**Solution** Electrical energy expended

$$= \frac{50 \times 75}{0.9} \text{ k cal}$$

$$= \frac{50 \times 75}{0.9 \times 860} \text{ kWh} \qquad 1 \text{ kWh} = 860 \text{ k cal}$$

$$= 4.85 \text{ kWh}$$

If the height required is $h$ metre

$$\frac{mgh}{\eta} = 4.85 \times 3.6 \times 10^6 \quad 1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$$

$$\frac{5000 \times 9.81\, h}{0.7} = 4.85 \times 3.6 \times 10^6$$

or

$$h = \frac{4.85 \times 3.6 \times 0.7}{5 \times 9.81} \times 10^3$$

$$= 249 \text{ metre.}$$

**Problem 1.16** A 80 V battery drives a 3000 kg truck at 20 km/h on the level against a frictional resistance of 525 N. The overall efficiency is 0.6. Find the hourly discharge of the battery in ampere-hours. If the same power be taken from the battery on an up gradient of 1% find the speed.

[61 Ah : 12.8 km/h]

**Solution** $20 \text{ km/h} = \frac{20 \times 1000}{3600} = \frac{1}{0.18} \text{ m/s}$

$$\text{Input power (on level)} = 525 \times \frac{1}{0.18} \times \frac{1}{0.6} = 4861 \text{ W}$$

$\therefore$ hourly consumption $= 4861$ Wh $\qquad Wh = VIh$

$\therefore$ hourly discharge $= \frac{4861}{80} = \mathbf{61\ Ah}$ $\qquad \therefore \quad Ih = Ah = \frac{Wh}{V}$

*Up 1% gradient*

Let the speed be $v$ m/sec

The mass of the train is raised thro $\frac{v}{100}$ $m$ in 1 see.

$$\therefore \quad 0.6 \times 4861 = 525\, v + \frac{v}{100} \times 3000 \times 9.81$$

$$= 819.3\, v$$

$$v = \frac{0.6 \times 4861}{819.3} = 3.56 \text{ m/s}$$

$$\therefore \quad \text{The speed} = \frac{3.56 \times 3600}{1000} = 12.8 \text{ km/h}$$

Energy supplied for washing etc

$$= 25000 \times 60 = 1.5 \times 10^6 \text{ kcal}$$

$\therefore$ Total heat supplied

$$= 3.425 \times 10^6 \text{ kcal}$$

If the temperature at 5 PM is $t$ °C

$$100{,}000\,(95 - t) = 3.425 \times 10^6$$

or $\quad 95 - t = 34.2 \quad$ or $\quad t = \mathbf{60.8}$

The total energy to be supplied in 4 hr (12 to 4 Am)

$$= 3.425 \times 10^6 \text{ kcal}$$

$$= \frac{3.425 \times 10^6}{860} \text{ kWh}$$

$$= 3982 \text{ kWh}$$

$\therefore$ The kW rating with 97% efficiency

$$= \frac{3982}{4 \times 0.97}$$

$$= \mathbf{1030\ kW} \text{ (nearly)}$$

**Problem 1.28** A cubic tank 1 m side is filled to 90% capacity five times daily. The water is heated from 10° to 55 °C. The loss per $m^2$ of tank surface per 1 °C temperature difference is 17 W for un-lagged tank and 7 W for lagged tank. Find the loading in each case and the corresponding efficiency. [14.4 kW, 68% 11.7; kW 84%]

**Solution** Mass of water in each fill

$$= 90\% \text{ of } 1 \text{ m}^3 \times 1000 \text{ kg} \qquad [1 \text{ m}^3 = 1000 \text{ kg}]$$

$$= 900 \text{ kg}$$

Total water heated in 5 fills

$$= 5 \times 900 = 4500 \text{ kg}$$

Energy supplied to water

$$= \text{mass in kg} \times \text{Temprise kcal}$$

$$= \frac{4500 \times (55 - 10)}{860} \text{ kWh} \qquad 1 \text{ kWh} = 860 \text{ kcal}$$

$$= 235.5 \text{ kWh}$$

*Un-lagged*

Total loss per day (24 hr)

$$= 17 \times \text{area of the surfaces of the cube} \times \text{diff. in temperature} \times 10^{-3} \times 24 \text{ kWh}$$

**Problem 1.37** Is the following equation dimensionally correct for the current in a particular circuit, containing mutual inductance $M$, self-inductances $L_1$ and $L_2$ and resistanaes $R_1$ and $R_2$

$$I = \frac{V\omega M}{[(\omega^2 M^2 + R_2)^2 + \omega^2 L_1 L_2 R_2^2]^{1/2}}$$

[$R_2$ should read $R_2^2$]

**Solution** $I\,(=)\,\dfrac{\text{Volts}}{\text{ohms}}$

Since the numerator contains one term $\omega M$ which is in ohms the denominator must be (ohms)$^2$

Since there is a square root each term in the denominator must be (ohm)$^4$. The term $\omega^2 L_1 L_2 R_2^2 = (\omega L_1)(\omega L_2) R_2^2$ satisfies this condition

$$(\omega^2 M^2)^2\,(=)\,(\text{ohm})^4$$

But $(R)^2 = (\text{ohm})^2$ only

so $R_2$ should read $R_2^2$ so that $(R_2^2)^2 = (\text{ohm})^4$

$\therefore$ The ratio of capacitance

$$= 1 : \frac{4}{3} \quad \text{or} \quad 3:4$$

**Problem 2.11** A capacitor is composed of two plates separated by a sheet of insulating materital 3 mm thick and of relative permittivity 4. The distance between the plates is increased to allow of the insertion of a second sheet 5 mm thick and of relative permittivity $\epsilon_r$. If the capacitance so formed is one third of the original capacitance. find $\epsilon$ [3.33]

**Solution** $C_1 = \frac{A\,\epsilon_0}{d_1}\,\epsilon_r = \frac{A\,\epsilon_0 \times 4}{3}$ ($d_1$ in mm

$$C_2 = \frac{A\,\epsilon_0}{d_1/\epsilon_1 + d_2/\epsilon_2}$$

$$= \frac{A\,\epsilon_0}{3/4 + 5/\epsilon_r} \quad (d_1 \text{ and } d_2 \text{ in mm})$$

$$C_2 = \frac{1}{3}\,C_1$$

$$\therefore \quad \frac{1}{\frac{3}{4} + \frac{5}{\epsilon_r}} = \frac{4}{9} \quad \text{or} \quad \frac{3}{4} + \frac{5}{\epsilon_r} = \frac{9}{4}$$

$$\therefore \quad \frac{5}{\epsilon_r} = \frac{9}{4} - \frac{3}{4} = \frac{6}{4} \quad \text{or} \quad \epsilon_r = \frac{20}{6} = 3.33$$

**Electric Field.**

**Problem 2.12** A parallel-plate capacitor has plates 0.15 mm apart, a plate area of 1000 cm$^2$, and a dielectric with relative permittivity of 3. Find the electric flux density, the electric field intensity and the voltage between the plates if the capacitor has a charge of 0.5 $\mu$C.

[5 $\mu$C/m$^2$; 188.5 kV/m 28.3V]

**Solution** The area

$$A = 1000 \text{ cm}^2 = 1000 \times 10^{-4} = 0.1 \text{ m}^2$$

The distance $d = 0.15 \text{ mm} = 1.5 \times 10^{-4}$ m

$$\epsilon_r = 3., \; Q = 0.5\,\mu C$$

The electric flux deristy

$$= \frac{Q}{A} = \frac{0.5\,\mu C}{0.1 \text{ m}^2} = 5\,\mu\text{C/m}^2 = D$$

$$D = \epsilon_0\,\epsilon_r\,E$$

$\therefore$ The electric field intensisty

$$E = \frac{D}{\epsilon_0\,\epsilon_r} = \frac{5 \times 10^{-6}}{8.854 \times 10^{-12} \times 3}$$