Pop Quiz!

5.2 Practice Problems

Worldwide energy production (WEP) in 1987 was 320 quadrillion ($320 x 10^{15}$) Btu (British thermal units; 1 Btu = 1.055 kJ = energy to heat 1 pound of H_2O from 60° to 61° F). By 1996, it had increased by 55 quadrillion Btu.

1. Determine the magnitude of energy production in 1996 in joules and the percentage increase from 1987. Calculate the average annual rate of increase in WEP between 1987 and 1996.
2. In 1996, the USA produced 73 quadrillion Btu, more than any other country. Calculate the contribution of the USA to WEP in 1996.
3. Only about 0.025% of the Sun's radiant energy that reaches Earth is captured by photosynthetic organisms. Calculate the magnitude of this energy (in $kJ.s^{-1}$), using the data provided in section 5.1.3 above. Find the ratio of WEP_{1996} to the Sun's energy captured by photosynthetic organisms.
4. Assuming that $173{,}000 x 10^{12}$W of the energy reaches Earth and is then either reflected or absorbed, calculate the total energy output of the Sun (1 W = 1 $J.s^{-1}$). (Diameter of Earth = 12,756 km; area of a circle = p x $(\text{diameter}/2)^2$; surface area of a sphere = 4 x $(\text{diameter}/2)^2$; mean distance of Earth from Sun = $149.6 x 10^6$ km).
5. Using your result from the previous problem, calculate the number of moles of ^2H consumed when a heat this large is released. Calculate the energy equivalent of the Earth (mass = $5.976 x 10^{27}$ g). Compare the mass energy of Earth to the radiant energy of the Sun that reaches Earth in one year.

[from Haynie, D. T. 2008. Biological Thermodynamics. Cambridge University Press]

these & more : will cover in tutorial & then will post answers on Canvas

Exam – some relevant questions

Physics of Energy – 18 marks

21) Global energy use has steadily increased over the last 15 years, except for the last two years. This is surprising, given the continued increase in the world's population. What is the main cause of this 'plateau' in global energy consumption? **(1 mark)**

Answer:________________________________

22) Worldwide energy consumption in 2005 was 488 EJ (exa=10^{18}). In class we estimated 2015 worldwide energy consumption to be 13,000 Mtoe (1 toe = 42 x 10^9 J). What has been the percentage increase in worldwide energy consumption in the last 10 years? **(2 marks)**

Percentage Increase: ______________

23) Which of the following sectors is mainly responsible for the growth in NZ energy consumption over the last 15 years? **(1 mark)**

A. Industrial
B. Residential
C. Transport
D. Commercial and Public Services
E. Agriculture, Forestry, and Fishing

Answer:__________

24) The radiant energy from the Sun that reaches the Earth is 1.74 x 10^{17} W. Approximately 52% of these photons are either reflected back to space, or absorbed by the atmosphere. We know that 0.025% of the energy that reaches the land is absorbed by photosynthetic organisms. Calculate the radiant energy that is converted by photosynthetic organisms over one year. **(3 marks)**

Lecture 03/04 (Part II) {5.3 & 5.4 (L3), 5.5 (L4)} EngGen140

Topics:
- Units
- some key quantities (eg force, energy, power ...)
- Forms of energy

What you should be able to do	Basic unit types & conversions
	Basic calculations involving force, energy power & pressure (etc)
	Basic energy conversion & calc.

L3:

Units

SI system: $\boxed{\text{seven basic units}}$ for $\boxed{\text{seven basic 'types' of quantity}}$

- seven 'types' or dimensions eg 'time' or 'mass' } T, M, L etc
- Seven units to measure these types eg 'seconds' or 'kilograms' } s, kg, m etc

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Note: same 'type' of quantity eg 'time', can be measured with different units

→ compare a 'thing' eg (a 'length')
standard 'thing' of same 'type' (one 'metre')

Compare ⇒ = 2.5× ie 2.5 metres

unit = a 'standard thing' of some type.

Dimensions & units

Dimension (Type)

Unit

standard 'thing' from world/universe = fixed number of units

Table 1: The seven *base SI units* and their new, proposed definitions.

Quantity Name	Unit Name	Symbol	Definition
Time	Second	s	By taking the fixed numerical value of the caesium frequency $\Delta\nu_{Cs}$, the unperturbed ground-state hyperfine transition frequency of the caesium 133 atom, to be 9192631770 when expressed in the unit Hz, which is equal to s^{-1}
Length	Metre	m	By taking the fixed numerical value of the speed of light in vacuum c to be 299792458 when expressed in the unit $m \cdot s^{-1}$, where the second is defined in terms of the caesium frequency $\Delta\nu_{Cs}$
Mass	Kilogram	kg	By taking the fixed numerical value of the Planck constant h to be $6.626070040 \times 10^{-34}$ when expressed in the unit J s, which is equal to $kg \cdot m^2 \cdot s^{-1}$, where the metre and the second are defined in terms of c and $\Delta\nu_{Cs}$
Amount of substance	Mole	mol	By taking the fixed numerical value of the Avogadro constant[3] N_A to be $6.022140857 \times 10^{23}$ when expressed in the unit mol^{-1}
Temperature	Kelvin	K	By taking the fixed numerical value of the Boltzmann constant k to be $1.38064852 \times 10^{-23}$ when expressed in the unit $J\ K^{-1}$, which is equal to $kg \cdot m^2 \cdot s^{-2} \cdot K^{-1}$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$
Electric current	Ampere	A	By taking the fixed numerical value of the elementary charge e to be $1.6021766208 \times 10^{-19}$ when expressed in the unit C, which is equal to A s, where the second is defined in terms of $\Delta\nu_{Cs}$
Luminous intensity	Candela	cd	By taking the fixed numerical value of the luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, to be 683 when expressed in the unit $lm \cdot W^{-1}$, which is equal to $cd \cdot sr \cdot W^{-1}$, or $cd \cdot sr \cdot kg^{-1} \cdot m^{-2} \cdot s^3$, where the kilogram, metre and second are defined in terms of h, c and $\Delta\nu_{Cs}$

[https://en.wikipedia.org/wiki/International_System_of_Units]

Note: can check dimensional consistency without specific units, just dimensions (types)

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eg $P = \frac{dW}{dt} = F \times v$? dimensions OK ?

$$\underbrace{\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}}_{\text{LHS}} \overset{\checkmark}{=} \underbrace{\text{Force} \times \frac{\text{Distance}}{\text{Time}}}_{\text{RHS}}$$

Derived units / quantities

Build up from seven basic units/quantities

Eg $\boxed{\text{Quantity}}$: Area $= \text{Length}^2$ } Type of 'thing'

('thing' or 'dimension')

$\boxed{\text{SI Units}}$: m^2 } unit for measuring

$\boxed{\text{Quantity}}$: $\boxed{\text{pressure}}$

$$= \frac{\text{Force}}{\text{area}} = \frac{\text{Force}}{\text{Length}^2} = \frac{\text{Mass} \times \text{Accel.}}{\text{Length}^2}$$

$$= \text{Mass} \times \frac{\text{Length}}{\text{Time}^2} \times \frac{1}{\text{Length}^{\cancel{2}}} = \frac{M}{T^2 \cdot L}$$

$\boxed{\text{SI units}}$: $$\frac{N}{m^2} = \frac{kg \cdot \cancel{m}}{s^2} \cdot \frac{1}{m^{\cancel{2}}} = \frac{kg}{m \cdot s^2} = \boxed{Pa}$$

"Pascal"

Derived units (and quantities) are formed by powers, products, or quotients of the base units and are commonly used across multiple disciplines. The dimensions of derived units can be expressed in terms of dimensions of the base units.

Table 3: Common *derived SI units* [fill in the gaps of the SI base units].

Unit Name	Symbol	Quantity (type)	Expressed in terms of other SI units	Expressed in terms of SI base units
hertz	Hz	frequency	1/s	s^{-1}
radian	rad	angle	m/m	dimensionless
newton	N	force, weight		$kg \cdot m \cdot s^{-2}$
pascal	Pa	pressure, stress	N/m^2	$kg \cdot m^{-1} \cdot s^{-2}$
joule	J	energy, work, heat	N·m	$kg \cdot m^2 \cdot s^{-2}$
watt	W	power, radiant flux	J/s	$kg \cdot m^2 \cdot s^{-3}$
coulomb	C	electric charge or quantity of electricity	F·V	s·A
volt	V	Voltage, electrical potential difference, electromotive force	W/A J/C	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-1}$
farad	F	electrical capacitance	C/V s/Ω	$kg^{-1} \cdot m^{-2} \cdot s^4 \cdot A^2$
ohm	Ω	electrical resistance, impedance, reactance	V/A	$kg \cdot m^2 \cdot s^{-3} \cdot A^{-2}$
degree Celcius	°C	Temperature relative to 273.15 K		K
sievert	Sv	equivalent dose of ionizing radiation	J/kg	$m^2 \cdot s^{-2}$

'most basic' units

Other entries in table

Joule (Energy)

$$J = \underbrace{N \cdot m}_{\substack{\text{Force} \times \text{distance!} \\ = \text{Work}}} = kg\,\frac{m}{s^2} \cdot m = \boxed{kg\,\frac{m^2}{s^2}}$$

Watt (Power)

$$W = \frac{J}{s} = \frac{kg \cdot m^2}{s^2} \cdot \frac{1}{s} = \frac{kg \cdot m^2}{s^3}$$

Sievert (dose of radiation)

$$\left.\frac{J}{kg}\right\} \quad \frac{\text{energy}}{\text{mass}}$$

$$\frac{J}{kg} = \frac{\cancel{kg} \cdot m^2}{s^2} \cdot \frac{1}{\cancel{kg}} = \frac{m^2}{s^2}$$

Key (ie common) quantities in the physics of energy

- Energy $\quad$ J = ?
- Force $\quad$ N = ?
- Power $\quad$ J/s = ?
- Pressure $\quad$ N/m^2 = ?

Notation:

$\boxed{X \; [=] \text{ units/dimensions}^* \text{ of } X}$ (useful for unit checks & conversions)

Eg

Speed [=] $\underbrace{\frac{\text{Length}}{\text{Time}}}_{\text{dimensions of}}$ [=] $\underbrace{\frac{m}{s}}_{\text{units of}}$

dimensions of ('type' of thing)

units of (SI)

(*Note: we use [=] to mean both 'dimensions of' & 'units of' to avoid using yet another symbol

→ but could use eg ~ & [=] to distinguish 'dim of' & 'unit of'

→ people also use [X] = ... instead of X [=] ...)

Force

Newton's 2nd Law:

Force = mass × acceleration

$[=]\ M \times \dfrac{L}{T^2}$ } has dimensions / types of

$[=]\ kg \cdot \dfrac{m}{s^2}$ } has units of (SI)

$= N$ ← use normal '=' since units = units is OK.

Units & Dim.

(So $\underline{1N = 1\ kg \cdot m \cdot s^{-2}}$)

Eg. ← use.

Force of gravity on 70kg person?

Actual Calc*

$F = m \times g$

$= 70\ kg \times 9.81\ \dfrac{m}{s^2}$

$= 686\ \underline{kg \cdot m \cdot s^{-2}}$

$= 686\ \underline{N}$

(*Note: don't need [=] in example above since not saying 'units of' or 'dimensions of'

→ we mean mass = 70kg

not mass [=] 70kg!)

Kinetic Energy

Dim & units

$KE = \frac{1}{2}$ mass x velocity^2

$[=]\ M \times V^2$

$= M \times \left(\frac{L}{T}\right)^2$

dimensions / types of

$[=]\ kg \times \frac{m^2}{s^2}$ SI units of

& $\underline{KE\ [=]\ J}$ (Joules) in SI units

so, $\boxed{1J = 1\,kg \cdot m^2 s^{-2}}$

use

Actual Calc.

what is the K.E. of 70kg person walking at 5 km/hr ?

① $KE = \frac{1}{2} \cdot 70\,kg \cdot \left(5 \frac{km}{hr}\right)^2$

important to include units inside ( )^2!

② Want in $\frac{kg \cdot m^2}{s^2} = J$

$\Rightarrow KE = \frac{1}{2} \cdot 70\,kg \cdot \left(\frac{5 \times 10^3\,m}{\cancel{hr}} \cdot \frac{\cancel{hr}}{3600\,s}\right)^2$

$= 35\,kg \cdot \left(\frac{5\cancel{000}}{3.6\cancel{00}}\ \frac{m}{s}\right)^2$

$\approx \underline{67.6\,kg \cdot \frac{m^2}{s^2}} = \underline{67.6\,J}$

Power

Power = (change in) energy per unit time = $\frac{dE}{dt}$

$[=]$ $\frac{\text{Energy}}{\text{Time}}$ } dimensions of

$= \left(M \cdot \frac{L^2}{T^2}\right) \cdot \left(\frac{1}{T}\right)$

$[=]$ $kg \cdot m^2 \cdot s^{-3}$ } SI units of

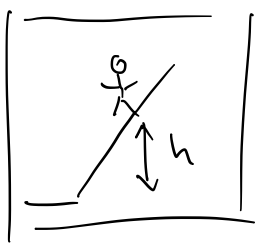
&

Power $[=]$ Watts } SI unit def.

so $\boxed{1 \text{ Watt} = 1 \, kg \cdot m^2 \cdot s^{-3} = 1 \, J/s}$

Power of 70kg person climbing stairs at 0.5 metres per second?

$\frac{\Delta E}{1 \text{ sec}} = \frac{m \cdot g \cdot h}{1 \text{ sec}}$ ← (work against gravity) $= \frac{70 \, kg \times 9.81 \, m/s \times 0.5 \, m}{1 \text{ sec}}$



$= 343 \, kg \, m^2 \, s^{-3}$

$= 343 \, J/s = \underline{343 \text{ Watts}}$

Pressure

Pressure = Force per unit area

$$= \frac{F}{A} \quad \left(\text{or } \frac{dF}{dA}\right)$$

$$\left.\begin{aligned} \text{Pressure} &\;[=]\; \text{Force} \cdot \text{Area}^{-1} \\ &= \left(M \cdot \frac{\cancel{L}}{T^2}\right) \cdot \left(\frac{1}{L^{\cancel{2}}}\right) \end{aligned}\right\} \text{dim.}$$

$$\left.\begin{aligned} &[=]\; \frac{kg \cdot \cancel{m}}{s^2} \cdot \frac{1}{m^{\cancel{2}}} \\ &= \underline{kg \cdot m^{-1} \cdot s^{-2}} \end{aligned}\right\} \text{SI units}$$

& Pressure [=] Pa $\}$ def of SI unit

$$\Rightarrow \boxed{1\,Pa = 1\,kg \cdot m^{-1} \cdot s^{-2} = 1\,N \cdot m^{-2}}$$

$cm^2 \equiv (cm)^2$

careful!

pressure on soles of feet ?

- 70 kg person
- contact area / foot = $125\,cm^2 = 125 \times (10^{-2}\,m)^2$

$= 125 \times 10^{-4}\,m^2$

$$\Rightarrow \text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{70\,kg \cdot 9.81\,m/s^2}{2 \times 125\,cm^2}$$

$$= \frac{70\,kg \cdot 9.81\,m/s^2}{2 \times 0.0125\,m^2}$$

$$= 27{,}440\,kg \cdot m^{-1} \cdot s^{-2}$$

$$= \underline{27{,}440\,Pa} = \underline{27.44\,kPa}$$

Questions

2017 Tut.

8. What is the unit of energy expressed in base SI units?
9. Show that kinetic energy and gravitational potential energy have dimensionally consistent base SI units.
10. What are the base SI units of force?

2017 Exam

25) Using base SI units, show that the units for work are dimensionally consistent with the units of gravitational potential energy. **(2 marks)**

Answer:

L4. Forms of Energy (5-5)

Key Points
- Energy is conserved!
- Energy comes in many 'forms'
- We don't really know what it 'is' but we know how to calculate with it!

eg Quotes from: the famous physics lectures by Richard Feynman:

4–1 What is energy?

In this chapter, we begin our more detailed study of the different aspects of physics, having finished our description of things in general. To illustrate the ideas and the kind of reasoning that might be used in theoretical physics, we shall now examine one of the most basic laws of physics, the conservation of energy.

There is a fact, or if you wish, a *law*, governing all natural phenomena that are known to date. There is no known exception to this law—it is exact so far as we know. The law is called the *conservation of energy*. It states that there is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same. (Something like the bishop on a red square, and after a number of moves—details unknown—it is still on some red square. It is a law of this nature.) Since it is an abstract idea, we shall illustrate the meaning of it by an analogy.

'constitutive equations' for diff types of energy!

has the following points. First, when we are calculating the energy, sometimes some of it leaves the system and goes away, or sometimes some comes in. In order to verify the conservation of energy, we must be careful that we have not put any in or taken any out. Second, the energy has a large number of *different forms*, and there is a formula for each one. These are: gravitational energy, kinetic energy, heat energy, elastic energy, electrical energy, chemical energy, radiant energy, nuclear energy, mass energy. If we total up the formulas for each of these contributions, it will not change except for energy going in and out.

It is important to realize that in physics today, we have no knowledge of what energy *is*. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way. However, there are formulas for calculating some numerical quantity, and when we add it all together it gives "28"—always the same number. It is an abstract thing in that it does not tell us the mechanism or the *reasons* for the various formulas.

Forms :

We often think of energy as coming in two basic 'types':

- Kinetic } 'motion'
- Potential } 'stored' / 'position'

[though this isn't always unambiguous
  - eg some 'forms' are combinations of 'motion' & 'position'/'stored' energies...]

More specifically some forms include:

- kinetic energy of motion (incl. translation & rotation)
- gravitational potential energy
- chemical potential
- elastic potential
- Nuclear potential
- Electrical potential
- Radiant
- thermal

⋮

All have same dimensions/units } *

'same thing'

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* Dimensions: $\underbrace{M \times \frac{L}{T^2}}_{\text{Force}} \cdot \underbrace{L}_{\text{Distance}} = M \cdot \frac{L^2}{T^2}$

Force x Distance

Wikipedia:

Some forms of energy (that an object or system can have as a measurable property)

Type of energy	Description
Mechanical	the sum of macroscopic translational and rotational kinetic and potential energies
Electric	potential energy due to or stored in electric fields
Magnetic	potential energy due to or stored in magnetic fields
Gravitational	potential energy due to or stored in gravitational fields
Chemical	potential energy due to chemical bonds
Ionization	potential energy that binds an electron to its atom or molecule
Nuclear	potential energy that binds nucleons to form the atomic nucleus (and nuclear reactions)
Chromodynamic	potential energy that binds quarks to form hadrons
Elastic	potential energy due to the deformation of a material (or its container) exhibiting a restorative force
Mechanical wave	kinetic and potential energy in an elastic material due to a propagated deformational wave
Sound wave	kinetic and potential energy in a fluid due to a sound propagated wave (a particular form of mechanical wave)
Radiant	potential energy stored in the fields of propagated by electromagnetic radiation, including light
Rest	potential energy due to an object's rest mass
Thermal	kinetic energy of the microscopic motion of particles, a form of disordered equivalent of mechanical energy

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(Note : here radiant is considered a type of potential energy, contra course book

→ not too imp. to 'classify' all as KE or PE

→ key is to understand :

– How do I calculate with it to ensure conservation of energy!)

Examples

- Gravitational potential
  - 'stored energy' due to an object's position in a gravitational field } general idea.

- A particular model, or constitutive eq^n, for this type is

$$\boxed{E_p = \underbrace{m}_{\text{mass}} \cdot g \cdot (h - h_0)}$$

mass

position h relative to reference h_0.

g: strength of field in terms of acceleration (eg 9.81 m/s on earth).

(⇒ There are others too!)

- Electrical potential
  - stored in electrical fields
  - $\frac{\text{Potential}}{\text{unit charge}} \equiv$ voltage

⇒ 1 volt = 1 Joule / Coulomb.

Chemical Potential

- Stored in bonds between atoms in compounds (also eg concentration gradients)

- Can transform to other types via chemical reactions
  - breaking or forming of bonds

Example (see later)

Cellular Respiration :

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

(solid) (gas) (liquid)

absorb & release energy & can use some to do work

(a transfer of energy)

Elastic Potential

(reversible process – see later)

Recoverable energy stored in 'springs' & similar materials & objects

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A particular, common model:

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

displacement relative to ref.

elastic/ spring constant

⇒ Can get by integrating Hooke's constitutive law for force, $F = k \cdot (x - x_0)$:

Do work to compress & 'store':

$$\int_x^{x_0} F \cdot dx = \int k \cdot (x - x_0)\, dx$$

$$= \frac{k}{2} \cdot (x - x_0)^2$$

Perfect spring: get back all stored energy as useful work (no energy converted to heat etc).

Nuclear:

- Potential stored in nuclear bonds

- splitting (fission) or fusing (fusion) releases a large amount of energy

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Nuclear fuel ~ 1×10^6 energy density of carbon fuels.

Radiant

- energy stored in electromagnetic fields

⇒ "radiation".

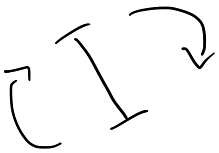
comes in small 'packets': photons

⇒ all travel at ..... speed of light!

Kinetic

Translational : $E_{Tr} = \frac{1}{2} m v^2$

Rotational $E_{Rot} = \frac{1}{2} I \omega^2$



moment of inertia (rotational mass)

angular velocity

Total KE : sum

$$\boxed{E_K = E_{Tr} + E_{rot}}$$

Example : conservation : $\boxed{\underbrace{E_p}_{\text{potential}} + \underbrace{E_K}_{\text{kinetic}} = \text{constant}}$

A cylinder of mass m and radius R (moment of inertia $I=1/2mR^2$) begins to roll from rest down an inclined plane. Calculate the linear speed of the cylinder when it reaches level ground, at height, h

$$\underbrace{\tfrac{1}{2} m v^2 + \tfrac{1}{2} I \omega^2}_{②} = \underbrace{mgh}_{①} \quad \} \text{ conservation}$$

$$\frac{1}{2} m v^2 + \frac{1}{2}\left(\frac{1}{2} m R^2\right)\frac{v^2}{R^2} = mgh$$

$$\frac{1}{2} v^2 + \frac{1}{4} v^2 = gh$$

$$\frac{3v^2}{4} = gh$$

$$v = \sqrt{\frac{4gh}{3}}$$

$E_p = mgh$ ①

$= \quad E_K = \frac{1}{2} m v^2 + \frac{1}{2} I \omega^2$ ②

$I = \frac{1}{2} m R^2$

$v = \omega R$

$\omega = \frac{v}{R}$

$$\boxed{\begin{array}{l} ① : E_p \neq 0, E_K = 0 \\ ② : E_p = 0, E_K \neq 0 \end{array}}$$

Thermal

- atoms 'jiggling'
- 'feel' via temperature

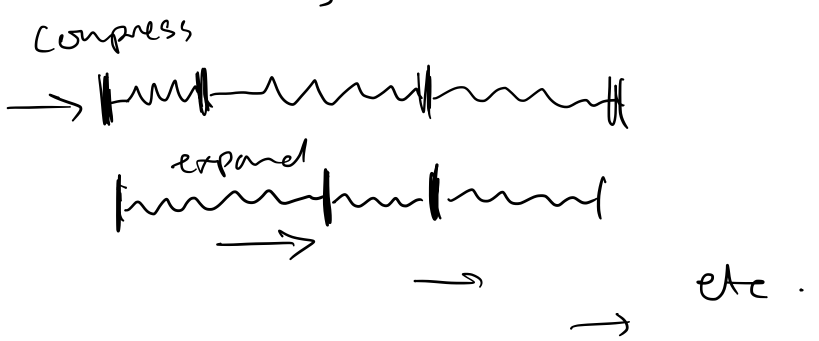
  ↑ not itself energy though!

- Thermal energy 'flows' down temperature gradients:

  $\boxed{\text{Hot} \rightarrow \text{Cold}}$

  Heat Flow

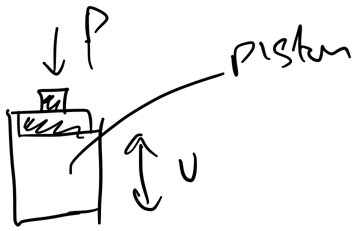
Sound:
- vibrations
  - mechanical
- require a medium
  - eg 'elastic waves'



Unit checks: $M \cdot L^2 T^{-2}$? ($=$ J)

- KE (translation): $\frac{1}{2} m v^2$ [=] $M \cdot \frac{L^2}{T^2}$ ✓ ($=$ J)

- Work (transfer of energy) / Potential (stored work): Force x distance [=] $M \cdot \frac{L}{T^2} \cdot L = M \cdot \frac{L^2}{T^2}$ ✓



- Pressure work (piston): $P \cdot \Delta V$ [=] $\frac{\text{Force}}{\text{Area}} \times \text{Volume}$

$$= \frac{ML}{T^2 \cdot \cancel{L^2}} \cdot \cancel{L^3} = \frac{M \cdot L^2}{T^2}$$ ✓

- Thermal (ideal gas):
  - N (number moles)
  - R (gas constant) [=] $J \cdot mole^{-1} \cdot K^{-1}$
  - T (temperature)

$PV = NRT$?

$\underbrace{PV}_{\text{see above ✓}}$ [=] $\cancel{\text{moles}} \times \frac{J}{\cancel{\text{mole}} \cdot \cancel{K}} \cdot \cancel{K} = J = \frac{M \cdot L^2}{T^2}$ ✓

Unit checks

- Energy of a light quantum (photon)

$$E = h\nu$$

h = Planck's constant

$= 6.626 \times 10^{-34}$ J.s

ν = frequency of light

[=] per time ie T^{-1}

eg s^{-1}

$$h . \nu \; [=] \; J.s.s^{-1} = J \checkmark$$

- Rest mass energy (Einstein)

$$E = mc^2$$

$$[=] \; M . \frac{L^2}{T^2} = J \checkmark$$

Problems

27) Auckland's Sky Tower is 328m high. Determine whether the energy content of a 'Whopper' burger (from you-know-where) would be sufficient to fuel a person weighing 72kg to climb the Sky Tower. The nutrition information shows that on average a Whopper contains 2649kJ. Assume 20% efficiency in converting nutritional energy to mechanical energy.

(2 marks)

Answer:

28) Simple physics provides us with ideas for reducing our transport energy cost. The work required to overcome air resistance (W_{air}) plays the biggest role in the total energy budget of a vehicle. The NZ Government are thinking about increasing the speed limit from 100 km/h to 110 km/h. What effect would this have on the percentage increase in fuel consumption?

(2 marks)

Answer:

(more relevant after next lecture....)