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Consider converting an ICE car into an Electric vehicle as per the data given below.

Calculate the following Parameters

1. Traction force
2. Energy consumption
3. Battery Pack calculation
4. Battery depth of Discharge
5. Battery Capacity and Voltage
6. Electric motor Torque and Efficiency
7. Range of Electric vehicle.

Given Data:

Engine	1.2L, 4 cylinder
Max. Torque	113 Nm @ 4200 RPM
Maximum Power	82 BHP
Maximum RPM	6000
Gear Ratio	4.388
Tire Symbol	165/80 R14
vehicle mass (kerb)	965 kg
Aerodynamic Drag	0.36 C_d
Top Speed	140 Kph
Acceleration Time	0 – 100 Kph in 12.6 S

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165/80 R14

Radius of Tire

Height of Tire = 50.39 inch

Radius 25.19 inch

Traction force Calculation:

Vehicle Kerb Mass → 965kg
Aerodynamic drag → 0.36 cd
Acceleration Time (0-100 kph) → 7.3 sec
Range → 150 KM
Tire → 165/80 R14
Co-efficient of Rolling Re → 0.01 μ_{rr}
Co-efficient of Friction μ_f → 1

Vehicle total Mass = (Vehicle Kerb Mass * Mass Factor) + Driver Mass (75Kg)

Mass Factor = $1 + 0.04 + 0.0025 N_{tf}^2$

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Traction force and Traction Torque

$$F_t = m_v \left[\frac{V_f - V_i}{t_f - t_i} \right]$$

f_t = Total force

m_v = Total Mass

V_f = Final velocity

V_i = initial velocity

T_f = Final Time

T_i = Initial Time

F_t = Traction force

Vehicle Total force $F = m \times a$

$= m \times \frac{V}{t}$

Final velocity $V_f = 100 - 0$

$\cancel{V_f} = 100$

$V_f - V_i = 100 \, sec$

$T_f = 7.3 \, sec - 0$

$T_f - T_i = 7.3. \, sec$

Vehicle Total force = ~~12159N~~

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$$F_t = 965 \times \left[\frac{100}{7.3}\right] = 965 \times 13.6$$

$$\boxed{F_t = 13,124 \text{ N}}$$

$\boxed{\text{~~Traction~~ Total Force} = 13,124\text{ N}}$

Traction Force = Total Force + [Drag Force + Rolling Res Force]

T_t = F_{tract} × radius of wheel.

Frictional Force = $G_v * \mu_f = m_v \times g \times \mu_f$

= Weight × frictional Co-eff

= 965 kg × 9.8 × 1

$\boxed{\text{Frictional Force} = 9457 \text{ N}}$

Drag force $= \frac{1}{2} \times \rho \times A_c \times C_d \times V_c^2$

$= \frac{1}{2}$ × Air density × Frontal Ar × Co-eff × Top Speed

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Air Density $= 1.204\,kg/m^3$

Aerodynamic drag $C_d = 0.36$

$V_c =$ Max speed $= 140\,km/h$

$= 38.8\,m/s$

$= \frac{1}{2} \times 1.204 (kg/m^3) \times 0.36_{cd} \times (38.8\,m/s)^2$

Rolling Resistance force $= M_{rr} \times G_v$

$M_{rr} =$ co-off of Resistance

$G_v = 965\,kg$

Roll. Res $= 0.01 \times 965\,kg$

Traction Force $= F_t + [D_{force} + RollRes_{force}]$

Traction Torque $= F_{Tract} \times$ Radius of Wheel.

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Energy consumption:

Power =

Same BHP needs to be maintained while converting from ICE to EV

Given Power = 82 BHP.

Kilowatts = 61.14 Kilowatts.

Power to weight Ratio $= \dfrac{P_{max}}{m_v (\text{kgh})}$

E_{avg} = Energy Consumption

$E_{Avg} = [E_p + E_{aux}] \times [2 - \text{efficiency of Power train}]$

P_{max} is Maximum Power

E_p is Avg. Energy consuption through Power train assumed as 137.8 Wh/km

E_{aux} is Avg. energy consumption through auxilary System assumed as 9.24 Wh/km

E_{vg} is Energy Consumption

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Assumption

$E_p = 137.8\ Wh/KM$
$E_{aux} = 9.24\ Wh/km$

Efficiency of Power Train = 0.9

$E_{Avg} = [137.8 Wh/k + 9.24 Wh/k] \times [2 - 0.9]$

$= \cancel{137.} [147.04\ Wh/k] \times [1.1]$

$= 161.744\ Wh/Km$

$\boxed{\text{Energy Consumption} = 161.744\ Wh/KM}$

Battery Pack Calculation:

Manufacturer → Panasonic NCR18650B

Length	0.0653 m
Diameter	0.0185 m
~~Hei~~ Mass	0.0485 kg
Capacity	3.2 Ah
Voltage	3.6 V
C rating	1 continous
C rating Peak	1 Peak

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Volume of Cylindrical Cell $= \dfrac{\pi \times D_{bc}^2 \times L_{bc}}{4}$

$E_{bc} = C_{bc} \times V_{bc}$

V_{cc} is Volume of Cylindrical cell

D_{bc} is Diameter of cell

L_{bc} is Length of Cell

E_{bc} is Energy of Cell

C_{bc} is Capacity of Cell

V_{bc} is Voltage of Cell

$= \dfrac{\pi \times (0.0185)^2 \times 0.0653}{4}$

$= \dfrac{\pi \times 0.000342 \times 0.0653}{4}$

$= 0.00007012$

$\boxed{\text{Volume of Cell} = 0.000753}$

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$$\text{Energy of Cell} = \overset{\text{Capacity}}{\text{Charge}} \times \text{voltage}$$

$$= 3.2\,Ah \times 3.6\,V$$

$$\boxed{\text{Energy of Cell} = 11.52\,Wh}$$

$$U_v = \frac{E_{bc}}{V_{cc}}$$

$$U_g = \frac{E_{bc}}{m_b}$$

$$U_v = \text{volumetric Cell density} = \frac{11.52\,wh}{0.00017}$$

$$U_g = \text{Gravitic Cell density} = \frac{11.52\,wh}{0.0485}$$

No of cell in Series $N_{cs} = \dfrac{U_{bp}}{U_{bc}}$

Energy of battery Pack $= E_{avg} \times P_v$

Capacity of battery Pack $= N_{sb} \times C_{bc}$

Total Number of Cells $= N_{sb} \times N_{cs}$

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mass of battery Pack =

$$m_{bp} = N_{cb} \times m_{bc}$$

Volume of battery Pack

$$V_{bp} = N_{cb} \times V_{cc}$$

$$I_{spc} = C - rate_{bcp} \times C_{bc}$$

$$I_{bpp} = I_{spc} \times N_{sb}$$

$$P_{bpp} = I_{bpp} \times U_{bp}$$

I_{spc} is String Peak Current

$C_{rate_{bcp}}$ is C-rate peak

I_{bpp} is Battery Pack Peak Current

P_{bpp} is Battery Pack Peak Current.

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Electric Motor:

Torque Power chare of

Borg Warner HVH250

Electric Motor

Required Power of Electric Motor

$$t = \int_0^{V_b} \frac{\frac{G_v \delta_a}{g}}{\frac{P}{V_b} - G_v N_f - \frac{1}{2}\rho C_d A_c V_b^2} dV$$

$$- \int_{V_b}^{V_f} \frac{\frac{G_v}{g}\delta_a}{\frac{P}{V_f} - G_v M_f - \frac{1}{2}\rho C_d A_c V_f^2} dV$$

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SRINATH KALYANARAMAN $\boxed{SA2.2}$

1 If $x+y = \begin{vmatrix} 7 & 0 \\ 2 & 5 \end{vmatrix}$

$x-y = \begin{vmatrix} 3 & 0 \\ 0 & 3 \end{vmatrix}$

find x and y

$x+y = \begin{vmatrix} 7 & 0 \\ 2 & 5 \end{vmatrix} \rightarrow 1$

$x-y = \begin{vmatrix} 3 & 6 \\ 0 & -1 \end{vmatrix} \rightarrow 2$

$1 + 2 \Rightarrow (x+y)+(x-y)$

2

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$$2x - 2y = \begin{vmatrix} 10 & 0 \\ 2 & 8 \end{vmatrix}$$

$$2[x - y] = \begin{vmatrix} 10 & 0 \\ 2 & 8 \end{vmatrix}$$

Subtracting 1 − 2

$$(x+y) - (x-y) = \begin{vmatrix} 4 & 0 \\ 2 & 2 \end{vmatrix}$$

$$2y = \begin{vmatrix} 4 & 0 \\ 2 & 2 \end{vmatrix}$$

$$y = \begin{vmatrix} 2 & 0 \\ 1 & 1 \end{vmatrix} = 2$$

$$x - y = \begin{vmatrix} 3 & 0 \\ 0 & 3 \end{vmatrix}$$

$$(x-1) = 9$$
$$x = 8$$

$$\boxed{\begin{array}{c} x = 8 \\ y = 2 \end{array}}$$

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(2) $A = \begin{bmatrix} 2 & 3 & -5 \\ 1 & 2 & -1 \end{bmatrix}$ $B = \begin{bmatrix} 0 & 5 & 1 \\ -2 & 7 & 3 \end{bmatrix}$

$A+B = \begin{bmatrix} 2+0 & 3+5 & -5+1 \\ 1-2 & 2+7 & -1+3 \end{bmatrix}$

$\boxed{A+B = \begin{bmatrix} 2 & 8 & -4 \\ -1 & 9 & -2 \end{bmatrix}}$

$A-B = \begin{bmatrix} 2-0 & 3-5 & -5-1 \\ 1+2 & 2-7 & -1-3 \end{bmatrix}$

$\boxed{A-B = \begin{bmatrix} 2 & -2 & -6 \\ 3 & -5 & -4 \end{bmatrix}}$

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③ If $\begin{vmatrix} x-2 & -3 \\ 3x & 2x \end{vmatrix} = 3$ find x

determinant of 2x2 matrix

$|A| = \begin{vmatrix} a & b \\ c & d \end{vmatrix} = ad - bc$

Determinant of given matrix

$(x-2) \times 2x - (-9x) = 3$

$\cancel{-2x}\ 2x(x-2) + 9x = 3$

$2x^2 - 4x + 9x = 3$

$2x^2 + 5x = 3$

$x(2x+5) = 3$

$2x + 5 = 3x$

$-x = 5$

$\boxed{x = -5}$

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4 Let $\begin{vmatrix} 3 & y \\ x & 1 \end{vmatrix} = \begin{vmatrix} 3 & 2 \\ 4 & 1 \end{vmatrix}$

Find the Values of x and y if x, y are natural numbers.

$$\begin{vmatrix} 3 & y \\ x & 1 \end{vmatrix} = \begin{vmatrix} 3 & 2 \\ 4 & 1 \end{vmatrix}$$

determinant of matrix

$$3 - xy = 3 - 8$$
$$3 - xy = -5$$
$$-xy = -5 - 3$$
$$= -8$$
$$-xy = -8$$
$$xy = 8$$

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$$xy = 8$$

$$x = \frac{8}{y}$$

$$y = \frac{8}{x}$$

Given x, y are natural number

$$\boxed{\begin{aligned} &\text{i/e } x = 1 \\ &\quad y = 8 \\ &\text{i/e } y = 1 \\ &\quad x = 8 \end{aligned}}$$

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(5) Find the distance between the points (2,3,1) and (-1,2,-3) using a vector method

Point A → A(2,3,1)
Point B → B(-1,2,-3)

distance can be calculate using the vector formula

distance between two points (x_1, y_1, z_1) and (x_2, y_2, z_2) is given by

$$PQ = \sqrt{(x_2-x_1)^2+(y_2-y_1)^2+(z_2-z_1)^2}$$

$$= \sqrt{(-1-2)^2+(2-3)^2+(-3-1)^2}$$

$$= \sqrt{(-3)^2+(-1)^2+(-4)^2}$$

$$= \sqrt{9+1+16} = \sqrt{26}$$

$$= \sqrt{\cancel{1}\cancel{6}}$$

$\boxed{\text{distance between points} = 5.099 \text{ units}}$

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⑥ Find $\vec{a}.\vec{b}$

$\vec{a} = 2i + 2j - k$

$\vec{b} = 6i - 3j + 2k$

$\vec{a}.\vec{b} = |\vec{a}||\vec{b}| \cos\theta$

$|\vec{a}|$ is the magnitude of $\vec{a}$
$|\vec{b}|$ is magnitude of $\vec{b}$

$|\vec{a}| = \sqrt{a_1^2 + a_2^2 + a_3^2} = \sqrt{4+4+1} = \sqrt{9}$

$|\vec{b}| = \sqrt{b_1^2 + b_2^2 + b_3^2} = \sqrt{36+9+4} = \sqrt{49}$

$\vec{a}.\vec{b} = |\vec{a}| |\vec{b}| \cos\theta$

$\vec{a}.\vec{b} = \sqrt{9} \sqrt{49} \cos\theta$

Teacher's Sign ....

(1) An Automobile Having a mass of 2000kg deflects its suspension spring 0.02m under static condition. Determine the natural frequency of the automobile in the vertical direction by assuming damping to be negligible.

The natural frequency of an Automobile in vertical direction is 3.52 Hertz

Static Equilibrium:

Static Equilibrium refers to the Physical State in which the components of a System are at rest and the net force acting through the System is equal to ~~8~~. zero.

In Static Equilibrium $Kd = mg$

K = effective spring constant of spring

mg = weight of the car, d = Static deflection

also $K = m\omega^2$ where ω is angular velocity.

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Where ω is angular velocity
m is mass

Thus $m\omega^2 d = mg$

$$\omega^2 d = g$$

$$w = \sqrt{\frac{g}{d}} = \sqrt{\frac{9.8}{0.02}}$$

$w = 22.15$ rad/sec

Converting to Hertz unit for frequency

1 rad/s = 0.159 Hertz

22.14 rad/s = 22.14 × 0.1591

22.14 rad/s = 3.525 Hertz

Therefore, the natural frequency of the Automobile in the vertical direction is 3.52 Hertz.

$$\boxed{\text{Frequency} = 3.52 \text{ Hertz}}$$

(8) The Natural Frequency of a Spring mass System is found to be 2 Hertz. When an additional mass of 1 Kg added to the orginal mass m, the natural frequency is reduced to 1 Hz. find the spring constant K and the mass m.

$$\omega_n = 2\ Hz$$

Natural Frequency $\omega_n = \sqrt{\frac{K}{m}}$

$$2 = \sqrt{\frac{K}{m}}$$

$$\sqrt{K} = 2\sqrt{m}$$

$$= 12.566\ rad/s \times \sqrt{m} \longrightarrow (1)$$

$$1\ Hertz = 6.28\ rad/s$$

$$1\ Hertz = \omega_n = \sqrt{\frac{K}{m+1}}$$

$$\sqrt{K} = 6.28 \times \sqrt{m+1} \longrightarrow (2)$$

From ① and ②

$$12.566\sqrt{m} = 6.28\sqrt{m+1}$$

Substituting in equation ① we get

$$\sqrt{K} = 12.566\sqrt{\frac{1}{3}}$$

$$K = (12.566)^2 \times \frac{1}{3}$$

$$K = 52.638 \frac{N}{m}$$

The springe and the mass is $m = \frac{1}{3}$ kg

and $K = 52.638 \frac{N}{m}$

⑨ A spring mass system has a natural period of 0.21 sec. What will be the new period if the spring constant is

ⓐ increased by 50 percent

ⓑ decreased by 50 percent

Given $T_n = 0.21$ seconds

$$= 2\pi\left(\sqrt{\left(\frac{m}{k}\right)}\right)$$

$$\sqrt{m} = \frac{0.21\sqrt{k}}{2\pi}$$

(a) If the spring constant is increased by 50 percent

$$(T_n)_{new} = \frac{2\pi\sqrt{m}}{\sqrt{K_{new}}}$$

$$= \frac{2\pi\sqrt{m}}{\sqrt{1.5k}}$$

$$= 2\pi\left(\frac{0.21\sqrt{k}}{2\pi}\right)\frac{1}{\sqrt{1.5k}}$$

$(T_n)_{new} = 0.17146$ sec

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(5) If the spring constant is decreased by 50 percent

$$(\tau_n)_{new} = \frac{2\pi\sqrt{m}}{\sqrt{K_{new}}}$$

$$= \frac{2\pi\sqrt{m}}{\sqrt{0.5K}}$$

$$= 2\pi\left(\frac{0.21\sqrt{K}}{2\pi}\right)\frac{1}{\sqrt{0.5K}}$$

$$(\tau_n)_{new} = 0.29698 \text{ sec}$$

increased by 50 percent $= 0.17146$ sec
decreased by 50 percent $= 0.29698$ sec