11.1 **11.1**

a) $F = k \cdot x \quad [k] = \frac{[F]}{[x]} = \frac{MLT^{-2}}{L} = MT^{-2}$

b) $W = F \cdot x \quad [W] = MLT^{-2} \cdot L = ML^2T^{-2}$

c) Torque : $T = F \cdot x \quad [T] = MLT^{-2}L = ML^2T^{-2}$

d) Tensão superficial : $\left[\frac{F}{X}\right] = \frac{MLT^{-2}}{L} = MT^{-2}$

e) $[\mu]$ = adimensional

f) coeficiente de viscosidade : $F = \eta \frac{V \cdot A}{y}$ ou $[\eta] = \left[\frac{F \cdot y}{V \cdot A}\right] = \frac{N \cdot m}{\frac{m}{s} \cdot m^2} = \frac{N \cdot s}{m^2}$

ou $[\eta] = \frac{MLT^{-2}T}{L^2} = ML^{-1}T^{-1}$

g) campo gravitacional : $\left[\frac{F}{M}\right] = \frac{MLT^{-2}}{M} = LT^{-2}$

h) campo eléctrico : $\left[\frac{F}{Q}\right] = \left[\frac{F}{I \cdot T}\right] = \frac{MLT^{-2}}{IT} = MLT^{-3}I^{-1}$

i) indução magnética : $F = i l B$ ou $B = \frac{F}{i l} \quad [B] = MLT^{-2} \cdot I^{-1}L^{-1} = MT^{-2}I^{-1}$

j) $\left[\frac{E}{B}\right] = \frac{MLT^{-3}I^{-1}}{MT^{-2}I^{-1}} = LT^{-1} = [\text{velocidade}]$

Nota: ver também www.qsl.net/g4cnn/units/units.htm

11.2 **11.2**

$\varepsilon_0 = \frac{1}{4\pi 10^{-7} c^2} \frac{\text{Farad}}{m} \quad ; \quad \varepsilon_0 c = \frac{1}{4\pi 10^{-7} c} \frac{\text{Farad}}{m} \frac{m}{s}$

$(\varepsilon_0 c)^{-1} = 4\pi 10^{-7} \cdot c \frac{s}{\text{Farad}} \quad [(\varepsilon_0 c)^{-1}] = \frac{T}{\frac{C}{V}} = \frac{V}{\frac{C}{T}} = \frac{V}{I} =$ Resistência

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11.3

$$[V] = \frac{L}{T} = \frac{\lambda^{-1} L'}{\tau^{-1} T'} = \frac{\tau}{\lambda}\frac{L'}{T'} = \frac{\tau}{\lambda}[V'] \qquad [V'] = \frac{\lambda}{\tau}[V]$$

$$[a] = L T^{-2} = \lambda^{-1} L' (\tau^{-1} T')^{-2} = \lambda^{-1} \tau^{2} L' T'^{-2} = \lambda^{-1} \tau^{2} [a'] \qquad [a'] = \lambda \tau^{-2} [a] = \frac{\lambda}{\tau^2}[a]$$

$$[F] = M L T^{-2} = \mu^{-1} M' \frac{\tau^2}{\lambda} L' T'^{-2} = \mu^{-1} \frac{\tau^2}{\lambda} M' L' T'^{-2} = \frac{\tau^2}{\mu\lambda}[F'] \qquad [F'] = \frac{\mu\lambda}{\tau^2}[F]$$

$$[E] = M L^2 T^{-2} = L \cdot M L T^{-2} = \lambda^{-1} L' \cdot \frac{\tau^2}{\mu\lambda} M' L' T'^{-2} = \frac{\tau^2}{\mu\lambda^2}[E'] \qquad [E'] = \frac{\mu\lambda^2}{\tau^2}[E]$$

11.4

$$[g] = L T^{-2}; \quad [l] = L; \quad \left[\frac{l}{g}\right] = \frac{L}{L T^{-2}} = T^2; \quad T \propto \sqrt{\frac{l}{g}}$$

11.5

$F = \frac{GMm}{r^2}$ e $m\omega^2 r = \frac{GMm}{r^2}$ donde $GM = \omega^2 r^3 = \left(\frac{2\pi}{T}\right)^2 r^3$

$GM = 4\pi^2 \frac{r^3}{T^2}$ e se $[r] = AU$ e $[T] = \text{ano}$ então $GM = 4\pi^2$

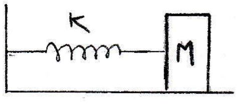
11.6

Do problema anterior vem: $T^2 = 4\pi^2 \frac{d^3}{GM}$ e após o factor de escala K vem $T'^2 = 4\pi^2 \frac{d'^3}{G \cdot M'}$ em que G se conserva.

Então $d' = K d$ e $M' = \rho \frac{4}{3}\pi r'^3 = \rho \frac{4}{3}\pi K^3 r^3 = K^3 M$ pelo que

$T'^2 = 4\pi^2 \frac{K^3 d^3}{G \cdot K^3 \cdot M} = T^2$. Assim o período T não depende de K.

11.7



$$[K] = \left[\frac{F}{x}\right] = \frac{M L T^{-2}}{L} = M T^{-2}$$

[período de oscilação] $= T = \sqrt{\frac{M}{M T^{-2}}}$ então $T \propto \sqrt{\frac{M}{K}}$

11.8

$[F] = L M T^{-2}$ $\quad [V] = L T^{-1}$ $\quad [l] = L$ $\quad [m] = M$

$[\text{Tensão}] = M L T^{-2} = M \frac{(L T^{-1})^2}{L} = \left[\frac{m v^2}{l}\right]$ $\quad T \propto \frac{m v^2}{l}$ e $[a] = L T^{-2} = \frac{(L T^{-1})^2}{L} = \left[\frac{v^2}{l}\right]$

11.9

$[T]=T;\ [L]=L;\ [v]=LT^{-1};\ [g]=LT^{-2}$

$[x]=\dfrac{(LT^{-1})^2}{LT^{-2}}=L \qquad x\propto\dfrac{v^2}{g} \qquad$ e $\qquad [T]=\dfrac{LT^{-1}}{LT^{-2}};\ T\propto\dfrac{v}{g}$

11.10

$[R]=L;\ [\rho]=ML^{-3};\ [\sigma]=MLT^{-2}L^{-2}=ML^{-1}T^{-2};\ [T]=T$

$L^2\dfrac{ML^{-3}}{ML^{-1}T^{-2}}=T^2 \qquad T^2=R^2\dfrac{\rho}{\sigma} \qquad T=\sqrt{\dfrac{\rho R^2}{\sigma}}\propto\sqrt{\dfrac{m}{\sigma}}$

11.11

$[\sigma]=\dfrac{M}{L};\ [\omega]=T^{-1} \quad [F]=MLT^{-2};\ [l]=L$

$MLT^{-2}=\dfrac{M}{L}\cdot L\cdot LT^{-2};\ [F]=[\sigma]\cdot[l]^2[\omega]^2 \qquad \omega\propto\dfrac{1}{l}\sqrt{\dfrac{F}{\sigma}}$

11.12

$[v]=LT^{-1} \quad [v]^2=L^2T^{-2}=L\cdot LT^{-2}=[\lambda]\cdot[g]$ e assim $v\propto\sqrt{g\lambda}$

11.13

$[p]=MLT^{-2}L^{-2}=ML^{-1}T^{-2}=M\dfrac{L^2}{L^3}T^{-2}=M\dfrac{(LT^{-1})^2}{L^3}\doteq\left[\dfrac{Nmv^2}{V}\right]$

$pV=Nmv^2$

11.14