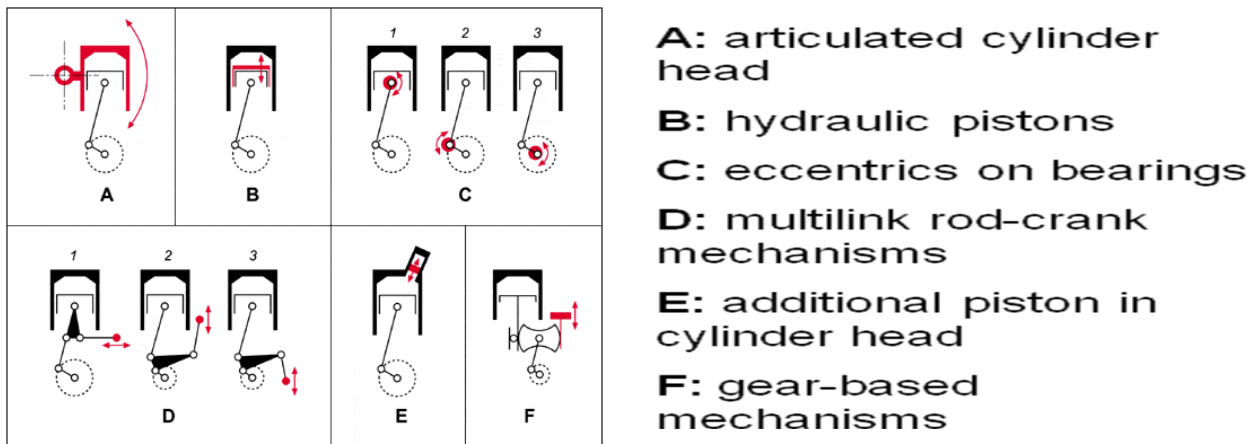
The student should draw the idealised P-V diagram and indicate the heat in (and more importantly) heat out sections and explain that work done is the area within the cycle. And that energy is being sent down the exhaust. The student could also show that the idealised cycle is not real and additional heat is lost into surroundings reducing the area further.

b) How can over expansion improve efficiency?.

The student should show on a P-V diagram how overexpansion reduces the exhaust gas temp, reducing the heat energy wasted and increasing the workdone area.

c) Explain two technology solutions for achieving over expansion.

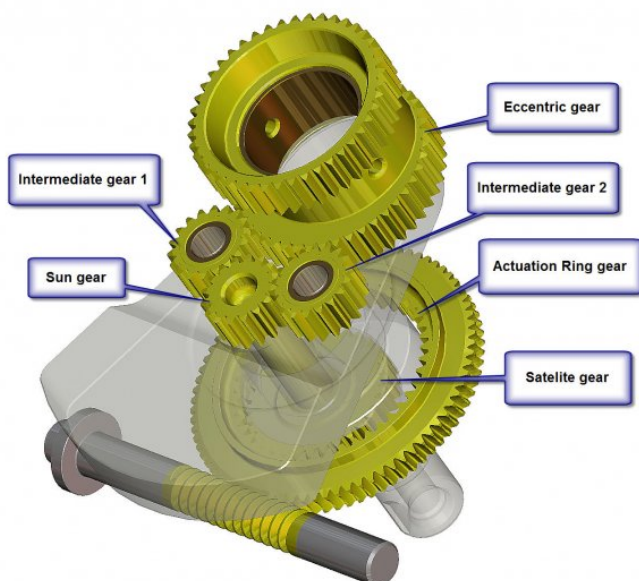
The student could explain two of:

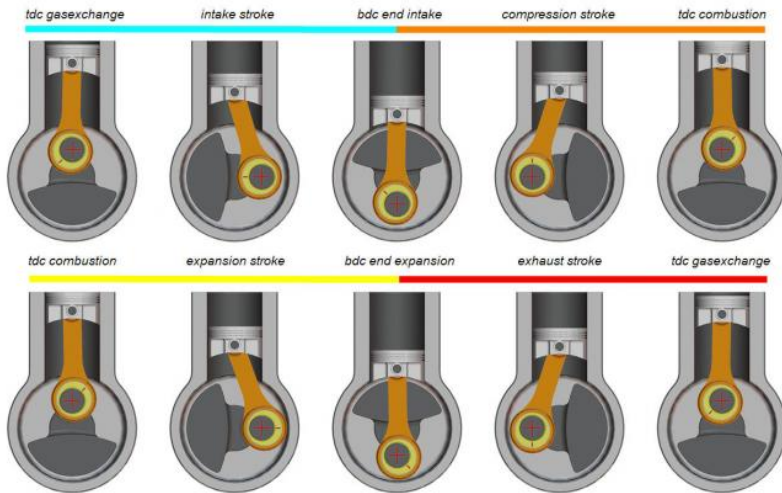


1. Variable valve opening, where the inlet valve is left open for the early part of the compression cycle causing some of the fresh fuel/air to be pushed back into the plenum, reducing the effective compression ratio whilst retaining the original expansion volume.

Mechanical variable compression ratio.

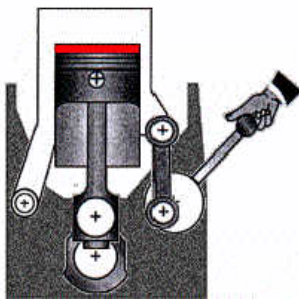
2. Using a geared system to change the loci of the big end bearing, to adjust stroke distances.



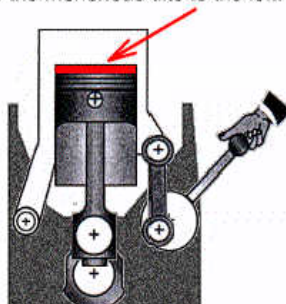


3. Using the rocking cylinder head relative to crankshaft approach

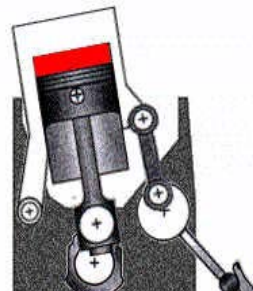
The compression ratio is now 14:1



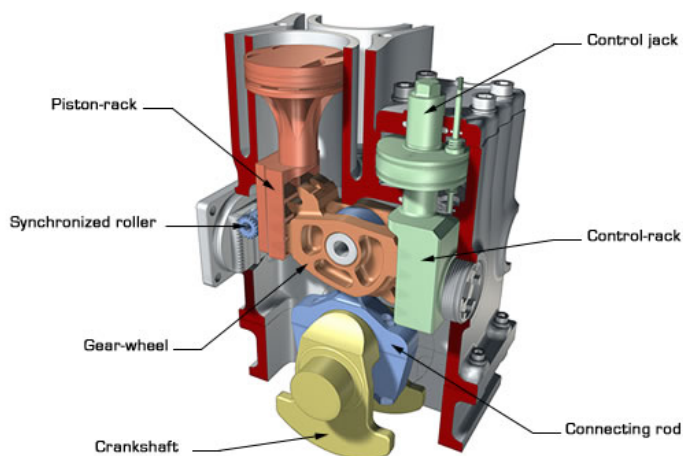
The clearance volume will increase as the monohead tilts to the left.



The compression ratio is now 8:1



4. The system of extracting further heat from the exhaust by expanding it in a separate cylinder (so called 5 stroke engine)



(8 marks)