Section A

Answer **all** questions in this section.

For Examiner's Use

1 A solid block is placed in water and in diesel in turn. In each liquid, the block remains stationary when it is partially submerged.
The block is 75% and 86% submerged in water and in diesel respectively.
The density of water is 1000 kg m^{-3}.

(a) Draw a free-body diagram of the block when it remains stationary while partially submerged in a liquid. Label the forces acting on the block clearly. [1]

It has been verified that when an object is partially or totally submerged in a liquid, the upthrust experienced by the object is equal to the weight of the liquid that is displaced by the object:

Upthrust = Weight of liquid displaced

(b) Since the solid block mentioned above remains stationary when it is partially submerged in (either of the two) liquids,

(i) comment on the relationship between the weight of the block and the weight of (either of the two) liquids displaced by the block,

…….

…….

……. [1]

(ii) comment on the relationship between the weight of the water displaced by the block and the weight of the diesel displaced by the block.

…….

…….

……. [1]

(c) Hence, find the density of diesel.

For Examiner's Use

density of diesel = …… [3]

[Total: 6]

2 **Figure 2** shows a cargo ship experiencing a big horizontal force T due to an oncoming tsunami (not drawn to scale).

The force on the ship by the tsunami T, is 45 kN and acts 10 m above sea level.
The weight of the ship W, is 400 kN and acts from point C.
The upthrust on the ship by sea water is U, 400 kN and acts from point D.

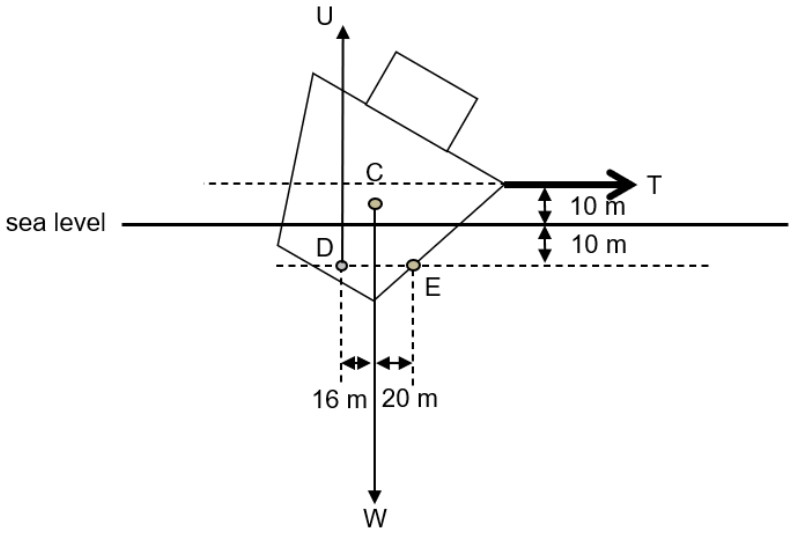


Figure 2

(a) At the time shown in **Figure 2**, the ship is over-turning about pivot point E.

(i) Suggest the direction of the over-turning moment at this time.

direction of over-turning moment is …… [1]

(ii) Calculate the magnitude of the resultant over-turning moment.

over-turning moment = …… [2]

(b) Without changing the physical attributes of the cargo ship, describe one way to make the ship more stable and reduce the probability of it over-turning.

……...

……... [1]

[Total: 4]

3 **Figure 3** shows a section of a swimming pool with its drainage hole being plugged. The steel plug is 1.9 kg and it covers the circular drainage hole of 0.02 m^2. The density of water in the pool is 1000 kg m^{-3}.

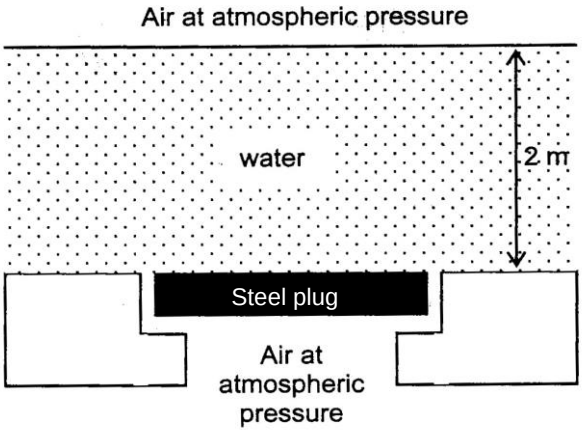


Figure 3

(a) Calculate the force exerted by the water on the steel plug.

force by water on plug = ……. [3]

(b) Hence, calculate the force exerted by the two side slabs on the steel plug. State the direction of this force.

force by slabs on plug = …….

direction of force = ……. [3]

[Total: 6]

For Examiner's Use

4 **Figure 4** shows a water heater.

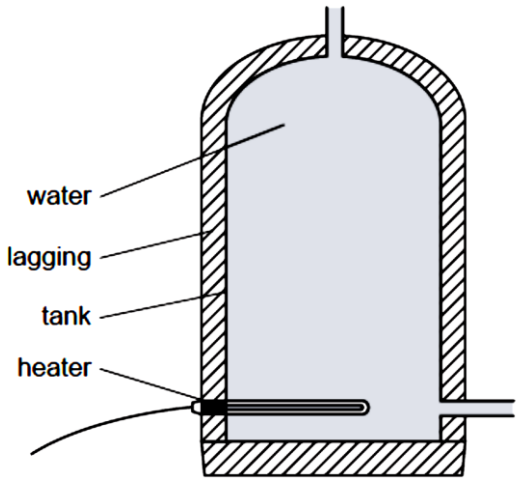


Figure 4

(a) Describe the process by which thermal energy is transferred throughout the water.

……

……

……

…… [2]

(b) Suggest a material to use as lagging and explain your choice.

……

……

…… [2]

(c) Suggest what the exterior colour and texture of the water heater should be and explain your choices.

……

……

…… [2]

[Total: 6]

For Examiner's Use

5 A thermocouple is used to measure the temperature of a thermistor.

Its cold junction is placed in a beaker of anti-freeze liquid at 0°C while its hot junction is placed in contact with the thermistor.

When the temperature of the thermistor is 30°C, the e.m.f. measured by the thermocouple is 0.5 mV.

(a) Calculate the e.m.f. measured by the thermocouple when the temperature of the thermistor is 66°C.

e.m.f. measured = ……. [2]

(b) Describe how the temperature of the thermistor T changes with the potential difference across it V, when the thermistor is connected in series with a fixed resistor in an electric circuit.

……

……. [1]

[Total: 3]

6 **Figure 6a** shows water waves in a pool of different depths. The frequency of the water waves in the pool is 50 Hz.

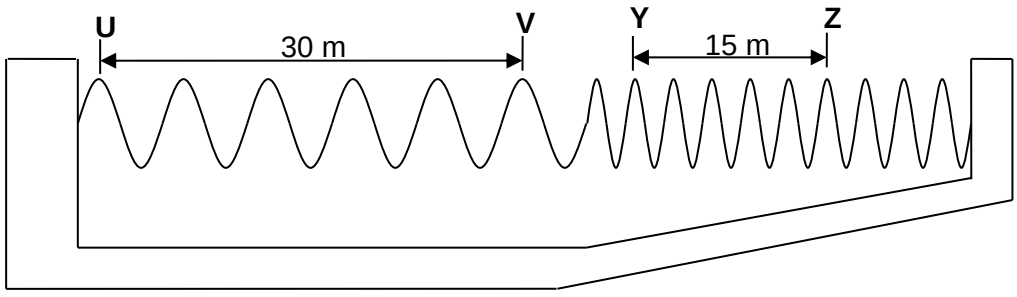


Figure 6a

(a) State what is meant by *frequency of 50 Hz*.

……

……. [1]

For Examiner's Use

(b) Calculate the speed of the water waves in region UV.

speed = ……. [2]

(c) Describe how the depth of water affects the speed of the water waves in the pool.

……..……

……..…… [1]

(d) Part of **Figure 6a** has not been drawn correctly.

Complete **Figure 6b** to show how the diagram can be drawn more correctly. [1]

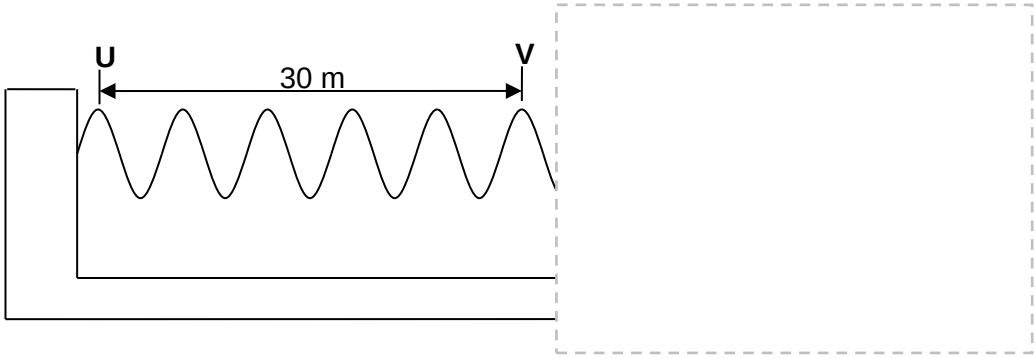


Figure 6b

[Total: 5]

7 **Figure 7** shows a ray of light being projected from air into a glass prism.

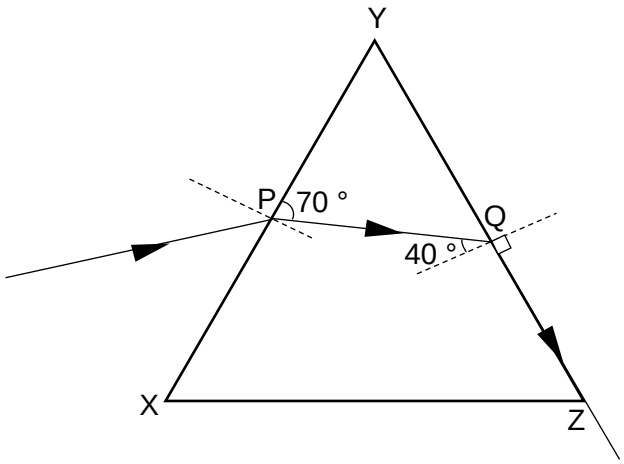


Figure 7

The ray hits external surface XY at point P.
It then hits the internal surface YZ at point Q and exits along the surface of YZ.

For Examiner's Use

(a) Calculate the refractive index of the glass.

refractive index = ... [2]

(b) Calculate the angle of incidence of the ray at point P.

angle of incidence = ... [2]

[Total: 4]

8 **Figure 8a** shows a cling wrap (made of insulator plastic) being peeled off itself from a roll.
The peeling action creates static charges on the two sides that were originally sticking together.

Figure 8b shows the peeled cling wrap being used to wrap around a cabbage to maintain its freshness.

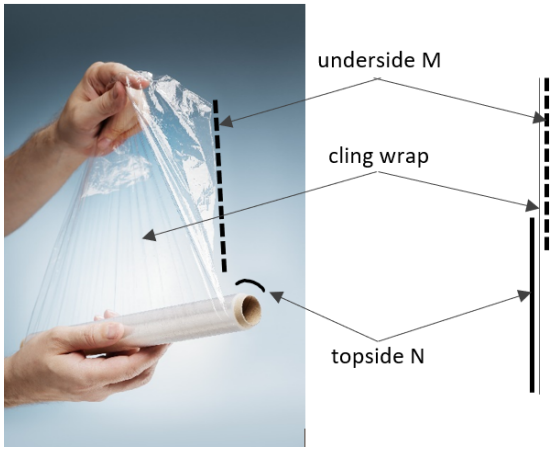


Figure 8a

Figure 8b

(a) **(i)** Suggest the types of charge on underside M and topside N of the cling wrap. Describe how the sides become charged as you suggested.

.....

.....

..... [2]

(ii) Hence explain why the cling wrap can stick onto itself to form a seal to maintain the freshness of the cabbage.

……

…… [1]

(b) **Figure 8c** shows a neutral ceramic bowl.

Figure 8c

On **Figure 8c,** sketch a cling wrap stretching just over the rim of the bowl.
Explain why the cling wrap can stick onto the ceramic bowl to form a seal.

……..

……..

[2]

(c) A child play-pretends and drums on the cling wrap.
Suggest one way to decrease the pitch of the sound of the "drum".

……... [1]

[Total: 6]

9 **Figure 9a** shows a conducting ***rod*** of length *L* and diameter *D*. When a potential difference of *V* is applied across it, the current that flows through the ***rod*** is 6 A.

Figure 9b shows a conducting ***pipe*** of the same material, length *2L*, outer diameter *2D* and inner diameter *D*. The same potential difference of *V* is applied across it.

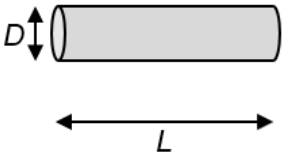


Figure 9a

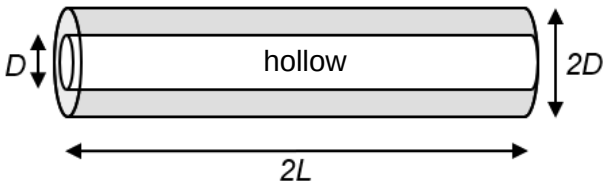


Figure 9b

(a) Find the ratio of the cross-sectional area of the ***rod*** to the cross-sectional area of the ***pipe***.

For Examiner's Use

ratio ……..…… [3]

(b) Hence, find the current that flows through the ***pipe***.

current in ***pipe*** = ……..… [2]

[Total: 5]

10 **Figure 10** shows a simplified circuit diagram of an industrial ventilation fan.
The mains supply is 240 V and the fan is rated '3 kW, 240 V'.

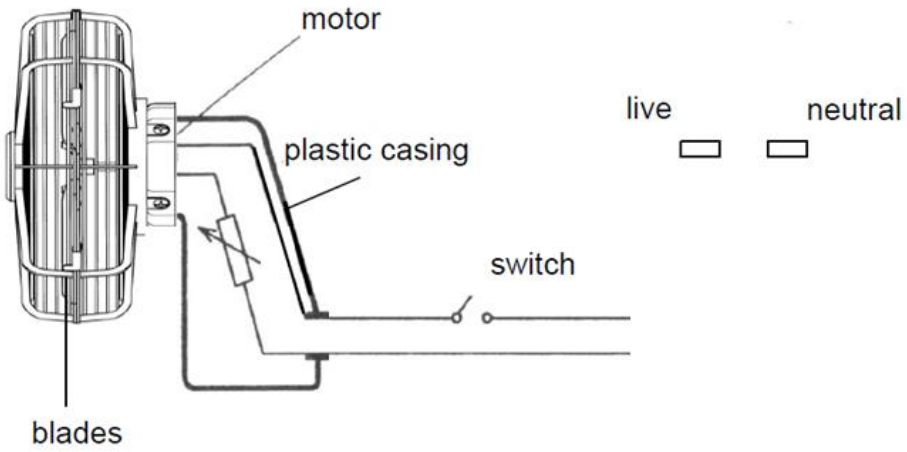


Figure 10

(a) Suggest a reason why an earth wire is **not** needed in this circuit.

……..……

……... [1]

For Examiner's Use

(b) On **Figure 10**,

(i) connect the two wires from the motor to the two labelled pin-holes of the wall socket and [1]

(ii) draw in the circuit symbol of a fuse to show its correct position. [1]

(c) Given that electricity costs $0.30 per kWh, calculate the weekly cost of using the fan if it is switched on 6 hours for a day.

cost = ……..……. [2]

[Total: 5]

Section B

Answer **all** questions from this section.
Answer only one of the two alternative questions in **Question 13**.

For Examiner's Use

11 *"A photovoltaic (PV) cell, commonly called a solar cell, is a **nonmechanical device that converts sunlight directly into electricity**[1]. Sunlight is composed of photons, or particles of light energy.*

*A PV cell is made of semiconductor material. When photons strike a PV cell, they may reflect off the cell, pass through the cell, or be absorbed by the semiconductor material. Only the absorbed photons provide energy to generate electricity. When the semiconductor material absorbs enough sunlight, electrons are dislodged from the material's atoms. Special treatment of the material surface during manufacturing makes the front surface of the cell more receptive to the dislodged, or free, electrons so that the **electrons naturally migrate to the front surface of the cell**[2]."*

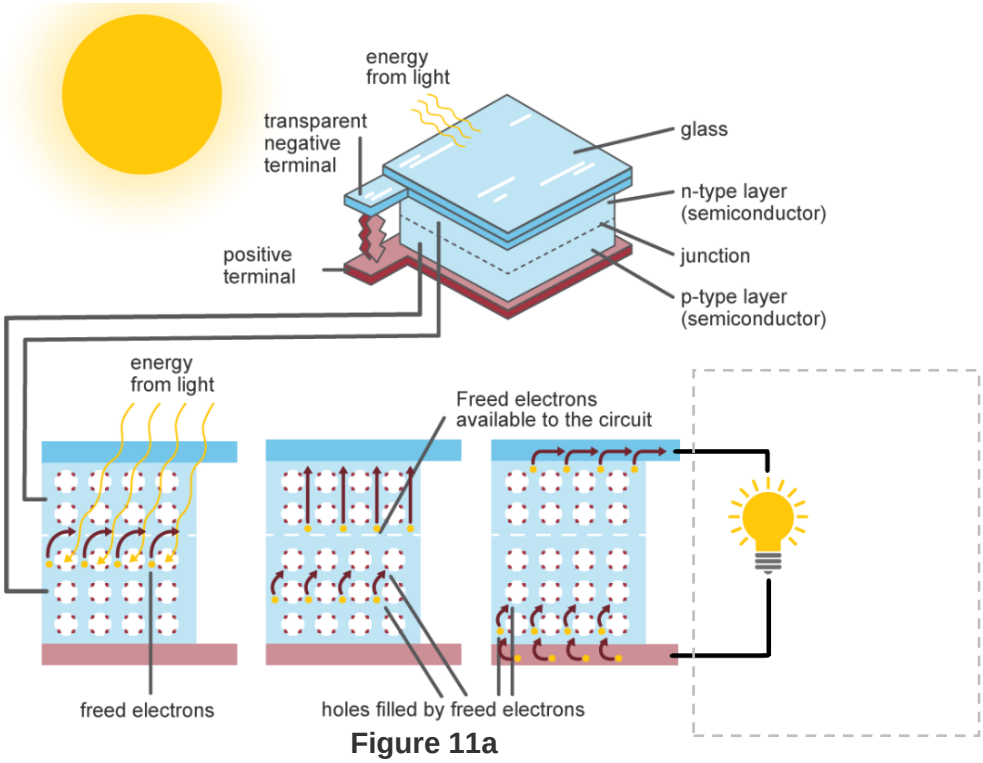


Figure 11a

Adapted from: https://www.eia.gov/energyexplained/solar/photovoltaics-and-electricity.php

(a) A PV cell is a ***nonmechanical device that converts sunlight directly into electricity***[1].

Name the mechanical device used in conventional power stations and describe the energy conversion that takes place as the device produces electricity.

.....

.....

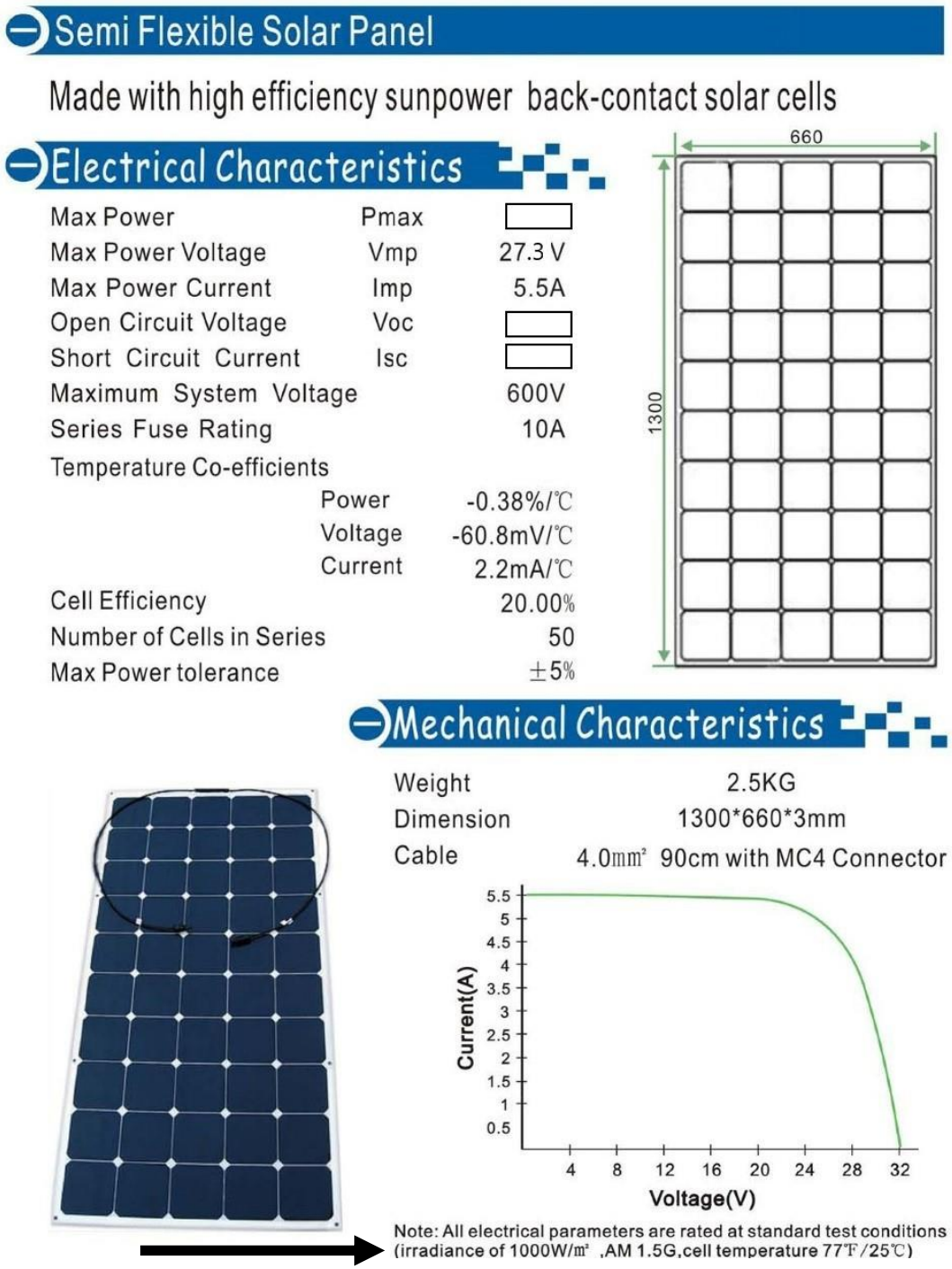
..... [2]

(b) In a PV cell, ***electrons naturally migrate to the front surface of the cell***[2].

For Examiner's Use

A lamp has been connected across a PV cell and it lights up.
In the boxed-up space in **Figure 11a**, draw a meter to measure the potential difference across the lamp and indicate the terminals of the meter. [2]

Figure 11b shows the specifications of a solar panel from one manufacturer.



Adapted from: https://www.alibaba.com/product-detail/thin-film-solar-panel-flexible-24v_60273576613.html

Figure 11b

For Examiner's Use

(c) Using data from its electrical characteristics, calculate the maximum power P_{max} that the solar panel can produce.

maximum power P_{max} = …… [2]

(d) Using data from its current-voltage graph, determine the solar panel's

(i) open circuit voltage V_{oc} and

open circuit voltage V_{oc} = …… [1]

(ii) short circuit current I_{sc}.

short circuit current I_{sc} = …… [1]

(e) The master solar panel is tested under artificial light before the manufacturer mass-produces thousands of copies of solar panels.

"All electrical parameters are rated at standard test conditions" which includes an ***"irradiance of 1000 W/m^2"***.

Suggest what is meant by *irradiance of 1000 W/m^2.*

……

……

…… [2]

[Total: 10]

12 A car travels along Tanah Merah Coast road, where a new type of speed camera called the Average Speed Camera (ASC) is used. The speed limit is 70 km h^{-1}.

There are two ASCs along the road. **ASC 1** records the time of entry and **ASC 2** records the time of exit of the car along the road.
Their system then computes the average speed of the car to determine if the car was speeding during the journey.

Figure 12a shows the speed-time graph of the car. The graph starts when the car passes by **ASC 1** and the graph stops when the car passes by **ASC 2**.

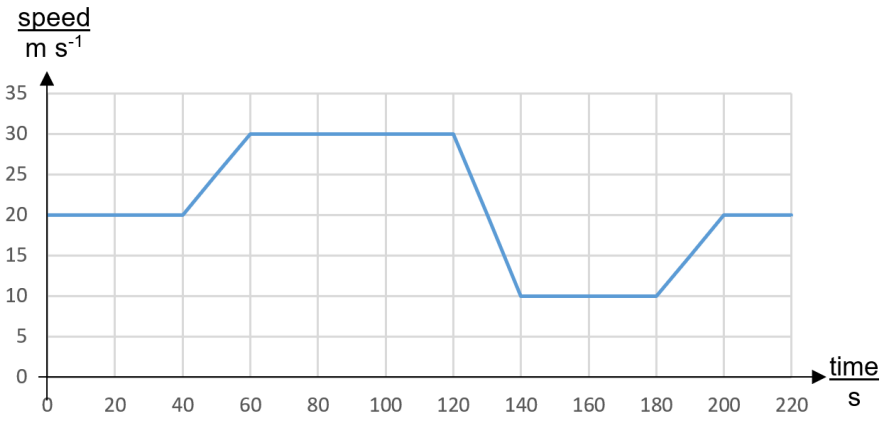


Figure 12a

(a) Express 70 km h^{-1} in m s^{-1}.

70 km h^{-1} = ... m s^{-1} [1]

(b) Calculate the distance between the two cameras.

distance = ... [2]

(c) Calculate the average speed of the car and state if the car was speeding during the journey.

average speed = ...

.....

..... [3]

(d) The car reaches its destination and is doing a stunt.
It needs to drive off a ramp and fly over a few stationary cars.

Figure 12b

The car has a mass of 1200 kg and the gravitational field strength is 10 N kg^{-1}.

The car's engine has a power of 40 000 W so that the car takes only 2 s to accelerate off a 15 m long ramp.
When the car is in air, its engine switches off and it flies over a few cars.
After the car lands on the second smooth ramp with a speed of 15 m s^{-1}, it cruises down without additional input from its engine.

(i) Calculate the driving force exerted by engine on the car as it accelerates up the 15 m long ramp.

driving force = …… [2]

(ii) Calculate the speed of the car when it reaches the end of the second ramp.

speed of the car = …… [2]

[Total: 10]

13 EITHER

For Examiner's Use

In an experiment, a coil of wire of resistance 28.0 Ω, is submerged in a beaker of water. When current is passed through the wire, the water heats up.

Student P uses a current of 2.5 A while student Q uses a current of 2.0 A. They plot the increase in temperature of the water, θ against time taken, t. Both of their graphs are shown in **Figure 13a**.

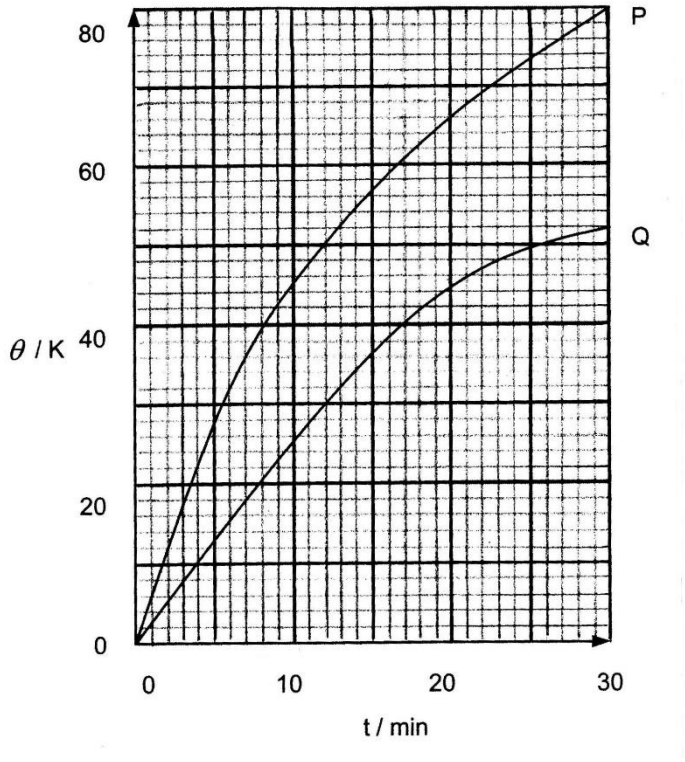


Figure 13a

(a) (i) Calculate the power input in each of the two experiments.

power input in P = …… [1]

power input in Q = ……..…… [1]

(ii) Hence, state and explain the difference between graph P and graph Q.

……..……

……..……

……..……

……..…… [2]

(b) State and explain the relationship between the increase in temperature of the water, θ and time taken, t.

……

……

……

……

…… [3]

(c) **(i)** Using the principle of Conservation of Energy, derive a formula to calculate power *P*, in terms of the following:

mass of water *m*,
specific heat capacity of water *c*,
increase in temperature of the water θ and
time taken t.

Assume no loss of energy to the surroundings.

formula: …… [1]

(ii) Hence, find the mass of water *m*, used by student P if the gradient of graph P at t = 0 min is 12 K min^{-1}.
Specific heat capacity of water is 4.2 J g^{-1} K^{-1}.

mass of water = …… [2]

[Total: 10]

13 OR

For Examiner's Use

A student was given three transformers labelled **X**, **Y** and **Z**. The primary coil of each transformer had 250 turns of copper wire.

The student wanted to investigate the relationship between the primary voltage V_1 and secondary voltage V_2 of each transformer.
He applied several input voltages V_1 to the primary coil, measured the output voltages V_2 from the secondary coil and represented the data he collected in **Figure 13b**.

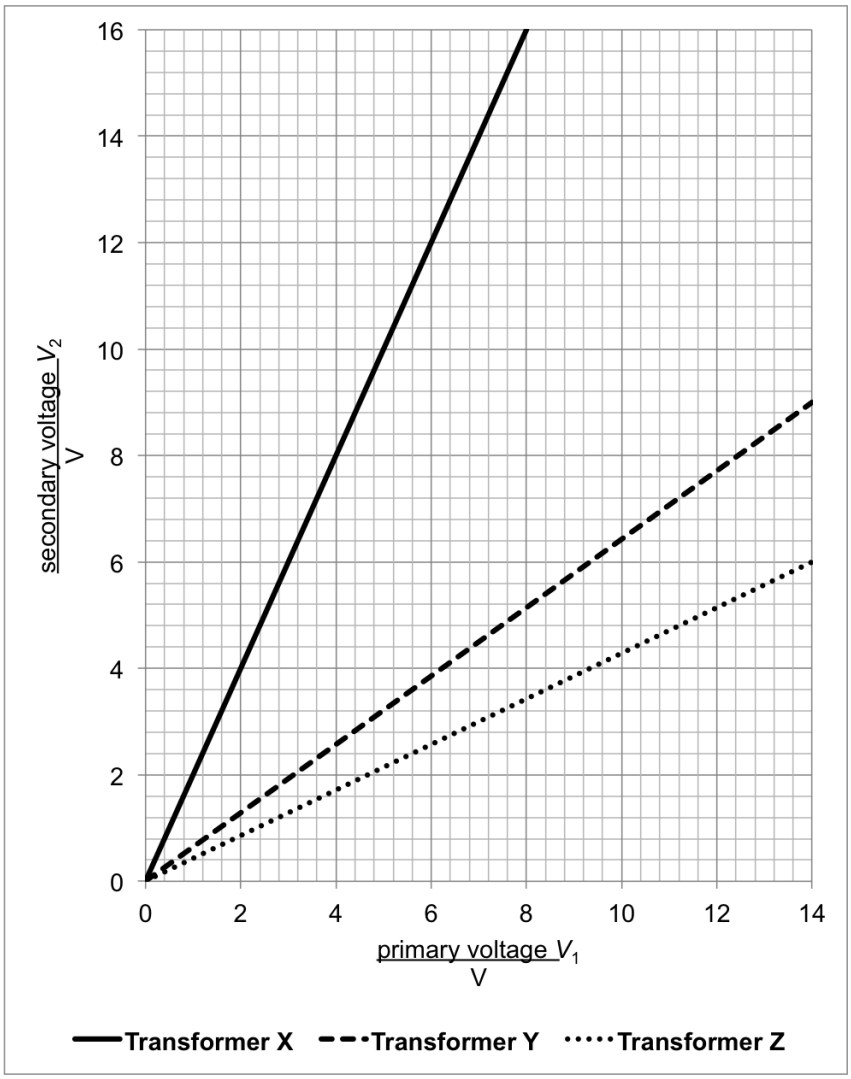


Figure 13b

(a) State which of the three transformers were

(i) step-up transformer(s) and

……

(ii) step-down transformer(s).

…… [2]

(b) Find the number of turns of copper wire in the secondary coil of transformer **X**.

For Examiner's Use

number of turns = ……. [2]

(c) Suggest two reasons why the transformers were not 100% efficient (ideal) in reality.

Reason 1 ……..……..……....

……..........

Reason 2 ..……..……....

……..……..... [2]

(d) The student tried to increase the efficiency of the transformers. However, upon modifications, the transformers malfunctioned. For each of the modifications listed below, explain why it caused the transformers to malfunction.

(i) Modification 1: Using a d.c. voltage for input at the primary coil.

……

……

……

…… [2]

(ii) Modification 2: Using a copper core instead of an iron core.

……

……

……

…… [2]

[Total: 10]

**********End of Paper**********