EngGen 140. Energy Tut. I. Answers

1. D – constitutive eq^n for spring forces

2. $E \; [=] \; kg \cdot \frac{m^2}{s^2}$ (Base SI) (eg via $KE = \frac{1}{2} m v^2$)

3. $W = F \times d \; [=] \; kg \cdot \frac{m}{s^2} \cdot m = kg \cdot \frac{m^2}{s^2}$

   $KE = \frac{1}{2} m v^2 \; [=] \; kg \cdot \left(\frac{m}{s}\right)^2 = kg \cdot \frac{m^2}{s^2}$

   same ✓

4. $U = \frac{1}{2} k \cdot (x - x_0)^2$

   $$\Rightarrow k = \frac{2U}{(x-x_0)^2} \; [=] \; kg \cdot \frac{m^2}{s^2} \Big/ m^2$$

   $$= kg/s^2$$

   (Check $F = k \cdot (x - x_0)$

   $[=] \; kg \cdot \frac{m}{s^2} = N$ ✓)

5. $F \; [=] \; kg \cdot \frac{m}{s^2}$ (eg via F = mass × acceleration)

→

6. Raw energy = 2500 kJ

Available (food) = 0.25×2500 kJ $= 0.25 \times 2500 \times 10^3$ J

mass = 79 kg

Climb to height $h \Rightarrow \Delta E_p = m \times g \times h$

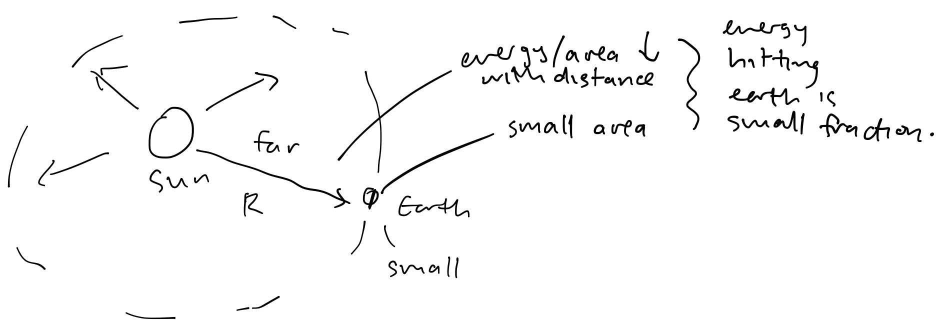
Max : Available (food) = ΔE_p

$$\Rightarrow h = \frac{0.25 \times 2500 \times 10^3 \text{ J}}{79 \text{ kg} \times 9.81 \text{ m/s}^2}$$

$$\approx \underline{806 \text{ m}}$$ (updated).

7.
- As they fall, gravitational potential energy is converted to kinetic energy, which reaches a maximum just before they hit the ground (some is also 'lost' to thermal, sound etc energy via air resistance...)
- When they hit the mattress they compress the springs, storing some as elastic potential, while some more is 'lost' to heat & sound energy.
- The springs transfer some back to the person, causing them to 'bounce', but each time some is 'lost' to heat/sound etc until all is either stored in springs as elastic potential or has been converted to thermal/sound energy.

8. Earth is far away & relatively small, compared to the sun:



$\Rightarrow$ The energy radiates out from the sun & only a small fraction 'hits' the earth.

If the total flux J is constant then

$$J = j \cdot A = \text{const.}$$

flux intensity (j), area (A)

$A \sim R^2$ so $j \sim \frac{1}{R^2}$ where R is dist. from sun to earth.

$\Rightarrow$ flux intensity ↓ with $\frac{1}{R^2}$

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9. $$\frac{\text{Power absorbed}}{\text{Geothermal}} = \frac{0.7 \times 173{,}000 \text{ TW}}{32 \text{ TW}} \simeq 3{,}784$$

ie power absorbed$_{\text{atm}}$ $\simeq$ 3800 × larger than geothermal.

10. Power = 173,000 TW

$$\text{Power abs. atmosphere} = 173{,}000\ \text{TW} \times 0.17$$

$$= 29{,}410\ \text{TW}$$

Power in Energy/Year ?

$$\frac{\text{Energy}}{\text{Year}} = 29{,}410\ \text{TW} \times \left(\frac{24 \times 365\,\text{h}}{1\ \text{year}}\right)$$

$$\simeq 2.6 \times 10^{8}\ \frac{\text{TW.h}}{\text{Year}} \leftarrow \frac{\text{energy}}{\text{year}}$$

So Energy in one year $= \underline{2.6 \times 10^{8}\ \text{TW.h}}$

11. A (20%)

12. A (25%)

13. $$\text{World power} = 13{,}000\ \text{Mtoe} \times \frac{11.63\ \text{TW.h}}{1\ \text{Mtoe}} \simeq 151{,}190\ \text{TW.h}$$

$$\Rightarrow \frac{\text{China}}{\text{world}} = \frac{35{,}000\ \text{TW.h}}{151{,}190\ \text{TW.h}} \times 100\% \simeq \underline{23\%}$$

14. $$\text{US} \sim 2{,}200\ \text{Mtoe} \Rightarrow \frac{\text{US}}{\text{World}} = \frac{2{,}200\ \text{Mtoe}}{13{,}000\ \text{Mtoe}} \times 100\% \simeq \underline{17\%}$$

15. Oil.

16. a) $1\ \text{kW}\cdot\text{h} = 1\times10^3 \left(\frac{J}{s}\right)\cdot h = 1\times10^3 \frac{J}{\cancel{s}} \times \frac{60\times60\cancel{s}}{1\cancel{h}} \cdot \cancel{h}$

$= 3600\times10^3\ J$

$= 3.6\times10^6\ J \quad (3.6\ MJ)$

b) US consumption (one year) $\simeq 15{,}000\times10^{15}\ J \times \left(\frac{1\ \text{kW}\cdot\text{h}}{3.6\times10^6\ J}\right)$

$\simeq 4.167\times10^{12}\ \text{kW}\cdot\text{h}$.

$\Rightarrow$ US consumption per capita $\simeq \frac{4.167\times10^{12}\ \text{kW}\cdot\text{h}}{320\times10^6\ \text{people}} \simeq \underline{13{,}000\ \frac{\text{kW}\cdot\text{h}}{\text{person}}}$

17. Norway consumption $\simeq 461\ PJ = 461\times10^{15}\ J \times \frac{1\ \text{kW}\cdot\text{h}}{3.6\times10^6\ J}$

$\frac{\text{Norway consumption}}{\text{capita}} \simeq \frac{461\ PJ}{5.2\times10^6\ \text{people}} = \frac{461\times10^{15}}{3.6\times10^6 \times 5.2\times10^6}\ \frac{\text{kW}\cdot\text{h}}{\text{person}}$

$\simeq \underline{25{,}000\ \text{kW}\cdot\text{h}/\text{person}}$.

18. F_D is shape drag $\sim v^2$

so $\frac{F_D^{\text{after}}}{F_D^{\text{before}}} = \frac{(\cancel{\ \ })v_2^2}{(\cancel{\ \ })v_1^2} = \frac{80^2}{100^2} = \underline{0.64}$

ie $\downarrow$ $\underline{\text{drag by} \simeq 36\%}$ } so estimate fuel consumption $\downarrow \simeq 36\%$ (rough!)

19. Reynolds number:

$$Re = \frac{\rho v a}{\eta} \sim \frac{\text{inertial forces}}{\text{viscous forces}} \text{ or } \sim \frac{\text{shape drag}}{\text{skin drag}} \text{ etc}$$

where η : viscosity (of fluid)
ρ : density (of fluid)
v : velocity (relative)
a : typical/characteristic length (of object)

Indicates dominant types of forces/energy in fluid environments

dominant:
- shape / inertial ($Re >> 1$)
- skin / viscous ($Re << 1$)

→ allows us to optimise design to minimise dominant drag types &/or determine appropriate ways to generate motion (eg 'swimming' styles for submarine vs 'nanobot')

20. Design experiment by matching Re } give 'same balance' / relative importance of force types

To match Re of small object (small a) in experiment on larger object (bigger a), can increase η.
⇒ ie use more viscous fluid than original.

Eg: $(Re)_1 = \frac{\rho v a_1}{\eta_1} = (Re)_2 = \frac{\rho v a_2}{\eta_2}$

$$\Rightarrow \frac{\eta_1}{\eta_2} = \frac{a_1}{a_2}$$

if $a_2 >> a_1$, ie a_2 is larger than a_1
need $\eta_2 >> \eta_1$, ie more viscous than η_1
to match Re & give 'same' dominant forces.