12 ATAR Physics
Section B Questions 2017

SECTION B: Problem Solving

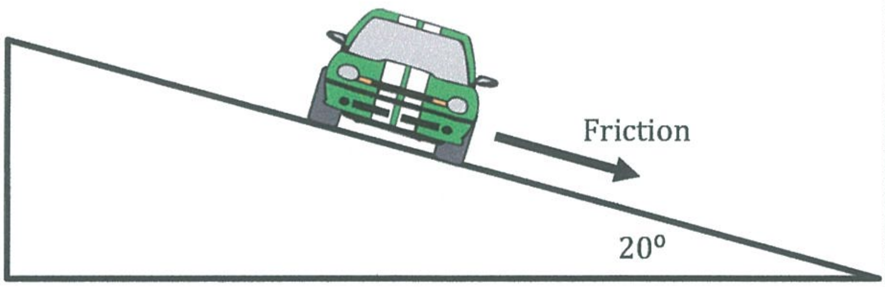
Marks Allotted: 92 marks out of total of 180 marks (52%)

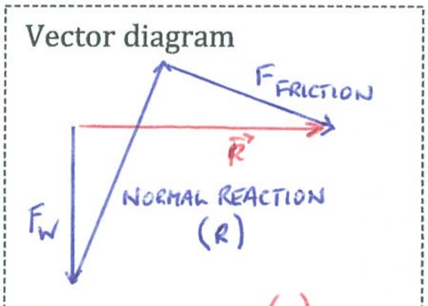
This section contains 7 questions. You should answer **ALL** of the questions.
Answer all questions in the spaces provided.

---

15. [7 marks]

A car of mass 2.20×10^3 kg is in horizontal circular motion on a banked track. The car has a speed of 14.0 ms^{-1} and is relying on friction to stay at a fixed height on the banked track. The radius of the circle is 32.0 m. The track is banked at an angle of 20.0° to the horizontal. Friction acts from the track onto the car parallel to the track as shown.



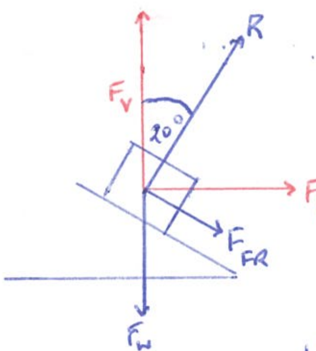


Head-to-tail (1)

Friction parallel to slope (1)

(a) Construct a vector diagram to the right of the diagram above. Show the forces acting on the car and the nett force. (2 marks)

(b) Calculate the magnitude of friction acting on the car from the banked track. (5 marks)



$\Sigma F_v = 0$

$\Rightarrow R\cos 20.0° = F_w + F_{FR}\cos 70.0°$ (1)

$\Rightarrow R = \dfrac{(2.20\times10^3)(9.80) + F_{FR}\cos 70.0°}{\cos 20.0°}$

$\Rightarrow R = 2.294\times10^4 + 0.364\,F_{FR}$ — ① (1)

HORIZONTALLY: $F_h = F_c$

$\Rightarrow R\cos 70.0° + F_{FR}\cos 20.0° = \dfrac{mv^2}{r}$ (1)

Sub ① for R

$\therefore (2.294\times10^4 + 0.364\,F_{FR})(\cos 70.0°) + F_{FR}\cos 20.0° = \dfrac{(2.20\times10^3)(14.0)^2}{(32.0)}$

$\Rightarrow 7.846\times10^3 + 0.1245\,F_{FR} + 0.9397\,F_{FR} = 1.348\times10^4$ (1)

$\Rightarrow \underline{F_{FR} = 5.29\times10^3\ N}$ (1)

[There are alternative methods - be generous.]

16. [15 marks]

Our Sun is a medium sized star that is part of a spiral galaxy called the Milky Way. Like all spiral galaxies, the stars in the Milky Way rotate around a galactic centre.

Our Sun's orbit is virtually circular with a radius of 2.50 x 10^{20} m (about 26 000 light years); its average orbital speed is about 2.20 x 10^{5} ms^{-1}.

(a) Calculate the orbital period of the Sun around the galactic centre of the Milky Way (in years). (4 marks)

$$v = \frac{2\pi r}{T} \quad (1)$$

$$\Rightarrow T = \frac{2\pi(2.50\times10^{20})}{2.20\times10^{5}} \quad (1)$$

$$= 7.14\times10^{15}\ s \quad (1)$$

$$= \underline{2.26\times10^{8}\ years} \quad (1)\ (\text{using } 1\text{ year} = 365.25\text{ days})$$

(b) Calculate the gravitational field strength due to the Milky Way galaxy at the Sun's distance from the galactic centre. (3 marks)

$$g = a_c = \frac{v^2}{r} \quad (1)$$

$$= \frac{(2.20\times10^{5})^2}{2.50\times10^{20}} \quad (1)$$

$$= \underline{1.94\times10^{-10}\ Nkg^{-1}}\ (ms^{-2}) \quad (1)$$

(c) The circular orbit of the Sun around the galactic centre of the Milky Way is due to the gravitational force of attraction between the Sun's and Milky Way's centres of mass.

Use the data provided and answers calculated thus far to show that the mass of our galaxy inside our Sun's orbit must be about 1.80 x 10^{41} kg.

[If you could not calculate an answer to part (a), use 7.00 x 10^{15} s; if you could not calculate an answer to part (b), use 1.90 x 10^{-10} Nkg^{-1}]

(3 marks)

$$g = \frac{GM}{r^2}$$

$$\Rightarrow M = \frac{gr^2}{G} \quad (1)$$

$$= \frac{(1.94\times10^{-10})(2.50\times10^{20})^2}{(6.67\times10^{-11})} \quad (1)$$

$$= \underline{1.81\times10^{41}\ kg} \quad (1)$$

[Alternate answer = 1.78×10^{41} kg]

(d) If the mass of our Sun can be considered to be an average mass for the stars in our galaxy, estimate how many stars there must be inside our Sun's orbit in the Milky Way. Show your working. (2 marks)

$$\text{Number of stars} = \frac{1.81 \times 10^{41}}{1.99 \times 10^{30}} \quad (1)$$

$$= \underline{9.09 \times 10^{10}} \quad (1)$$

(e) The mass of the Milky Way inside our Sun's orbit is about 1.80 x 10^{41} kg, which is about 10^{11} times the mass of our Sun. However, when scientists estimate the mass of the ***visible matter*** inside the Sun's orbit, it only comes to about 10^{10} times the mass of our Sun.

(i) What does this imply about the types of matter in our Galaxy? (2 marks)

- A significant amount of matter is not visible. (1)
- This invisible matter still exerts a gravitational force on other matter. (1)

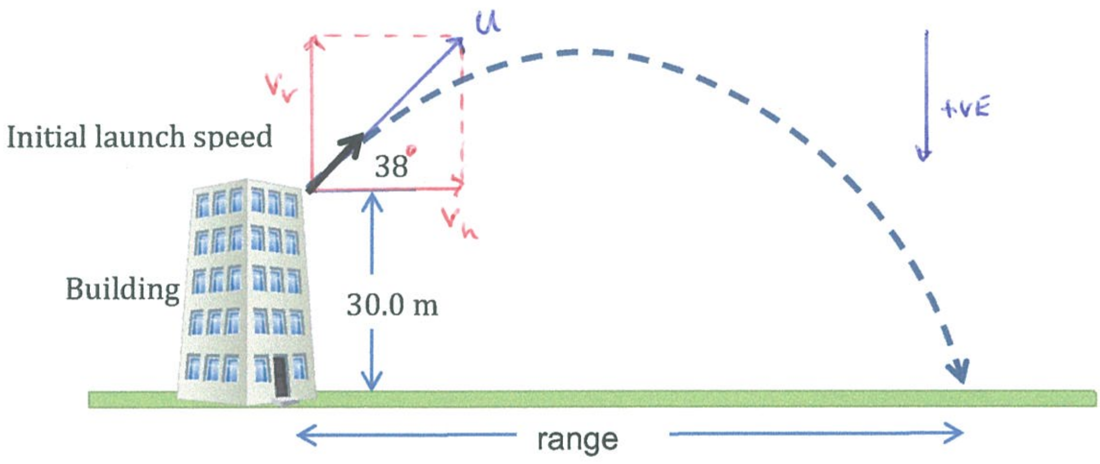
(ii) If the mass of our galaxy was only 10^{10} times the mass of our Sun, describe one (1) effect this would have on our Sun's motion. (1 mark)

- A decrease in orbital velocity.
- An increase in orbital period.

} Either OK - 1 mark.

17. [13 marks]

A stone of mass 52.0 g is thrown from a building of height 30.0 m. The stone is launched with an angle of elevation of 38.0º above the horizontal. It takes a time of 3.15 s for the stone to reach ground level. You can ignore air resistance for this question.



(a) Calculate the initial launch speed ***u*** of the stone. (4 marks)

VERTICALLY

+VE

$v = ?$ Correct sign convention (1)

$u = -u\cos 52.0^\circ \text{ ms}^{-1}$ (1)

$a = 9.80 \text{ ms}^{-2}$

$t = 3.15 \text{ s}$

$s = 30.0 \text{ m}$

$s = ut + \frac{1}{2}at^2$

$\Rightarrow 30.0 = -(u\cos 52.0^\circ)(3.15) + \frac{1}{2}(9.80)(3.15)^2$ (1)

$\Rightarrow$ $\underline{u = 9.60 \text{ ms}^{-1}}$ (1)

[For the following calculations, use a numerical value of ~~9.60~~ 9·50 ms^{-1} for the initial launch speed of stone if you could not calculate an answer for part (a).]

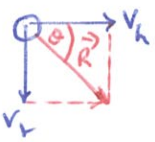
(b) Calculate the horizontal range of the stone. (2 marks)

$$v_h = \frac{s_h}{t}$$

$$\Rightarrow \quad s_h = (9{\cdot}60 \cos 38{\cdot}0^\circ)(3{\cdot}15) \quad (1)$$

$$= \underline{23{\cdot}8\text{ m}} \quad (1)$$

(c) Calculate the velocity of the stone after 2.50 s of flight. You must give a magnitude and direction. (5 marks)



<u>VERTICALLY</u>

$v = ?$

$u = -9{\cdot}60 \cos 52{\cdot}0^\circ \text{ ms}^{-1}$

$a = 9{\cdot}80 \text{ ms}^{-2}$

$t = 2{\cdot}50\text{ s}$

$s = ?$

$$v = u + at$$

$$= (-9{\cdot}60 \cos 52{\cdot}0^\circ) + (9{\cdot}80)(2{\cdot}50) \quad (1)$$

$$= 18{\cdot}6 \text{ ms}^{-1} \text{ down} \quad (1)$$

$$v_h = 9{\cdot}60 \cos 38{\cdot}0^\circ$$

$$= 7{\cdot}56 \text{ ms}^{-1} \quad (1)$$

$$\vec{R} = \sqrt{(18{\cdot}6)^2 + (7{\cdot}56)^2}$$

$$= 20{\cdot}1 \text{ ms}^{-1} \quad (1)$$

$$\tan\theta = \frac{18{\cdot}6}{7{\cdot}56}$$

$$\Rightarrow \theta = 67{\cdot}9^\circ \quad (1)$$

$\therefore$ <u>velocity</u> = <u>20·1 ms^{-1} at 67·9° to the horizontal</u>

(d) Calculate the work done on the stone by the Earth's gravitational field in the motion from launch to reaching ground level. (2 marks)

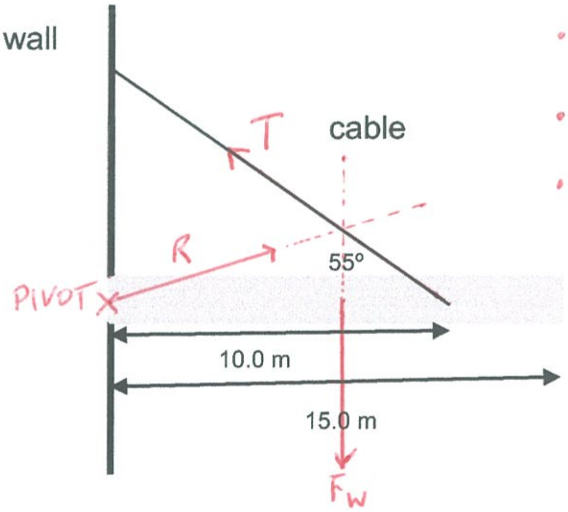
$$W = \Delta E_p = mg\Delta h$$

$$= (0{\cdot}0520)(9{\cdot}80)(30{\cdot}0) \quad (1)$$

$$= \underline{15{\cdot}3\text{ J}} \quad (1)$$

18. [16 marks]

A nature lookout consists of an elevated concrete walkway high above the ground. A uniform platform has been constructed so people can walk out over a gorge and view it. The entire platform structure is shown in the figure below.



• 3 forces shown (1)
• Forces labelled (1)
• No force missing / no unnecessary forces. (1)

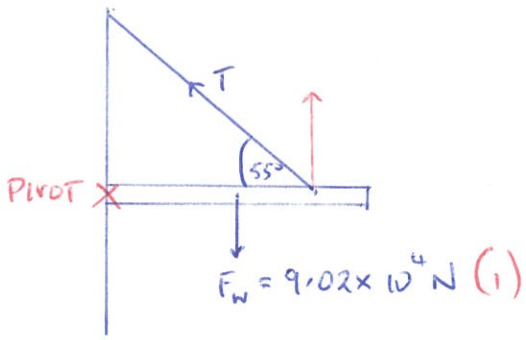
The platform is designed to support a load of 8.50 tonnes and is 15.0 m long. A single steel cable supports the platform, attached 10.0 m from the end at 55.0° as shown in the figure. The platform has a mass of 0.700 tonnes.

The platform is uniform and it can be assumed that – when it is acting - the 8.50 tonne maximum load acts half-way along its length.

The steel cable shown has a maximum tensile strength of 1.50 x 10^5 N.

(a) On the diagram above, draw all the forces acting on the platform when in it is an unloaded state as drawn above. Label the forces appropriately. (3 marks)

(b) Show that with the maximum load acting through the platform's midpoint, the cable will be able to support the platform. Support your answer with calculations. (4 marks)



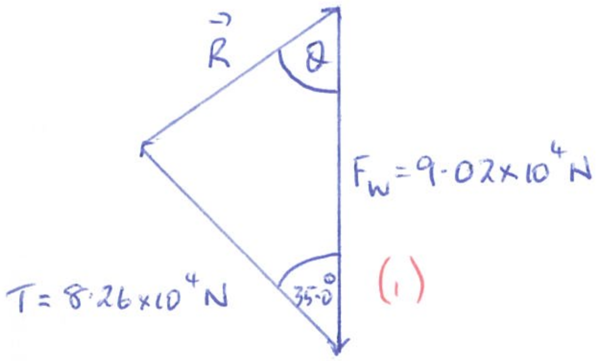
$\Sigma CM = \Sigma ACM$

$\Rightarrow (9.02 \times 10^4)(7.50) = (T \cos 35.0°)(10.0)$ (1)

$\Rightarrow T = 8.26 \times 10^4$ N (1)

As $T < 1.50 \times 10^5$ N, cable does not break. (1)

(c) Hence, calculate the ~~magnitude of the~~ force that the wall exerts on the platform.
[Hint - if you could not calculate an answer for part (a), use a value of 9.00×10^4 N for the tension in the cable.] (4 marks)



$$\vec{R} = \sqrt{(9.02\times10^4)^2 + (8.26\times10^4)^2 - 2(9.02\times10^4)(8.26\times10^4)\cos 35.0^\circ}$$

$$= 5.25 \times 10^4 \text{ N} \quad (1)$$

$$\frac{8.26\times10^4}{\sin\theta} = \frac{5.25\times10^4}{\sin 35.0^\circ}$$

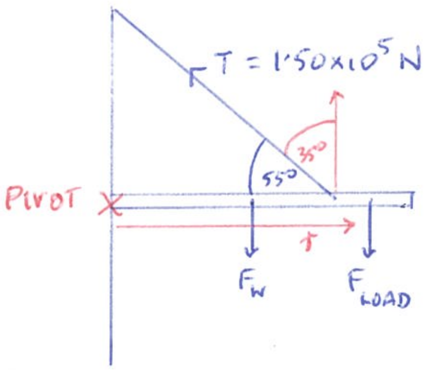
$$\Rightarrow \theta = 64.5^\circ \quad (1)$$

$$\therefore \underline{\vec{R} = 5.25\times10^4 \text{ N at } 64.5^\circ \text{ to the vertical}} \quad (1)$$

(d) If the maximum load of 8.50 tonnes is gradually moved towards the end of the platform, describe what happens to the magnitude and direction of the force you calculated in part (c). No calculation is required. (2 marks)

By inspection: $\vec{R}$ gets bigger. (1)
θ gets bigger. (1)

(e) If the maximum load continues to move towards the end of the platform, the cable will eventually exceed its load limit and snap. Calculate how far towards the edge of the platform the load can move until the load limit on the wire is exceeded.
(3 marks)



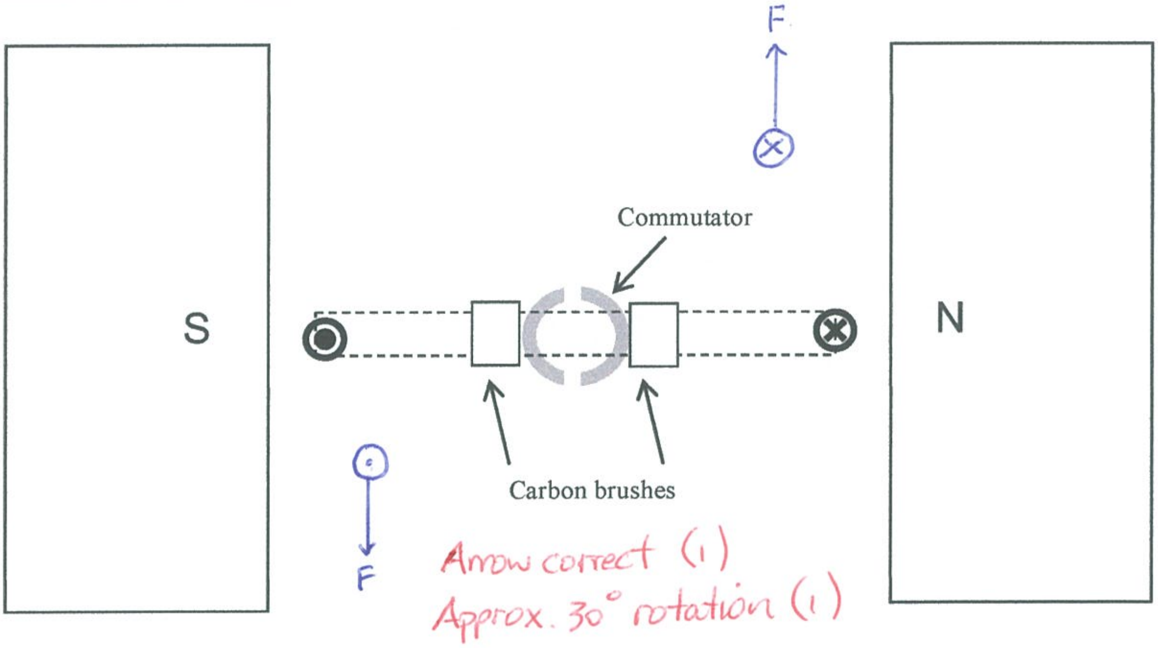
$$\Sigma CM = \Sigma ACM$$

$$\Rightarrow (7.00\times10^2)(9.80)(7.50) + (8.50\times10^3)(9.80)r = (1.50\times10^5 \cos 35.0^\circ)(10.0) \quad (2)$$

$$\Rightarrow \underline{r = 14.1 \text{ m}} \quad (1)$$

19. [14 marks]

The diagram shows the side view of a DC electric motor. A square coil is placed flat in the uniform magnetic field between the North and South magnetic poles. Current direction in the coil is shown on the sides adjacent to the magnetic poles. The commutator and carbon brushes are also shown.



(a) In which direction will the coil turn from this start position? (1 mark)

• Anti-clockwise (1)

(b) Explain the function of the ***brushes*** and the function of the ***commutator***. (3 marks)

BRUSHES - transfer current from an external source into the coil. (1)

COMMUTATOR - switches the direction of the current in the coil every 180° of rotation. (1)

- ensures force (torque) is in a constant direction. (1)

(c) On the diagram above, use the symbols ⊙ and ⊗ to sketch the location of the coil sides adjacent to the magnetic poles after 30.0° of rotation from this start position. Put arrows on your symbols to indicate the direction of magnetic force acting on them.

(2 marks)

(d) At this new position after 30.0° of rotation from the start position, determine the torque value of the motor as a percentage of maximum torque. (2 marks)

$\tau(max) = Fr \sin 90°$

$\tau = Fr \sin 60°$

$\therefore \frac{\tau}{\tau(max)} = \frac{\sin 60.0°}{\sin 90.0°} \times \frac{100}{1}$ (1)

$= \underline{86.6\,\%}$ (1)

(e) A single 0.120 m length of wire, adjacent to one of the magnetic poles, experiences a 0.0280 N magnitude of force when a current of 5.30 A is present. Calculate the magnetic flux density between the poles.

(2 marks)

$F = I\ell B$

$\Rightarrow B = \frac{F}{I\ell}$

$= \frac{0.0280}{(5.30)(0.120)}$ (1)

$= \underline{4.40 \times 10^{-2}\ T}$ (1)

(f) After the motor is switched on, its rate of rotation increases. As this happens, the nett current in the coil decreases. Clearly explain why this happens.

(3 marks)

- As the wire cuts through the magnetic field, an EMF is induced in the coil (called a back EMF). (1)
- This moves the charges in the opposite direction in the coil to produce an opposing force. (1)
- The current will decrease due to the reduction in the EMF. (1)

20. [12 marks]

The trains on the Perth to Fremantle rail line are powered by four 600.0 V DC motors. The current is delivered to the motors from the sub-station overhead power lines, which are at a potential of 2.50×10^4 V AC. The AC voltage needs to be converted to 600.0 V DC by a transformer.

The overhead lines have a resistance of 2.10 Ωkm^{-1} and the motors each have a resistance of 2.00 Ω. When the train is close to the Perth sub-station and operating at full power, the train draws 1.00 MW of electrical power.

(a) Why do overhead transmission lines operate at 25.0 kV AC and not at 600.0 V DC? (2 marks)

- Transformers only work on AC - they need a continual change in flux. (1)
- Power is transmitted at high voltage (25.0 kV) to minimise energy losses in the transmission lines. (1)

(b) What is the current in the overhead lines when the train is close to the Perth sub-station and operating at full power? (2 marks)

$$P = VI$$

$$\Rightarrow I = \frac{P}{V}$$

$$= \frac{1.00 \times 10^6}{2.50 \times 10^4} \quad (1)$$

$$= \underline{40.0\ A} \quad (1)$$

(c) What is the starting current in ***ONE*** motor? (2 marks)

$$V = IR$$

$$\Rightarrow I = \frac{V}{R}$$

$$= \frac{6.00 \times 10^2}{2.00} \quad (1)$$

$$= \underline{3.00 \times 10^2\ A} \quad (1)$$

(d) If the train is 20.0 km from the sub-station, the power developed by the train will be less than when it is close to the substation. If the train is now drawing 0.700 MW and the current drawn from the power lines is 28.0 A, what is the voltage available to the motors? (6 marks)

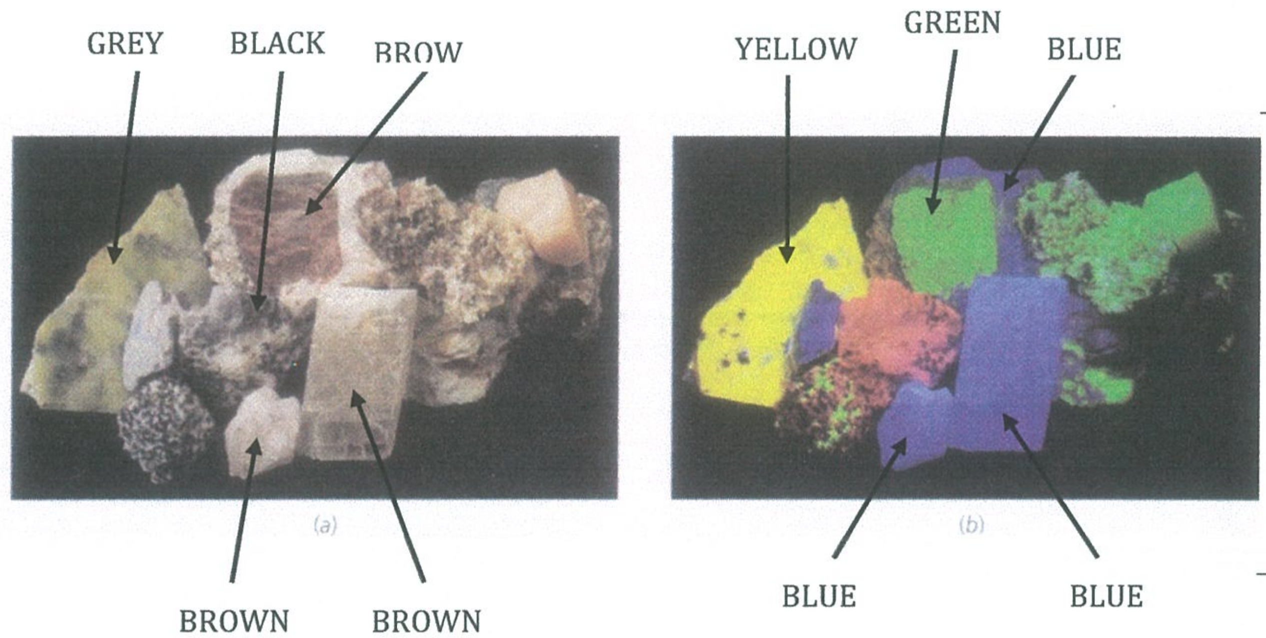
$$R_{wires} = (20.0)(2 \times 2.10) \quad (1)$$
$$= 84.0\ \Omega. \quad (1)$$

$$V_{drop} = I R_{wires}$$
$$= (28.0)(84.0) \quad (1)$$
$$= 2.35 \times 10^{3}\ V. \quad (1)$$

$$V_{train} = V_{wires} - V_{drop}$$
$$= 2.50 \times 10^{4} - 2.35 \times 10^{3} \quad (1)$$
$$= \underline{2.26 \times 10^{4}\ V} \quad (22.6\ kV) \quad (1)$$

21. [15 marks]

Consider the following diagram that shows the same collection of minerals in (a) daylight and (b) "black light".



(a) Complete the following sentence: The correct terminology for "black light" is

ultraviolet light (1) and the phenomenon is called

fluorescence (1). (2 marks)

(b) The first 4 energy levels for a potassium mineral are shown (not to scale) as follows.

______________________	E_4 = - 1.10 eV	3·29 eV.
______________________	E_3 = - 1.78 eV	2·61 eV
______________________	E_2 = - 2.87 eV	1·52 eV
______________________	E_1 = - 4.39 eV	0·00 eV

Could a sample of this potassium mineral display the phenomenon as shown in (a) above? Justify your answer, showing the necessary calculations. (4 marks)

Max. energy $= E_4 - E_1 = hf$ (1)

$= [(-1{\cdot}10) - (-4{\cdot}39)](1{\cdot}60\times10^{-19}) = (6{\cdot}63\times10^{-34})f$ (1)

$\Rightarrow \quad f = 7{\cdot}94\times10^{14}$ Hz (1)

From the data sheet, this would be in the visible region of the spectrum.

$\therefore$ Fluorescence won't occur. (1)

(c) Consider again the first 4 energy levels for the potassium mineral in (b). What would be detected if particles of the sample were bombarded by:

(4 marks)

(i) photons of energy 2.65 eV.

- Nothing - doesn't match an energy level above ground state. (1)

(ii) electrons of energy 2.65 eV?

Mention scattered electrons (1)

- Transition $E_1 \to E_3$ ⇒ Scattered electrons would have $E_K = 0{\cdot}04\,eV$. (1)

⇒

- Transition $E_1 \to E_2$ ⇒ Scattered electrons would have $E_K = 1{\cdot}13\,eV$. (1)

(d) If an electron was excited from the ground state to the ~~- 1.10~~ $-1{\cdot}78$ eV level:

(i) when it returned to the ground state, what would be the ~~frequency~~ wavelength of the photon emitted?

(3 marks)

$$E_3 - E_1 = hf = \frac{hc}{\lambda} \quad (1)$$

$$\Rightarrow \left[(-1{\cdot}78) - (-4{\cdot}39)\right](1{\cdot}60 \times 10^{-19}) = \frac{(6{\cdot}63 \times 10^{-34})(3{\cdot}00 \times 10^{8})}{\lambda} \quad (1)$$

$$\Rightarrow \underline{\lambda = 4{\cdot}76 \times 10^{-7}\,m} \quad (1)$$

(ii) To which region of the electromagnetic spectrum would the photon belong? Support your answer by referring to its wavelength or frequency.

(2 marks)

- $\lambda \approx 5 \times 10^{-7}\,m$ (1)
- From the data sheet, this is in the blue/violet region of the visible spectrum. (1)