National Junior College
Physics Department
2004 JC2 Common Test 2
Suggested Solution

26a it states that the **total momentum** of a **SYSTEM** is conserved if there is **no EXTERNAL force** acting on the system.

OR

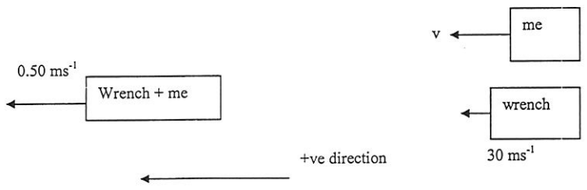
it states that the **total momentum** of a **CLOSED SYSTEM** is conserved.

Comments:
Below are some of the common mistakes:

- $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$
- "Relative speed of approach = relative speed of separation"
- "momentum cannot be destroyed or created. It can only be transferred."
- "for an object to be in equilibrium, the sum of clockwise moment = sum anticlockwise moment."

Generally, it is disappointing to see students not able to state the law correctly. Level of preparation is minimal.

26b(i) Considering myself and the wrench as a system,



$82(0.50) = 80v + 2(30)$

$v = -0.238\ ms^{-1}$

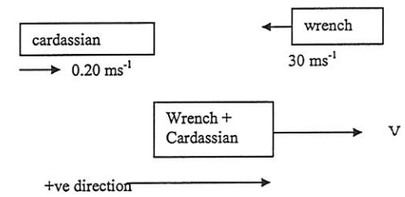
Hence I am moving toward the spaceship at $0.24\ ms^{-1}$.

Comments:

- In general, students did not do well because they did not know how to choose an appropriate system to apply the law of conservation of momentum. The weaker student did not understand the problem and tried to apply kinematics to solve.
- Students who managed to score 1 out of 3 for this question failed to see that the initial momentum of the wrench is not zero. They left their answer in numerical value without stating the direction of the velocity. Many did not draw proper diagram and assign positive direction to their working.

26b(ii) $t = 10 / 0.238 = 42.0$ s
Hence it would take only 42 s to reach the spaceship. Oxygen supply is sufficient.

26b(iii) Considering the Cardassian and the wrench as a system,



Inelastic Collision assuming the Cardassian held on to the wrench after catching it:

$0.20(95) - 2.0\ (30) = (95 + 2)\ V$

$V = -0.423\ ms^{-1}$

Comments:

A common mistake is as follows:

$P_{wrench} = 2 \times 30 = 60$ $P_{alien} = 95 \times 0.20 = 19$

"the wrench exerts a larger force on aliensince $P_{wrench} > P_{alien}$. Hence it can be repelled."

- Students compared the momentum of the wrench and the monster to make the conclusion which is not thoughtful enough.
- Others failed to see that the wrench also traveled with the same speed as the monster after the collision. It could be due to carelessness but there are reasons to believe they do not understand that the conservation of momentum appiies to a system of bodies not a single body.

27a The frequency of collision between pellets and cylinder **increases.**

Or

Rate of change of momentum of pellets due to each collision **increases.**

Hence force exerted and pressure on the piston increases.

Comments:

- Many students use pV = NkT, thinking that it is a kinetic theory equation!!!
- Some use $pV = 1/3\ Nm\langle c^2\rangle$. Yes, this is derived from Kinetic Theory but it is not the theory itself!!!
- Those who scored partial credits were those who were not very clear in making links between frequency of collision and the force exerted on the piston.

27b

- The volume of pellets is not negligible compared to the volume of the cylinder.
- There is no large number of pellets in the model.
- The pellets have significant weight.

Comments:

- A number of students did not read the question carefully and concluded that the collisions made by the pellets are not elastic.
- "volume of gas in the mechanical model is not negligible compared to the volume of the cylinder." Such was the imprecision of the answer given by the students that warrants no credit for them.

27c $$p = \frac{1}{3}\frac{Nm\langle c^2\rangle}{V}$$

gradient of P – 1/V graph = $\frac{1}{3}Nm\langle c^2\rangle$

gradient = $$\frac{2.2x10^2 - 0}{5x10^3 - 0} = 0.044$$

$$\langle c^2\rangle = \frac{3x0.044}{0.010} = 13.2$$

$c_{rms} = 3.63\ ms^{-1}$

Comments:

- Students were very careless to read the axes incorrectly. They cannot handle the mathematics which is so simple. For instance, they substituted 10 for the value of the mass instead of 0.010.
- They also did not realize that the equation required can be obtained from the data sheet. A handful of them started from erroneous equation.
- Students are expected to use the gradient instead of using a point from the graph to calculate the rms speed.
- For some reasons, a handful of students stop at the value of mean-square-speed and concluded it was the rms speed. Extremely careless!!!

28a(i)

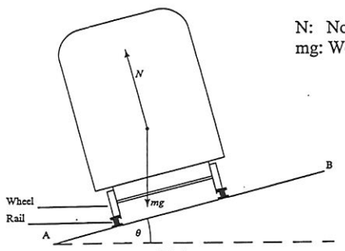


Fig. 1

N: Normal contact force
mg: Weight of the train

Comments:

Students can either draw the normal contact force as a single force passing through the centre of gravity of the train or as two contact forces originating from the point of contact at the two wheels.

Below are some of the common mistakes:

- Almost all students, with the exception of a handful, did not indicate what N and mg (or W) represent. No marks were deducted though.
- Majority of students drew in the frictional forces at both wheels in addition to N and W. Again no marks were deducted.
- Some students drew in the centripetal force. Again no marks deducted.
- Some students just drew the arrow without labeling. 1 mark was deducted.
- About 2 or 3 students drew the weight vector perpendicular to the slope.
- Handful of students leave this part blank or did not attempt the question at all.

28a(ii) Resolving forces vertically: $N\cos\theta = mg$
Resolving forces horizontally: $N\sin\theta = mv^2/r$

Solving, $\theta = \tan^{-1}(v^2/rg)$

Alternatively, candidates can solve using vector diagram which is closed with direction of forces indicated clearly.

Comments:
Many students scored zero for this part.
Below are some of the common mistakes:

- Centripetal force is directed along the slope instead of in the horizontal direction. Because of this, many students ended up with a sin or cos function instead of tan.
- Due to the wrong direction of the centripetal force, students proceeded to resolve the weight instead of the normal contact force.

28b $\tan\theta = v2/(2000x9.81) = 0.14/1.4$

$v = 44.3\ ms^{-1}$

Comments:
Many students scored the full 2 marks for this part because of error carried forward from part a(ii).

For those who failed to obtain the full marks, below are some of the common mistakes:

- $\tan\theta$ was computed wrongly.
- Value of r (= 2000 m) was wrong. Some used 1.4 m
- Did not convert 2 km to metres.

28c The force acting on the outer wheel, parallel to the plane will increase. This is due to the larger centripetal force required which causes the train to try to move outwards to a larger radius. As such, the force acting on the wheel by the outer rail increases.

Comments:

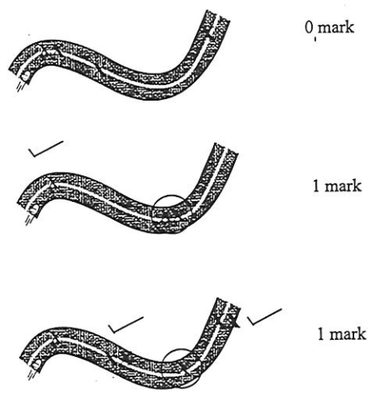
Most students were able to state that the force acting on the wheel increases. However they were not able to explain why it increases.
Common mistakes made by students:

- Normal contact force increases. The angle does not change and since $N\cos\theta = mg$ and weight does not change, it follows that N should also stay constant. However the contact force which is a resultant of the normal force and force along AB will increase to provide for the increase in centripetal force.
- θ increases because of the larger centripetal force. (as explained earlier).
- The train will lift off / derail. This answer is not to the point as the question is asking for the force along AB and not what is going to happen to the train.

28d

Comments:

Common mistakes made:

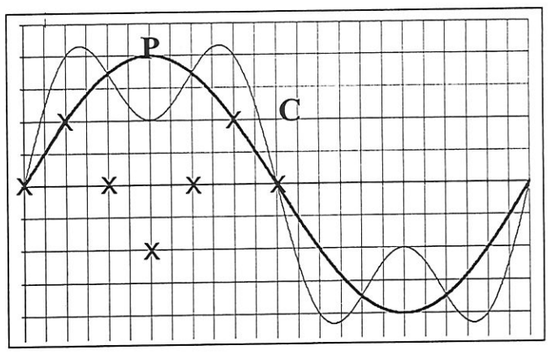


0 mark

1 mark

1 mark

29a (i)



By the principle of superposition: P + H = C

Therefore H = C – P

(i) Amplitude of P = 4 units = X_0 (given)
Amplitude of H = 2 units = $0.5X_0$

(ii) Period of P = 24 units, f = 1/24
Period of H = 8 units, freq = 1/8 = 3f

Comments:

- A fair majority of students were able to sketch the waveform of H correctly. These students proceeded to deduce the amplitude and frequency of H correctly. Only a small number deduced the frequency as f, 2f or 1/3 f probably due to carelessness, misinterpretation of the axes or plainly did not understand the term frequency.
- A handful of students did not sketch the waveform of H but nevertheless obtain the correct value of either amplitude or frequency or both.

29b(i) $v = f\lambda$

$\lambda = v/f = 320/80 = 4.0$ m

$\therefore$ distance between 2 nodes is $\frac{1}{2}\lambda = 4.0/2 = 2.0$ m.

Comments:

- Most students were able to answer this question correctly.
- A handful of students used the speed of the microphone in the calculation, which thus led to an erroneous answer. This could indicate that the students had misread the question.

29b(ii) Distance between 2 consecutive loud notes is the distance between two consecutive antinodes = $\lambda/2 = 4.0/2 = 2.0$ m

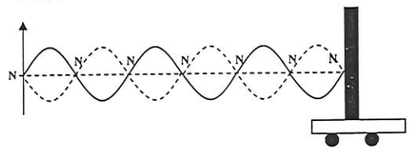
Time interval = $d/v = 2.0/4.0 = 0.5$s

Comments:

- Majority of the students were able to get this question correct.
- Some students still made the following common mistakes:

  - Distance between 2 consecutive loud notes = wavelength
  - Time interval = speed / distance
  - Time interval = 1 / frequency

29b(iii)(1)



Comments:

- Students were unable to draw the proper number of wavelengths for the stationary wave.
- Some students drew damped oscillations instead.
- Most of the sketches were poor and not in proper proportion.

(2) The minimum distance to be moved is $\lambda/2$ or 2.0 m towards S_1 or 2.0 m away form S_1.

Comments:

- most students knew the answer but fail to present it properly. Answers were simply left as '2 m' without proper statement or references.

30a

p.d across rheostat = 1.0 V

$I = V_{CD}/R_{CD} = 1.0$ m A

Resistance of the voltmeter $= 11/1.0 \times 10^{-3}$

$= 11$ kΩ

Comments:

- Many students were not able to understand the questions. They used the wrong p.d value across the voltmeter to calculate the resistance. Many students skipped the entire questions.

30b

Current through voltmeter = V/R

$= 3/11 \times 10^{3}$

$= 0.273$ mA

Comments:

- Students who attempted the first part will usually get this correct allowing error carry forward.

30c

If the voltmeter draws negligible current,

$R_{CP}/R_{CD} \times 12 = 9$ V

$R_{CP} = 0.75\ R_{CD}$

Since R proportional to L, $L_{CP} = 0.75\ L_{CD}$

Comments:

- Many students knew the answer is ¾ l. They could not show the working. Many students gave working in terms of length without mention about the relation of resistance with length.

30d(i)

The resistance of the lamp given by V/I = 15 Ω is far much smaller than the resistance of the voltmeter and hence will draw significant amount of current from the circuit, affecting the p.d.

With lamp, $R'_{PD} = (1/250 + 1/15)^{-1}$
$= 14.2\ \Omega$
$V'_{PD} = [\ 14.2/\ (14.2 + 750)\ ] \times 12$
$= 0.28\ V << 3\ V$
Hence the lamp does not light up.

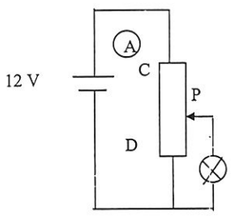
Comments:

- Many students thought that the lamp resistance is larger than the resistance of the voltmeter.
- Many students mentioned that the current is less/more without giving explanation why the value is lesser.
- Some mentioned that the current is too large and the bulb fused.
- Some students inferred from the current worked out from above that its too small without considering the effect of the resistance of the lamp at all.

30d(ii)

$R_{total} = R_{CP} + R_{PD}$
$= 750 + (1/250 + ½)^{-1}$
$= 750 + 1.984$
$= 752\ \Omega$

$E = IR$
$12 = I\ (752)$
$I = 0.016\ A$



Comments:

- Some of the students obtained the answers without considering the parallel resistance combination of the lamp and rheostat resistance.
- The better students were able to get the full marks for this question.

30e

Figure 30.3 is a better method as it provides a wider range of voltage variation due to the parallel combination of the rheostat and the lamp's resistance. The circuit in fig 30.3 can range from 0 V to 3.0 V. For fig 30.4 circuit, as the slider distance increases, most of the p.d will appear across it leaving little variation for the lamp.

Comments:

- This question was poorly answered. Many students mentioned that the bulb will fused using the choice that they made.
- Only a handful of students saw the advantage of the putting the lamp in parallel with the rheostat and the wider range as a result.
- Many students mentioned the circuit in fig.30.3 is used as a potential divider without going into details.

General Comments:

On the whole, this entire question is poorly answered. Possible reasons are:

- They are not able to handle too much information in a given questions.
- They cannot interpret the circuit diagram.
- They are not aware of how the change in resistance of a parallel combination circuit will affect the current and p.d across components in the circuit.

They are not able to present and show detailed explanation of their answers

31a(i) $C = (8.85\times10^{-12})\ (10\times10^{6}) / 500 = 177\ nF$

Comments:

- Some students were unable to convert 10 km^2 into m^2.
- Several students mistook nC to mean 10^{-6} C or 10^{-12} C. These students were obviously uncertain what the suffix n meant.

31a(ii) $Q = CV = (177\times10^{-9})(1.0\times10^{4}) = 1.77\ mC$
$E = ½\ CV^2 = ½\ (177\times10^{-9})(1.0\times10^{4})^2 = 8.85\ J$

Comments:

- Many students were able to get this question correct.
- Among those who got it wrong, most used the wrong form of the equations (e.g. Q = C/V, E = QV or used an inappropriate equation (E = V/d). It seems that some students confused energy E as used in the question, with electric field strength which is represented by the same symbol.

31b(i) When height of cloud is <u>doubled</u>, the capacitance of the cloud will be <u>halved</u>. As the <u>charge remains constant</u>, the energy stored by the cloud $E = \frac{1}{2} Q^2/C$ will be <u>doubled</u>.

Comments:

- Generally, an overwhelming majority of the students were not awarded the full credit for this question. This is because most of them used vague descriptors such as "increase" or "decrease" without being specific about how great the change was i.e. "doubled" or "halved".
- Many students concluded that energy decreases as capacitance decreases based on the equation $E = \frac{1}{2} CV^2$ without due consideration for whether V changes.
- Some students merely stated equations without further elaboration or explanation in a qualitative manner.
- A handful of students used $V = Q/(4\pi_0 \varepsilon r)$ to account for change in V as Q changes when the question refers to a capacitance and not a charged particle.

31b(ii) The increase in energy stored by the cloud is caused by mechanical work done by wind blowing.

Comments:

- Very few students managed to get any marks for this question.
- Most students misinterpreted the question, and proceeded to calculate the change in energy of the capacitor.
- Others gave answers based on energy conversion between the gravitational potential energy of the cloud and electrical energy stored in the capacitor.

31c Using $E = \frac{1}{2} Q^2/C$, when half of its charges are lost,
Energy left = ¼ ×2.0 kJ = 0.5 kJ
Energy lost in lightning = (2.0 – 1.5)kJ = 1.5 kJ

∴Power dissipated in lightning = energy lost / time taken
$= 1.5\times10^3/(50\times10^{-3}) = 30$ kW

Comments:

- Many students used $E = \frac{1}{2} QV$ and concluded erroneously that the final energy is equal to half the initial energy, since half the charges are left. They have not considered if V has changed as a result of a change in Q.
- Some students mistook to energy left to be the energy dissipated.
- Several students did not attempt this question, perhaps due to insufficient time left to complete the paper.

32a

$$v_1 = \frac{V}{A_1} = \frac{1.2\times10^{-2}}{4\times10^{-3}} = 3 \text{ ms}^{-1}$$

$$v_2 = \frac{V}{A_2} = \frac{1.2\times10^{-2}}{8\times10^{-4}} = 15 \text{ ms}^{-1}$$

Comment:

Some students used two equations: equation of continuity and Bernoulli equation, to solve for the two speeds instead of only using the equation of continuity. Students need to know that Bernoulli equation is only applicable when they are sure that energy is conserved.

32b

Total KE gain = $\frac{1}{2} m(v_2^2 - v_1^2)$

KE gain per unit mass = $\frac{1}{2}(v_2^2 - v_1^2) = \frac{1}{2}(15^2 - 3^2) = 108 \text{ J kg}^{-1}$

Comment:

Most students did not understand the meaning of 'unit mass' and let the mass be 1 kg or 1 g. Majority of the students made mistake by taking the different in speeds first then squared the speed.

32c

Work done on petrol at entrance = $p_1 V_1$

Work done per unit mass, $W_1 = \frac{p_1 V_1}{m} = \frac{p_1}{\rho}$ as $\rho = m / V_1$

Comment:

The following approaches are not acceptable:

1. Check the homogeneity of the equation.
2. Start from $\frac{p_1}{\rho}$ and does not show an understanding of the meaning of 'work done per unit mass'.

32d

(i) the work done per unit mass of petrol at the entrance,

$$W_1 = \frac{p_1}{\rho} = \frac{1\times10^4}{750} = 13.3J \text{ kg}^{-1}$$

(ii) the work done per unit mass of petrol at the exit,

$$W_2 = \frac{p_2}{\rho} = \frac{2.8\times10^5}{750} = 373.3J \text{ kg}^{-1}$$

32e the net work done per unit mass of petrol at the entrance and exit,

$$\Delta W = W_2 - W_1 = 360J \text{ kg}^{-1}$$

Comment:

- Well done except most students had given the wrong unit as J.

32f

Without pump, the pressure drops when velocity increases according to Bernoulli principle. In this case, the pressure increases in the region of higher velocity at the exit. Hence, there must be an external power source.

Comment:

The following comments scored no mark:

1. Some briefly wrote that 'there is work done, therefore an external power source is needed'.
2. Some attributed that 'viscous forces in the fluid that oppose the flow, hence an external power source is needed to prevent fluid from stopping'.

Students did not draw from the information given in the question, i.e. the speed and pressure at the exit are high compared to the entrance.

32g the work done by the pump, W_P, in delivering unit mass of petrol,

W_P = Net work against pressure difference + Gain in KE

= 360 + 108 = 468 J kg^{-1}

Comment:

Most students did not attend this part. Only 5 % of the student got the answer correct.

32h the mechanical power developed by the pump in order to maintain the above flow conditions,

P = W_p x mass / time = W_p x (Vol flow rate x density)

= 468 x 750 x 1.2 x 10^{-2}

= 4210 W

Comment:

Most students did not attend this part. Only 5 % of the student got the answer correct. 10% of student showed correct method.

32i The mechanical power of the pump required is higher than that calculated in (g) because

Heat is lost due to friction between the moving parts of the pump/ friction between fluid and wall or Work needs to be done against viscous forces / turbulence.

Comment:

'Heat is lost due to friction' without further elaboration on the nature of friction (which required in A Level) will not be awarded 1 mark.

Q33

(a)(i)

- Excitation of atoms by free electrons in discharge lamp to higher energy level
- Upon excitation, a photon of a specific energy is given out. This give rise to the discrete emission spectrum.

Comments:
Below are some of the common mistakes:

- Majority were confused with absorption spectrum where students state that electrons in th atom are excited due to the absorption of photons
- Excitation due to collision by neutrons
- Photoelectrons are emitted from the atom due to excitation and appear as bright specks on screen.

This is book work, it really reflects how well you have prepared for Quantum physics if you could get this concept wrong.

(ii) Energy of photon, $E = hf = hc/\lambda$
By proper substitution, you should get the following values,

$E_{97.1} = 2.05 \times 10^{-18}$ J
$E_{485} = 4.10 \times 10^{-19}$ J
$E_{654} = 3.04 \times 10^{-19}$ J
$E_{1875} = 1.06 \times 10^{-19}$ J

Comments:
Below are some of the common mistakes:

- Wrong/No conversion from nm to m during substitution
- Forget units
- Wrong substitution of the planck constant, h
- Wrong formula: $E = h\lambda$

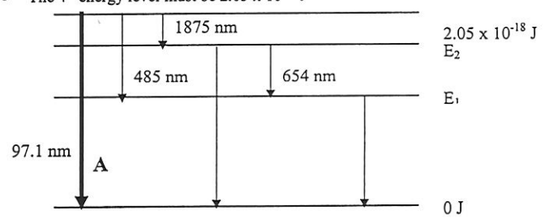
This formula is the fundamental of Quantum Physics. YOU MUST KNOW IT!!

(iii) What is given in the question?

- Exactly 4 lowest energy level give rise to the spectrum (this includes the lowest energy level)
- 0J is assigned to the lowest energy level

What can you further derive from the information?

- Smallest λ will give rise to largest energy difference
- The 4th energy level must be 2.05×10^{-18} J



$E_2 = 2.05 \times 10^{-18} - 1.06 \times 10^{-19}$
$= 1.94 \times 10^{-18}$ J

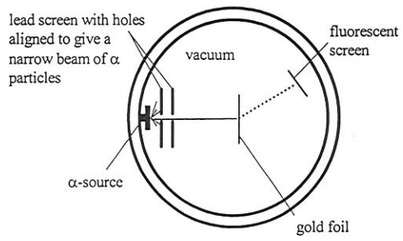
$E_1 = 2.05 \times 10^{-18} - 4.10 \times 10^{-19}$
$= 1.64 \times 10^{-18}$ J

(Can you think of another way to find E_1?)

Comments:
Below are some of the common mistakes:

- Spacing of the energy level were incorrect
- Majority drew a total of 5 energy level (including the lowest level, 0J)
- Students simply assigned $E_{97.1}$, E_{485}, E_{654}, E_{1875} for each energy level.
- 0J was assigned to the highest energy level and thus all the energy was labelled as negative value

(b)(i)



- Most α-particles went through without deflection ⇒ Gold atom is mostly empty spaces.
- Only a small fraction was deflected (or even 180°) ⇒ gold atom has a small concentrated nucleus which deflected α-particles strongly.

Comments:
Below are some of the common mistakes:

- Electrons were used to bombard gold foil
- α-particles were aimed at gold foil in many angles
- α-particles on Zn/Al/metal foil/H-gas/etc
- GM tube to emit α-particles at high velocity
- More scintillations were observed at C than B
- Most α-particles undeflected ⇒ Atoms are small
  ⇒ Nucleus is small
- Slightly deflected due to electrons orbiting around the nucleus

(b)(ii)
1

$$^{222}_{86}Rn \rightarrow ^{4}_{2}He + ^{218}_{84}Po$$

2 $E_k = 8.61 \times 10^{-13}$ J

$\frac{1}{2}mv^2 = 8.61 \times 10^{-13}$ J

$v = 1.61 \times 10^{7}$ ms^{-1}

3 Energy released = $(M_{Rn} - M_{He} - M_{Po})c^2$
$= 8.80 \times 10^{-13}$ J (5.50 MeV)

Energy of Polonium = $\frac{1}{2}mv^2 = 8.80 \times 10^{-13}$ J

Thus, $v = 3.23 \times 10^{5}$ ms^{-1}

4 Alpha particles have low penetrating power than beta and gamma particles and hence a shorter range. Thus, its effect are localised to a specific area and hence does not affect other healthy cells

OR Alpha radiation has the highest ionisation ability and therefore treatment of the target cells is more effective.

Comments:
Below are some of the common mistakes:

Q1
- Some forget to include A and Z

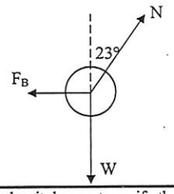
Q2
- Forget to convert u to kg
- Never square root
- Use mass of alpha as 1u instead of 4u

Q3
- Forget to find velocity
  Use value of energy released = KE of polonium (ie, did not subtract KE of alpha)
  USE OF CONSERVATION OF MOMENTUM AWARDED FULL MARKS

34a *magnetic flux, $\phi = BA \cos \theta$*
θ = angle between the flux density, B, and the normal of the area, A

- some students defined magnetic flux density instead
- mark usually lost when the angle is not clearly defined

b(i) 1. *Free-body diagram must show:*
* *angle*
* *forces labelled*



Common mistakes:
- normal contact force missing
- F_B drawn parallel to the plane

2. *Dirn: XW*

"current will flow in a clockwise direction" is not accepted as it does not specify the direction of current in the rod as required by the question.

3. *BIL = mg tan 23*
I = 0.42 A (instead of 0.37A as required by the question)

As there is an errata in the question, any working which is physically correct will be given full credit. Error-carried-forward from part 1 (eg. F_B drawn parallel to the plane) is not penalized.
Common mistakes:
- Unable to resolve forces correctly

b(ii) 1. Due to flux cutting, emf induced by the rod, *E = (B cos 23) Lv*
Current induced, *I = E/R = 0.249 A*
Dirn: XW

Common mistakes:
- Did not resolve the magnetic field perpendicular to the plane (ie, *B cos 23*)

b (ii) 2. *Lenz's law: direction of induced current such as to oppose the flux cutting*
Force generated opposes motion, tends to stop the rod
work done by gravitational force, ie. Change in grav PE has been converted to electrical energy (or heating effect of current flow)

Common answers:
- Lenz's law states that current flows in a direction to oppose:
  1. force acting on it (wrong)
  2. change in emf (wrong)
  3. the existing current which is flowing (wrong)
  4. the magnetic field (wrong)
  5. change in flux cutting (not very good, please don't confuse between change of flux & flux cutting)
  6. motion of the rod (ok)
  7. the change that causes it (ok)

3. No net force, ie. *I = 0.42 A (answer from (b)(i))*
Emf induced to produce this current, *E= IR*
Equate this with the formula for emf induced due to flux cutting;
E = (B cos 23) Lv
Hence, the rod must move with a speed, *v = 1.52 m s^{-1}*
(If I=0.37 A is used, v = 1.34 m s^{-1})

Comments:
- Full credit given for correct working using any value of current read off from the answer in (b)(i).

4. *Resistivity is constant.*
Mass = density x area x length;
density half, area double, resistance half
Same weight, same magnetic force, same current required
Emf required half, terminal velocity half

Comments:
- Many students insist that the weight of the rod changes, despite the question mentioning that the mass is constant.
- Some think that the symbol ρ in the formula for resistance $\left(R = \frac{\rho L}{A}\right)$ refers to density.