S2 Exam Practise 9

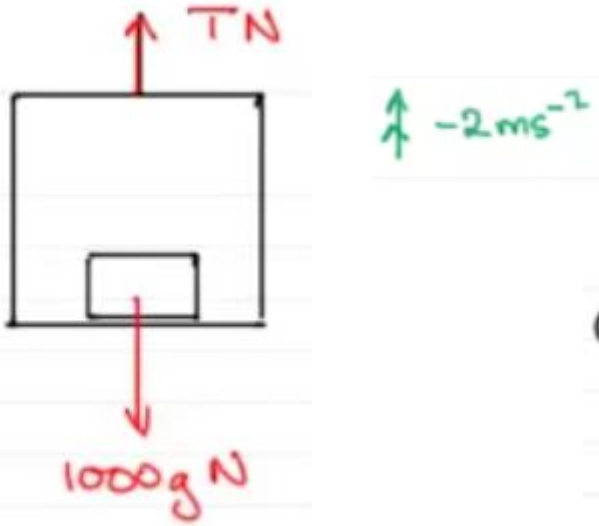
Q and A

Q1

A woman travels in a lift. The mass of the woman is 50 kg and the mass of the lift is 950 kg. The lift is being raised vertically by a vertical cable which is attached to the top of the lift. The lift is moving upwards and has constant deceleration of 2 m s^{-2}. By modelling the cable as being light and inextensible, find

(a) the tension in the cable, **(3)**

(b) the magnitude of the force exerted on the woman by the floor of the lift. **(3)**

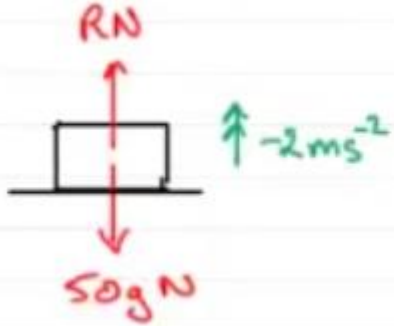


(a) $R(\uparrow)$ $T - 1000g = 1000(-2)$

$\therefore T = 1000g - 2000$

$\therefore T = 7800$ N

(b)



$R(\uparrow)$: $R - 50g = 50(-2)$

$\therefore R = 50g - 100$

$\therefore R = 390$ N

Q2

A train made up of 3 carriages is pulled along a level track by a force of 16 500 N. Each of the carriages has a mass of 8 000 kg, and each experiences 1500 N of resistive forces.

(a) Calculate the acceleration of the train.

$F = F_E - F_{friction}$

$= 16500 - 4500$

$F = 12000\,N$

$F = ma$

$12000 = 24000 \times a$

$a = 0.5\,ms^{-2}$

(b) Work out the tension in link **B**.

$F = T - F_{friction}$

$4000 = T - 1500$

$T = \underline{5500\,N}$

$F = ma$

$= 8000 \times 0.5$

$= 4000\,N$

Q3

Two blocks are linked by a newton balance of negligible mass.

The blocks are placed on a level, frictionless surface. A force of 18·0 N is applied to the blocks as shown.

The reading on the newton balance is

$$F = ma$$

$$18.0 = 10 \times a$$

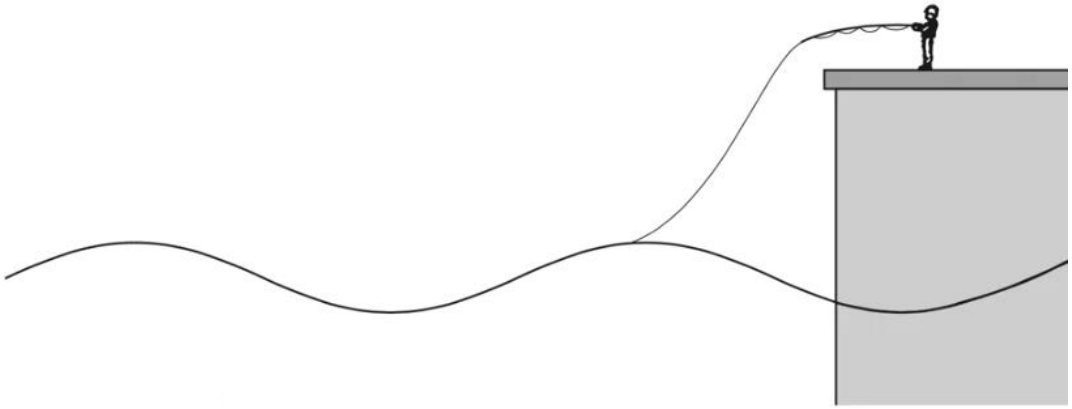
$$a = \frac{18}{10} = 1.8\ ms^{-2}$$

$$F_{4kg} = 4 \times 1.8$$

$$= 7.2N$$

Q4

A student, fishing from a pier, counts four waves passing the end of the pier in 20 seconds. The student estimates that the wavelength of the waves is 12 m.



Calculate the speed of the water waves.

Period = time for 1 wave = $\frac{20}{4} = 5s$

$v = \frac{d}{t} = \frac{12}{5} = 2.4 ms^{-1}$

Q5

When the battery is completely discharged it then takes 6·0 hours of direct sunlight to fully charge the battery. During this time, there is a constant current of 0·135 A to the battery.

Calculate the total charge supplied to the battery during this time.

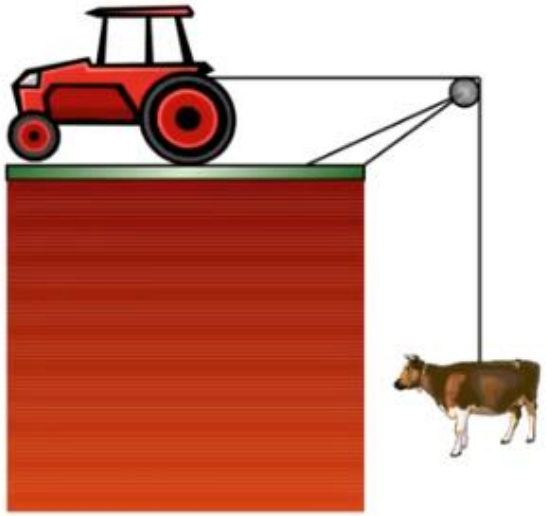
$$Q = It$$

$$Q = 0.135 \times 6 \times 60 \times 60$$

$$= \underline{\underline{2900\,C}}$$

Q6

A cow has fallen over a cliff and cannot get back up to the field. The farmer has to rescue it by attaching a rope and harness, and lifting it using a pulley and his tractor (as shown in the diagram).



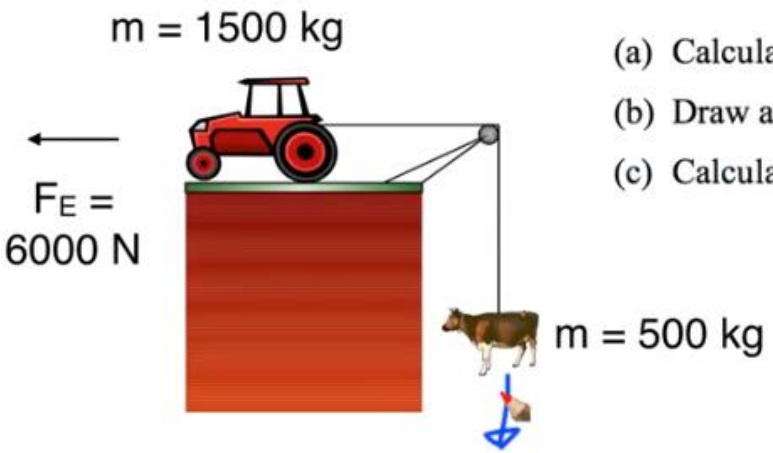
The tractor has a mass of 1500 kg, and the cow has a mass of 500 kg. The tractor's engine can apply a force of 6000 N. Ignore friction between the tractor and the ground.

(a) Calculate the initial acceleration of the tractor as it lifts the cow.

(b) Draw a free body diagram showing the forces acting on the cow as it is being lifted.

(c) Calculate the tension in the rope lifting the cow.

Q6 continued



(a) Calculate the initial acceleration of the tractor as it lifts the cow.

(b) Draw a free body diagram showing the forces acting on the cow as it is being lifted.

(c) Calculate the tension in the rope lifting the cow.

$m = 2000\,kg$

$F = ma$

$F = F_E - W$

$= 6000 - 4900$

$= 1100N$

$F = ma$

$1100 = 2000 \times a$

$a = \frac{1100}{2000}$

$= 0.55\,ms^{-2}$

$W = mg = 500 \times 9.8$

$= 4900N$

$F = ma$

$= 500 \times 0.55$

$= 275N$

$F = T - W$

$275 = T - 4900$

$T = 4900 + 275 = 5175N$

Q7

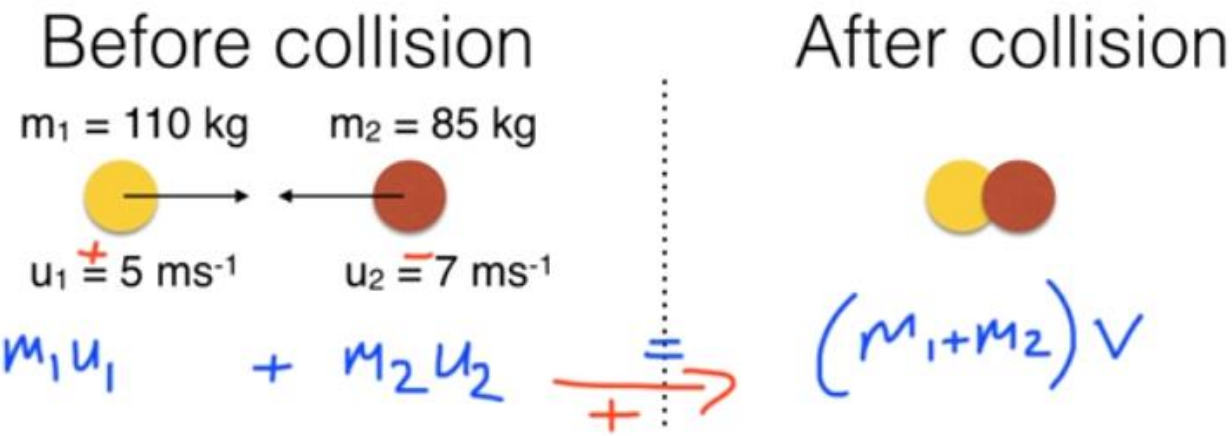
In a rugby match, a 110 kg forward in one team tackles an 85 kg back in the other team. The forward is travelling at 5 ms^{-1} and the back at 7 ms^{-1} in the opposite direction when they collide and 'stick' together.

Take the direction of the forward as the positive direction.

(a) Calculate the velocity of the pair immediately after the collision.

(b) Show by calculation whether this collision is elastic or inelastic.

Q7 continued



$m_1u_1 + m_2u_2 = (m_1+m_2)v$

(a) Calculate the velocity of the pair immediately after the collision.

(b) Show by calculation whether this collision is elastic or inelastic.

$E_{ky} + E_{kr}$

$\frac{1}{2}m_1u_1^2 + \frac{1}{2}m_2u_2^2$

$\frac{1}{2}\times 110\times 5^2 + \frac{1}{2}\times 85\times 7^2$

$= 1375 + 2082.5 = 3458\,J$

$E_k = \frac{1}{2}(m_1+m_2)v^2$

$= \frac{1}{2}(110+85)\,0.23^2$

$= 5.16\,J$

INELASTIC

Q8

Nuclear power workers routinely are checked for radiation exposure when handling mainly alpha decay isotopes. Safety limits are approached if they are exposed to more than 100 mSv a month. How much radiation energy a worker can safely absorb in a month.

- $absorbed\ dose = \frac{equivalent\ dose}{quality\ factor} = \frac{100 \times 10^{-3}}{20} = 5.00 \times 10^{-3}\ Gy$ (1)
- Workers mass as 75 kg
- $absorbed\ dose = \frac{E}{m} \quad \therefore E = absorbed\ dose * m$
- $E = 75 * 5.00 \times 10^{-3}$ (1)
- $E = 0.38\ J$

Q9

A 79.0 kg student rides a lift up to the top floor of an office block. During the journey, the lift accelerates upwards at $1.26\,m\,s^{-2}$ before travelling at a constant velocity of $3.78\,m\,s^{-1}$ and then finally decelerating at $1.89\,m\,s^{-2}$.

a Calculate the apparent weight of the student in the first part of the journey while accelerating upwards at $1.26\,m\,s^{-2}$.

$m = 79.0\,kg$

$a = +1.26\,m\,s^{-2}$

$g = -9.80\,m\,s^{-2}$

$$F_{net} = F_N + F_g$$
$$F_N = F_{net} - F_g$$
$$= ma - mg$$
$$= (79.0 \times 1.26) - (79.0 \times -9.80)$$
$$= 99.54 + 774.2$$
$$= 874\,N$$

b Calculate the apparent weight of the student in the second part of the journey while travelling at a constant speed of $3.78\,m\,s^{-1}$.

$m = 79.0\,kg$

$a = 0\,m\,s^{-2}$

$g = -9.80\,m\,s^{-2}$

$$F_{net} = F_N + F_{weight}$$
$$F_N = F_{net} - F_{weight}$$
$$= ma - mg$$
$$= (79.0 \times 0) - (79.0 \times -9.80)$$
$$= 0 + 774.2$$
$$= 774\,N$$

Q9 continued

c Calculate the apparent weight of the student in the last part of the journey while travelling upwards and decelerating at $1.89\,\mathrm{m\,s^{-2}}$.

$m = 79.0\,\mathrm{kg}$

$a = -1.89\,\mathrm{m\,s^{-2}}$

$g = -9.80\,\mathrm{m\,s^{-2}}$

$$F_{net} = F_N + F_{weight}$$

$$\begin{aligned} F_N &= F_{net} - F_{weight} \\ &= ma - mg \\ &= (79.0 \times -1.89) - (79.0 \times -9.80) \\ &= -149.3 + 774.2 \\ &= 625\,\mathrm{N} \end{aligned}$$

Q10

Calculate the apparent weight of a 50 kg person in an elevator under the following circumstances.

a accelerating upwards at $1.2\,\mathrm{m\,s^{-2}}$

b moving upwards at a constant speed of $5\,\mathrm{m\,s^{-1}}$

a $F_{net} = F_N + F_{weight}$

$F_N = F_{net} - F_{weight}$

$= ma - mg$

$= (50 \times 1.2) - (50 \times -9.80)$

$= 60 + 490$

$F_N = 550\,\mathrm{N}$

The person's apparent weight is 550 N.

b When the person is moving at a constant speed, their apparent weight is equal to their weight.

$F_N = F_{weight} = mg = 50 \times 9.80$

$= 490\,\mathrm{N}$

Q11

Calculate the apparent weight of a 45.0 kg child standing in a lift that is decelerating at 3.15 m s^{-2} while travelling upwards.

$$F_{net} = F_N + F_{weight}$$

$$\begin{aligned} F_N &= F_{net} - F_{weight} \\ &= ma - mg \\ &= (45.0 \times -3.15) - (45.0 \times -9.80) \\ &= -141.75 + 441 \\ &= 299\,\text{N} \end{aligned}$$

Q12

The wavelength of the fourth harmonic in a tube that can be considered as an open-ended air column is found to be 12 cm.

Calculate the length of the tube, assuming that the standing wave does not extend beyond the ends of the tube.

$\lambda = 0.12\,\text{m}$

$n = 4$

$$\lambda = \frac{2\ell}{n}$$

$$\ell = \frac{n\lambda_n}{2}$$

$$= \frac{4 \times 0.12}{2}$$

$$= 0.24\,\text{m}$$

b Determine the fundamental frequency.

$$\ell = \frac{\lambda_1}{2}$$

$$\lambda_1 = 2\ell$$

$$= 2 \times 0.24$$

$$= 0.48\,\text{m}$$

$$f_1 = \frac{340}{0.48}$$

$$= 708\,\text{Hz}$$

Q13

- Bree places a heating element and a paddle-wheel apparatus in an insulated container of water. She calculates that the heating element transfers 2530 J of heat energy to the water and the paddle does 240 J of work on the water. Calculate the change in internal energy of the water.

- Heat is added to the system, so Q is positive.
- Work is done on the system, so W is positive.

- $\Delta U = Q + W = (+2530) + (+240)$
- . $\Delta U = 2770$ J

Q14

- An astatine-219 nucleus is known to decay to a new element through the emission of a beta-minus particle. Determine the new element, write its symbol and write the decay equation.

$$^{219}_{85}\text{At} \rightarrow {}^{A}_{Z}X + {}^{0}_{-1}\beta + \bar{\nu}.$$

$$85 = Z - 1$$

$$Z = 86.$$

$$219 = A + 0$$

$$A = 219$$

$$^{219}_{86}\text{Rn}$$

$$^{219}_{85}\text{At} \rightarrow {}^{219}_{86}\text{Rn} + {}^{0}_{-1}\beta + \bar{\nu}$$

Q15

- A sample of the radioisotope sodium-24 contains 4.0 × 1010 nuclei. The half-life of sodium-24 is 15 hours. How many sodium-24 atoms will remain in the sample after 150 hours?

$$n = \frac{150}{15}$$
$$= 10 \text{ half-lives}$$

$$N = N_0\left(\frac{1}{2}\right)^n$$
$$= 4.0 \times 10^{10} \times \left(\frac{1}{2}\right)^{10}$$
$$= 3.9 \times 10^7 \text{ nuclei}$$

Q16

- A cancer tumour is exposed to 0.50 J of radiation energy. The absorbed dose is 3 Gy. Calculate the mass of the tumour. Assume that all of the radiation is absorbed by the tissue.

$$\text{AD} = \frac{E}{m}.$$

$$m = \frac{E}{\text{AD}}$$

$$m = \frac{3}{0.5}$$

mass of tissue = 6 kg

Q17

- a. Calculate the dose equivalent (in mSv) from various radioactive sources if the absorbed dose is 1.25 mGy.

- QF (alpha particles) = 20 QF (beta particles) = 1 QF (gamma rays) = 1

- The dose equivalent, DE = AD × QF. Convert the answer to mSv using 1 mSv = 1 × 10−3 Sv.

- DE (α) = 1.25 × 10−3 × 20 = 0.025 Sv = 25 mSv

- b Calculate the dose equivalent (in mSv) from a radiation source if the absorbed dose is 1.25 mGy and the source is emitting beta particles.

- DE = AD × QF
- Convert the answer to mSv.
- DE (β) = 1.25 × 10−3 × 1 = 1.25 × 10−3 = 1.25 mSv

Q17 continued

- c Calculate the dose equivalent (in mSv) from a radiation source if the absorbed dose is 1.25 mGy and the source is emitting gamma rays.

- Convert the answer to mSv.
- DE (γ) = 1.25 × 10−3 × 1 = 1.25 × 10−3 = 1.25 mSv

Q18

Plutonium-239 is a fissile material. When a plutonium-239 nucleus is struck by and absorbs a neutron, it can split in many different ways. Consider the example of a nucleus that splits into lanthanum-143 and rubidium-94 and releases some neutrons.

$$^{1}_{0}n + ^{239}_{94}Pu + ^{143}_{57}La + ^{94}_{37}Rb + a^{1}_{0}n + \text{energy}$$

How many neutrons are released during this fission process, i.e. what is the value of *a*?

$$1 + 239 = 143 + 94 + (a \times 1)$$
$$a = (1 + 239) - (143 + 94)$$
$$= 3$$

3 neutrons are released during this fission.

Q18 continued

b During this single fission reaction, there is a loss of mass (a mass defect) of 4.58×10^{-28} kg. Calculate the amount of energy that is released during fission of a single plutonium-239 nucleus. Give your answer in both MeV and joules to two significant figures.

$$\Delta E = \Delta mc^2$$
$$= (4.58 \times 10^{-28}) \times (3.00 \times 10^{8})^2$$
$$= 4.12 \times 10^{-11}\,\text{J}$$

To convert J into eV, divide by 1.6×10^{-19}.

Remember that 1 MeV = 10^6 eV.

$$\Delta E = \frac{4.12 \times 10^{-11}}{1.6 \times 10^{-19}}$$
$$= 2.58 \times 10^{8}\,\text{eV}$$
$$= 258\,\text{MeV}$$

Q18 continued

c The combined mass of the plutonium nucleus and bombarding neutron is 2.86×10^{-25} kg. What percentage of this initial mass is converted into the energy produced during the fission process?

percentage of initial mass converted into energy

$$= \frac{\text{mass defect}}{\text{initial mass}} \times \frac{100}{1}$$

$$= \frac{4.58 \times 10^{-28}}{2.86 \times 10^{-25}} \times \frac{100}{1}$$

$$= 0.16\%$$

Q19

- Calculate the average binding energy per nucleon for the uranium-235 nucleus in MeV and joules. Use the following data in your calculations: mass of a uranium-235 nucleus = 234.993 462 u, mass of a proton = 1.007 276 u and mass of a neutron = 1.008 664 u.

$$\begin{aligned}\text{total mass} &= \text{mass of 143 neutrons} + \text{mass of 92 protons}\\ &= 143 \times 1.008\,664 + 92 \times 1.007\,276\\ &= 236.908\,344\,\text{u}\end{aligned}$$

$$\begin{aligned}&= \text{mass of nucleons} - \text{actual mass of nucleus}\\ &= 236.908\,344 - 234.993\,462\\ &= 1.914\,882\,\text{u}\end{aligned}$$

$$\begin{aligned}&= \text{mass defect} \times 931\,\text{MeV}\\ &= 1.914\,882 \times 931\\ &= 1\,784\,\text{MeV}\end{aligned}$$

binding energy per nucleon in J.

$$\begin{aligned}&= 7.59 \times 10^{6} \times 1.60 \times 10^{-19}\,\text{J}\\ &= 1.21 \times 10^{-12}\,\text{J}\end{aligned}$$

Q20

- Calculate the number of electrons that flow past a particular point each second in a circuit that carries a current of 0.75 A.

$$I = \frac{q}{t}$$

$$\text{so } q = I \times t$$

$$q = 0.75 \times 1$$

$$= 0.75\,\text{C}$$

- Number of electrons = dividing the charge by the charge on an electron (1.6 × 10−19 C).

$$n_e = \frac{q}{q_e}$$

$$= \frac{0.75}{1.6 \times 10^{-19}}$$

$$= 4.69 \times 10^{18} \text{ electrons}$$

Q21

- An 85.0 g piece of metal is heated to a precise temperature of 195°C in an oven and then quickly transferred to an insulated cup containing 175 mL of water at an initial temperature of 14.5°C. Once thermal equilibrium is achieved, the temperature of the mixture in the cup reaches 23.0°C. Given that heat transfer only occurs between the piece of metal and the water in the cup, calculate the specific heat of the metal.
-
- **Heat lost by metal = Heat gained by water**
- **(m c DT)metal = (m c DT)water (✔)**
- **(0.085 kg) c (195 - 23 K) = (0.175 kg)(4180 $Jkg^{-1}K^{-1}$)(23 - 14.5 K) (✔)**
- **c = <u>425 $Jkg^{-1}K^{-1}$</u> (✔)**

Q22

- A 40 L hot water urn is used in the teacher's lunchroom at school to provide boiling water for cups of tea and coffee. The hot water urn is rated as having a maximum power, when turned up to its highest setting, of 2400 W.
- (a) What current does the hot water urn draw, when operating at its highest setting? (2 marks)

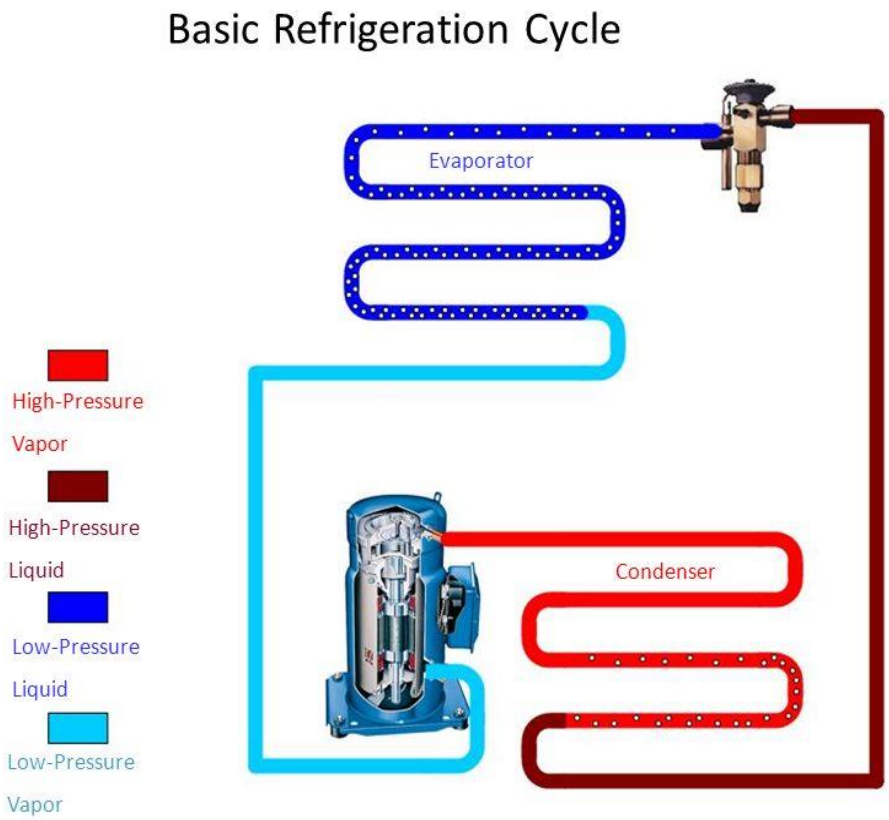
- P = V I ⇒ I = P/V (✔)
- = 2400W/240V
- = 10 A (✔)
- (b) What is the resistance of the hot water urn when operating at its highest setting? (2 marks)
-
- **R = V/I = 240V/10A = <u>24 W</u> (✔)**
- **(✔)**

Q22 continued

- (c) Given that electricity costs 25 cents per kilowatt-hour, find the cost of using the hot water urn, at its highest setting, for the six hours of a typical school day. (2 marks)
-
- **Cost = P (in kW) x t (in h) x unit cost (✔)**
- **= 2.4 kW x 6 h x 25 ¢/kW-h = <u>$3.60</u> (✔)**

Q23

- Both evaporative and refrigerative air-conditioners use the latent heat of vaporisation of a liquid in order to cool down the air that is blown through them.
- The diagram below shows the basic cycle of the refrigerant fluid in a refrigerative air-conditioner.



Q23 continued

- (a) Briefly describe what is happening, and why, in each of the following parts of the refrigerative air-conditioner.

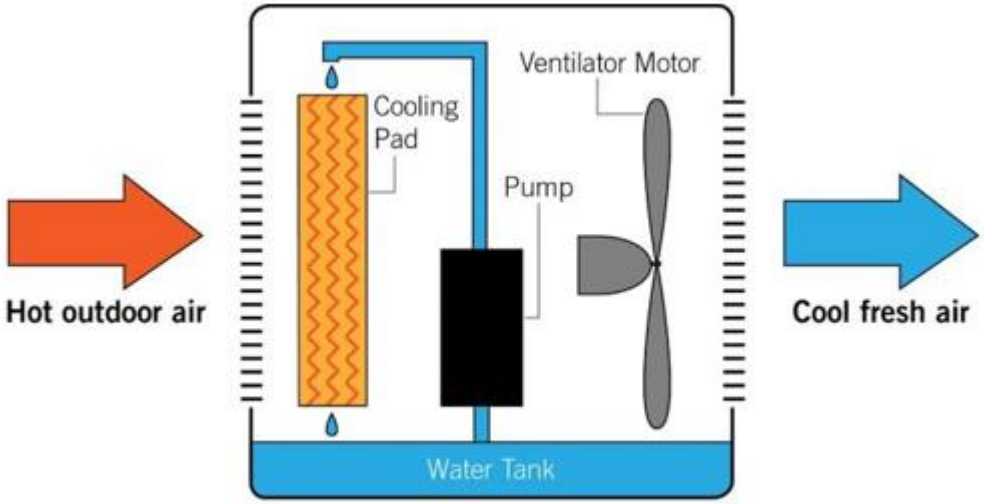
(4 marks)

- Condenser:
- **In the condenser, the refrigerant fluid has been compressed and makes the phase change from gas to liquid (✔)**
- **This phase change is exothermic and heat is released to the surroundings, typically the outside of the house (✔)**

- Evaporator:
- **In the evaporator, the refrigerant fluid has been allowed to expand and makes the phase change from liquid to gas (✔)**
- **This phase change is endothermic and heat is absorbed from the surroundings, typically the inside of the house (✔)**

Q23 continued

- (b) Draw a simple sketch of an evaporative air-conditioner and briefly explain how it cools down the air blown through it. (3 marks)



- **Hot air from outside is drawn through a moist cooling pad by a fan and causes water to evaporate from the cooling pad. (✔)**
- **Since evaporation is an endothermic process, this absorbs heat from the air, cooling it before it is blown into the room (✔)**

Q23

- (c) State one advantage and one disadvantage of refrigerative air-conditioners over evaporative air-conditioners.

  (2 marks)

-
- **Advantages of refrigerative air-con over evaporative air-con (✔)**
- **can produce larger temperature drops**
- **reduces the humidity of the air being cooled**
- **still works well in humid conditions**
- **Disadvantages of refrigerative air-con over evaporative air-con (✔)**
- **more expensive to operate (uses more electricity)**
- **can dry out air too much**

Q23 continued

- (d) When used in reverse cycle mode a refrigerative air-conditioner provides 200 J of thermal energy to a room for an electrical energy consumption of only 100 J, giving it an apparent efficiency of 200%. Does this violate the Law of Conservation of Energy? Briefly explain your answer.

  (2 marks)

-

- **No, it does not violate energy conservation (✔)**
- **The 100 J of electrical energy is consumed driving the heat pump, which moves 200 J of thermal energy from the air outside to the air inside the room (✔)**

Q24

- A metal saucepan has 2.50 L of water added to it from the hot tap in a kitchen, at a temperature of 45°C. The saucepan is then placed on a gas cook-top with the flame turned to HIGH, and the water is brought to the boil, taking 3.5 minutes to reach boiling point.
- (a) Find the quantity of heat needed to bring the water in the saucepan to the boil. (2 marks)

- $Q = m c \Delta T = (2.50 \text{ kg})(4180 \text{ Jkg}^{-1}\text{K}^{-1})(100 - 45 \text{ K}) = 575 \text{ kJ}$
- (✔) (✔)

- (b) Estimate the power of the gas flame when turned to HIGH. (2 marks)

- $P = Q/t = 575000\text{J}/210\text{s} = 2700 \text{ W}$
- (✔) (✔)

Q24 continued

- (c) Give two reasons why the actual power of the gas flame is likely to be larger than the value you estimated above.

  (2 marks)

- Some of the heat from the gas flame is absorbed by the metal of the saucepan as the water heats up (✔)
- Some of the heat from the gas flame escapes into the surroundings as the water heats up (✔)

- (d) In terms of the kinetic theory, describe what is happening to the water molecules as the water in the saucepan increases in temperature.

  (2 marks)

- As the water increases in temperature, the water molecules move around faster on average (✔) , and their average kinetic energy increases (✔)

Q24 continued

- (e) Use your estimate of the power of the gas flame (when turned to HIGH) to calculate the rate of decrease in mass of the water in the saucepan after the water reaches boiling point. Express your answer in g/s.

  (3 marks)

-
- **The gas flame provides 2700 J of heat per second to boil the water (✔)**
- **Q = m Lv → m = Q/Lv = (2700J/s)/(2.26 x 10^6J/kg) (✔)**
- **= 0.0012 kg/s = <u>1.2 g/s</u> (✔)**

Q24 continued

- (f) In terms of the kinetic theory, describe what is happening to the water molecules after the water reaches boiling point.
(2 marks)
-
- **After the water reaches boiling point, the water molecules absorb heat by increasing their potential energy (✔), separating from one another and moving much further apart in the gaseous phase (✔)**

Q25

- a) Kimberly measures the sound intensity at a distance of 5.0 m from a lawn-mower to be 3.0 × 10 − 2 W m − 2. Assuming that the lawn-mower acts as a point sound source and ignoring the effects of reflection and absorption, what is the total power of the sound emitted by the mower?

- P = 4πr2I
- = 4 π(5.0 m)2 × 3.0 × 10−2 W m−2
- = 9.4 W

- b) Explain the idea of the inverse square law in relation to waves.

- Formula for the sound intensity produced by a source $I = \frac{P}{4\pi r^2}$
- Sound intensity it produces is inversely proportional to the square of the distance from the source. $I \propto \frac{1}{r^2}$

- In other words the intensity of sound is inversely proportional to the square of the distance from the source.

Q25 continued

- c) How can this be used in comparing sound at different distances?
- When comparing the sound intensities at two distances r1 and r2 from a source, it should be remembered that the power of the source is a constant. Therefore, this relationship then gives the following useful formula:

$$\frac{I_2}{I_1} = \frac{r_1^2}{r_2^2}$$

- If the sound intensity 3.0 m from a sound source is 4.0×10^6 W m^2, what is the intensity at (a) 1.5 m and (b) 12 m from the source?

(a)

$r_1 = 3.0$ m

$I_1 = 4.0 \times 10^{-6}$ W m^{-2}

$r_2 = 1.5$ m

$I_2 = ?$

$$\frac{I_2}{I_1} = \frac{r_1^2}{r_2^2}$$

$$\Rightarrow \quad I_2 = \frac{I_1 r_1^2}{r_2^2}$$

$$= \frac{4.0 \times 10^{-6}\ \text{W m}^{-2} \times (3.0\ \text{m})^2}{(1.5\ \text{m})^2}$$

$$= 1.6 \times 10^{-5}\ \text{W m}^{-2}$$

(b)

$r_1 = 3.0$ m

$I_1 = 4.0 \times 10^{-6}$ W m^{-2}

$r_2 = 12$ m

$I_2 = ?$

$$\frac{I_2}{I_1} = \frac{r_1^2}{r_2^2}$$

$$\Rightarrow \quad I_2 = \frac{I_1 r_1^2}{r_2^2}$$

$$= \frac{4.0 \times 10^{-6}\ \text{W m}^{-2} \times (3.0\ \text{m})^2}{(12\ \text{m})^2}$$

$$= 2.5 \times 10^{-7}\ \text{W m}^{-2}$$