LOCUS EDUCATION · QCE PHYSICS UNITS 3 AND 4

Physics *Masterclass.*

Saturday 7 November, 12 to 3pm
UQ St Lucia 24-S304 and on Zoom

Paper 1 Monday 9 Nov, 9am · Paper 2 Monday 9 Nov, 12:30pm

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2
days to the exam

What you asked us for

Straight from your RSVP responses. Today is built around these.

Is there anything in particular you'd like us to do at this event?

Explain how to know which value in the question to put as the contracted length vs proper length

Which class are you attending? **Physics**

Is there anything in particular you'd like us to do at this event?

how to break down EXPLAIN questions to maximise marks against marking guides

Which class are you attending? **Both!**

Is there anything in particular you'd like us to do at this event?

Questions that combine different topics into one

Which class are you attending? **Both!**

Is there anything in particular you'd like us to do at this event?

Practice questions + mistakes to look out for

Which class are you attending? **Both!**

Is there anything in particular you'd like us to do at this event?

Physics question regarding a wire and magnet on top of a scale

Which class are you attending? **Both!**

Is there anything in particular you'd like us to do at this event?

Help to breakdown questions in order to know what to do and what formula to use

Which class are you attending? **Physics**

...and some other things you asked for

Also straight from your RSVP responses. We read every single one.

Is there anything in particular you'd like us to do at this event?

Help me gng im cooked for eas

Which class are you attending? **Physics**

Is there anything in particular you'd like us to do at this event?

Not advertise ur tutoring program for too long, we have exams to study for guys

Which class are you attending? **Methods**

Is there anything in particular you'd like us to do at this event?

Free food

Which class are you attending? **Both!**

Is there anything in particular you'd like us to do at this event?

Im so cooked for almost all topics
- Orbital Mechanics (still medium)
- Electrostatics (medium rare)
- Magnetic fields and Electromagnet (ts burnt af)
- Special Relativity, Quantum Theory (burnt as well)

Which class are you attending? **Both!**

Is there anything in particular you'd like us to do at this event?

KRILLION LESGOO

Which class are you attending? **Physics**

Is there anything in particular you'd like us to do at this event?

Save me i've only studied for spec

Which class are you attending? **Physics**

Is there anything in particular you'd like us to do at this event?

Make me locked me

Which class are you attending? **Both!**

The plan for today

12:00	Welcome		Rishabh	
12:05	**Gravity and motion**		Julian + Tusho	**3 questions**
12:30	**Electromagnetism**	MOST REQUESTED	Julian + Tusho	**7 questions**
1:20	Break + Krillion			
1:30	**Special relativity**		Himank + Imira	**3 questions**
1:55	**Quantum theory**		Himank + Julian	**3 questions**
2:20	Break			
2:30	**Standard Model**		Tusho + Imira	**3 questions**
2:45	**Exam technique + FAQs**		Rishabh	**2 questions**

How every question runs

1

Try it alone

About half the slot. Use the blank space in your workbook. Write down every quantity first.

2

Worked live

The tutor works it out on the next slide, step by step, saying what earns each mark.

3

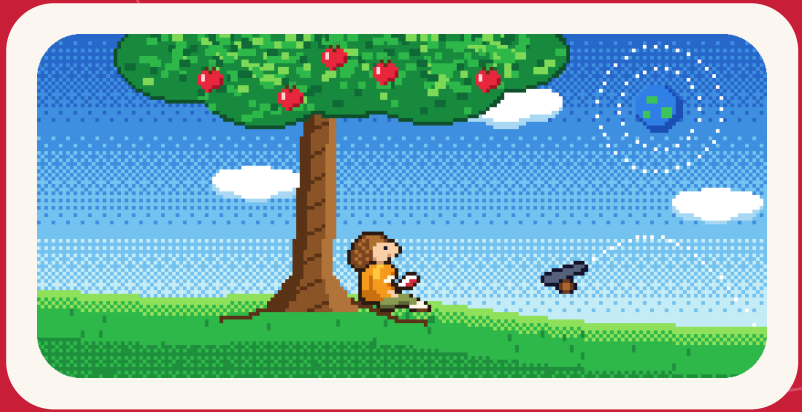
Mark yourself

Tick the marks you earned. Circle the step you missed: that is your revision list for Sunday.

Level 1 warm-up · **Level 2** exam standard · **Level 3** hardest. Each block builds up.

BLOCK 1 OF 6 · 12:05 TO 12:30

Gravity and *motion.*

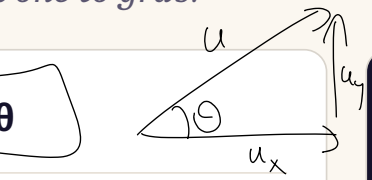


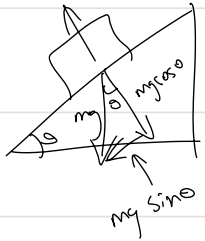
Julian + Tusho
5 min of key ideas, then 3 questions (20 min)

Gravity and motion: formulas and traps

From the QCAA formula and data book. Know which one to grab.

Projectile	$u_x = u\cos\theta,\quad u_y = u\sin\theta$
Vertical	$s = ut + \frac{1}{2}at^2,\quad v^2 = u^2 + 2as$
Slope	$F = mg\sin\theta,\quad N = mg\cos\theta$
Newton	$F_{net} = ma$
Circles	$v = 2\pi r/T,\quad a = v^2/r$
Gravity	$F = GMm/r^2,\quad g = GM/r^2$
Orbits	$T^2/r^3 = 4\pi^2/GM$





Common mistakes

- ✗ Calculator in degrees, not radians
- ✗ r is from the centre: add the planet's radius
- ✗ mg sin θ acts along the slope, not mg cos θ
- ✗ Connected masses: divide by the TOTAL mass
- ✗ T in seconds, not hours or days

Projectile motion

The only thing horizontal and vertical share is time.

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

$s_x = u_x t$ $\quad s_y = u_y t + \frac{1}{2}at^2$

$v_y^2 = u_y^2 + 2as$

- **Horizontal: a = 0**

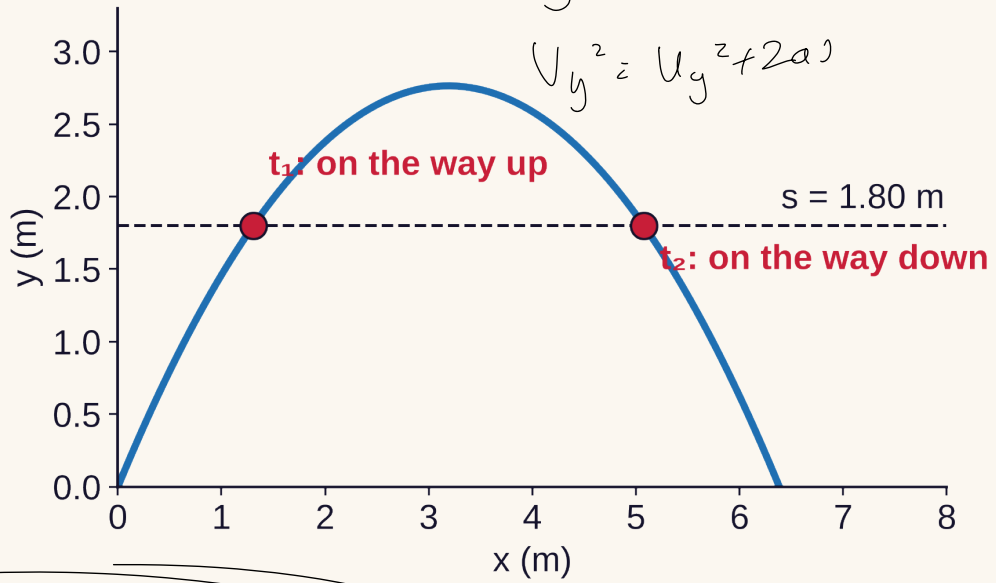
  $u_x = u \cos\theta$ never changes, so $x = u_x t$

- **Vertical: a = −9.8 m s⁻²**

  $s = u_y t + \frac{1}{2}at^2$. Set up positive first, keep signs

- **Two roots? Read the story**

  Up through the height, then back down. Pick the one that matches



$v^2 = u^2 + 2as$ **$s = ut + \frac{1}{2}at^2$** **$v = u + at$**

QUESTION

1

Level 2

4 marks

Exam standard

WORKBOOK

Page 2

UP NEXT

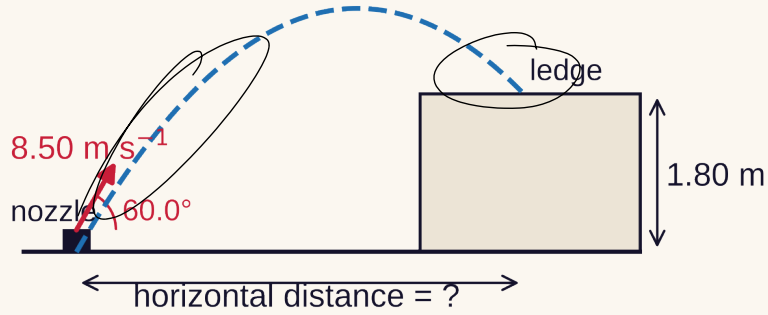
12:30
Electromagnetism
1:20 Break

Fountain jet onto a ledge

A fountain nozzle at ground level fires a jet of water at 8.50 m s^{-1} at 60.0° above the horizontal. The water lands on a flat ledge 1.80 m above the nozzle, while it is moving downwards. Ignore air resistance.

Determine the horizontal distance from the nozzle to where the water lands on the ledge. Show your working. [4]

Q1 Not to scale



$s_x = u_x t$

$= 8.50\cos(60°)(1.19)$

$= 5.07\text{ m}$

$u_x = 8.50\cos(60°)$

$=$

$u_y = 8.50\sin(60°)$

$=$

$s_y = u_y t + \frac{1}{2}at^2$

$1.80 = 8.50\sin(60°)t + \frac{1}{2}(-9.8)t^2$

$t = 1.19\text{ s}$ or 0.307 s

Workbook page 2. Try it on your own first.

WORKING

1

Level 2

4 marks

Exam standard

WORKBOOK

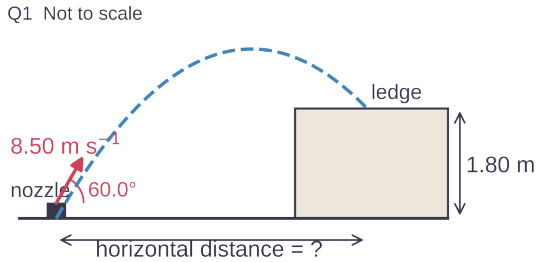
Page 2

UP NEXT

12:30
Electromagnetism
1:20 Break

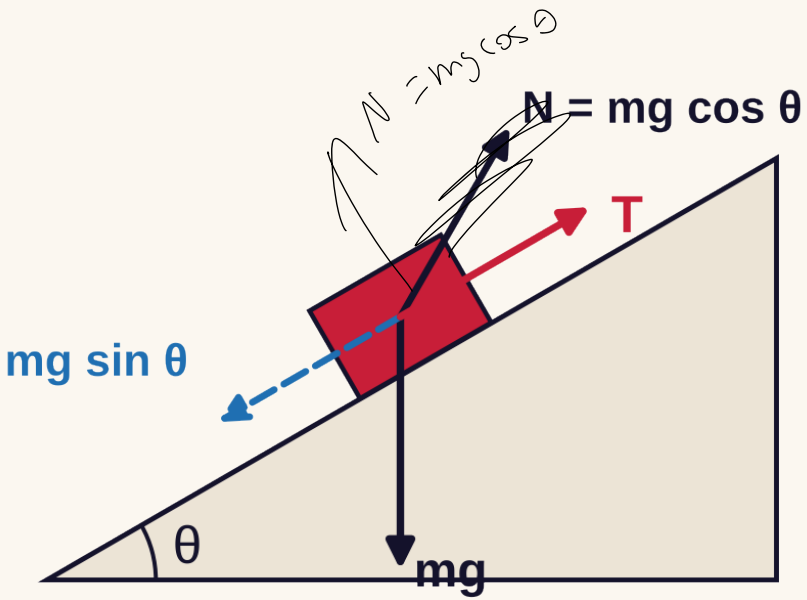
Fountain jet onto a ledge: working

Tutor works this one live. 4 marks



Slopes and tension

Resolve the weight, not the axes.



- **Along the slope: mg sin θ**

  This is a component of the weight, not an extra force

- **Into the slope: mg cos θ**

  On a frictionless slope the normal force balances it, so N = mg cos θ

- **Connected by a string?**

  Find the direction first, then a = net force ÷ total mass. Get T from one mass on its own

F = mg sin θ **N = mg cos θ** **Fnet = ma**

QUESTION

2

Level 2

4 marks

Exam standard

WORKBOOK

Page 3

UP NEXT

12:30
Electromagnetism
1:20 Break

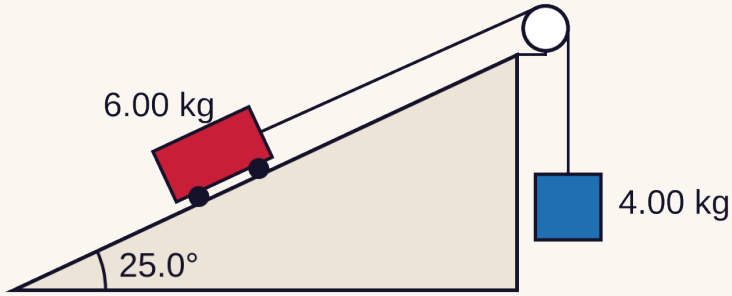
Trolley, ramp and pulley

A 6.00 kg trolley sits on a frictionless ramp inclined at 25.0° to the horizontal. A light string runs from the trolley, parallel to the ramp, over a frictionless pulley at the top, to a hanging 4.00 kg mass. The system is released from rest.

a) Determine the magnitude of the acceleration of the system. Show your working. [3]

b) Determine the tension in the string. [1]

Q2 Frictionless ramp and pulley



Workbook page 3. Try it on your own first.

WORKING

2

Level 2

4 marks

Exam standard

WORKBOOK

Page 3

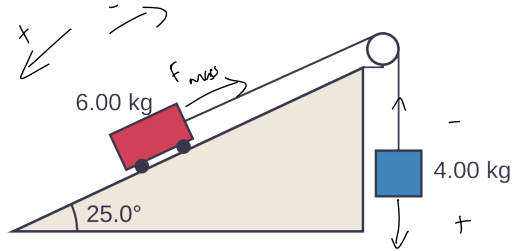
UP NEXT

12:30
Electromagnetism
1:20 Break

Trolley, ramp and pulley: working

Tutor works this one live. Parts: a) [3] b) [1]

Q2 Frictionless ramp and pulley



a) $F_{net} = F_{trolley} + F_{mass} =$

$F_{trolley} = mg\sin\theta$

$= 6g\sin 25°$

$= 24.8\,N$

$= -14.35\,N$

$F_{mass} = mg$

$= 4 \cdot 9.8$

$= -39.2\,N$

$\frac{F_{net}}{m_{total}} = a_{total} = \frac{-14.35}{10} = -1.44\,ms^{-2}$

$= 1.44\,ms^{-2}$

b) $F_{net} = mg - T$

$ma = mg - T$

$T = m(g-a)$

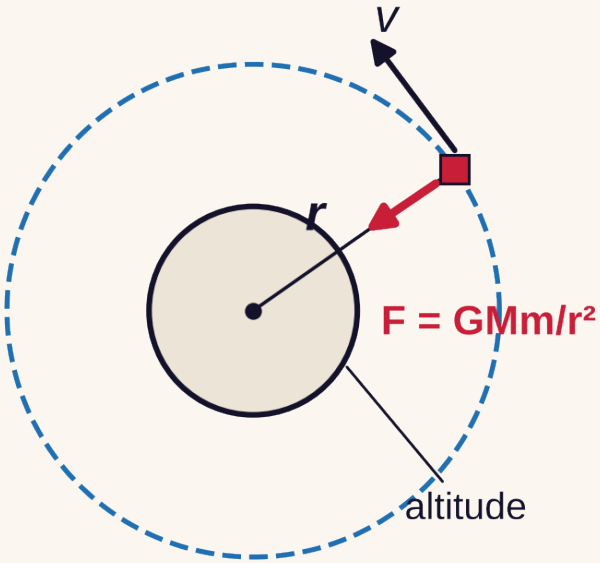
$= 4(9.8 - 1.44)$

$= 33.5\,N$

$$T = \frac{m_1 m_2 g(1+\sin\theta)}{(m_1+m_2)}$$

Circles and orbits

Centripetal force is not a new force. Something real supplies it.



r = planet radius + altitude

Hill crest: weight minus normal

mg − N = mv²/r. The car leaves the road when N = 0, so v = √(gr)

Orbit: gravity is the centripetal force

GMm/r² = mv²/r gives v = √(GM/r), and with v = 2πr/T, T²/r³ = 4π²/GM

$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

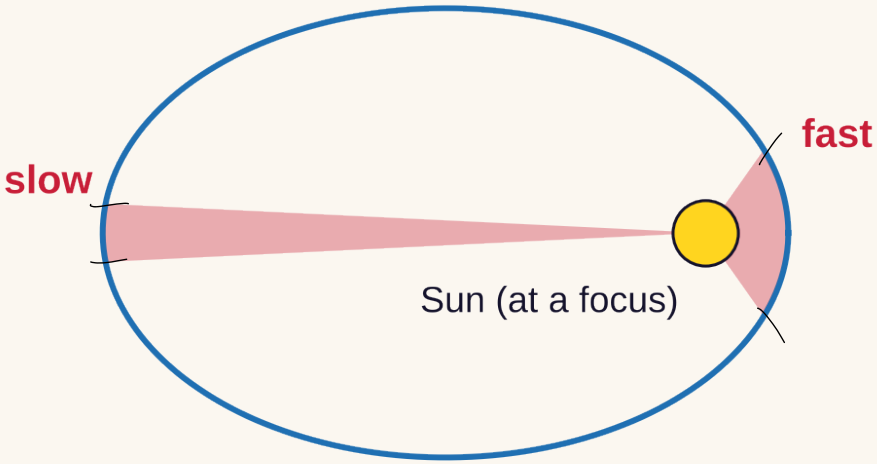
r is centre to centre

Add the planet's radius to the altitude. Subtract it at the end

v = 2πr/T **a = v²/r** **F = GMm/r²** **g = GM/r²**

Kepler's three laws of planetary motion

QCAA: 'State the three laws of planetary motion.'



Equal areas in equal times

1. Orbits are ellipses

with the Sun (or planet) at one focus

2. Equal areas in equal times

A line to the Sun sweeps equal areas, so a planet moves fastest when closest

3. $T^2 \propto r^3$

For everything orbiting the same body: $T^2/r^3 = 4\pi^2/GM$. A graph of r^3 against T^2 is a straight line

$$\frac{T^2}{r^3} = \frac{T^2}{r^3}$$

QUESTION

3

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 4

UP NEXT

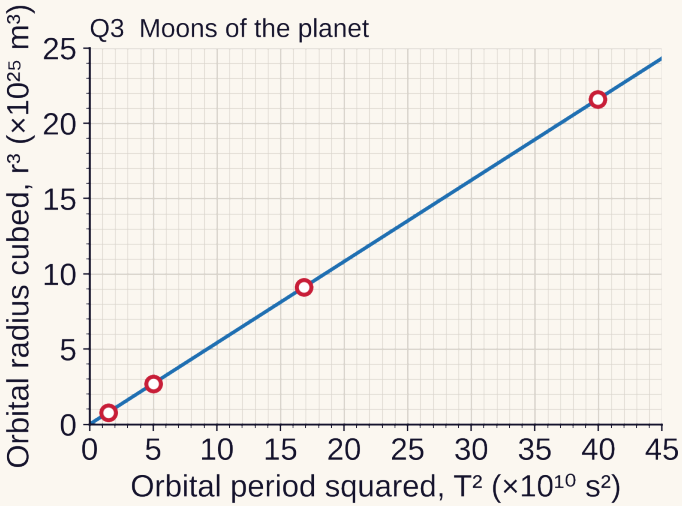
12:30
Electromagnetism
1:20 Break

Weighing a planet with its moons

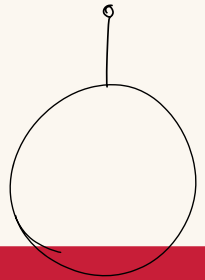
An astronomer measures the orbital radius r and period T of four moons of a gas giant planet. The graph shows r^3 against T^2 for the moons. The planet has a radius of 5.80×10^7 m and rotates once every 11.0 h.

a) Use the graph to determine the mass of the planet. Show your working. [4]

b) A satellite is to stay above the same point on the planet's equator. Determine its altitude above the planet's surface. [2]



Workbook page 4. Try it on your own first.



WORKING

3

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 4

UP NEXT

12:30
Electromagnetism
1:20 Break

Weighing a planet with its moons: working

Tutor works this one live. Parts: a) [4] b) [2]

$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$

$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$

$r^3 = \left(\frac{GM}{4\pi^2}\right) T^2$

$y = mx$

2

$(39.95 \cdot 10^{10},\ 21.6 \cdot 10^{25})$ $(0,0)$

$m = \frac{\Delta y}{\Delta x} = \frac{21.6 \cdot 10^{25}}{39.95 \cdot 10^{10}}$

$\frac{GM}{4\pi^2} = 5.41 \cdot 10^{14}$

$M = \frac{4\pi^2 \cdot 5.41 \cdot 10^{14}}{6.67 \cdot 10^{-11}}$

$= 3.2 \cdot 10^{26}$ kg

b) $11 \cdot 3600 = 3.96 \cdot 10^4$ s (60 · 60)

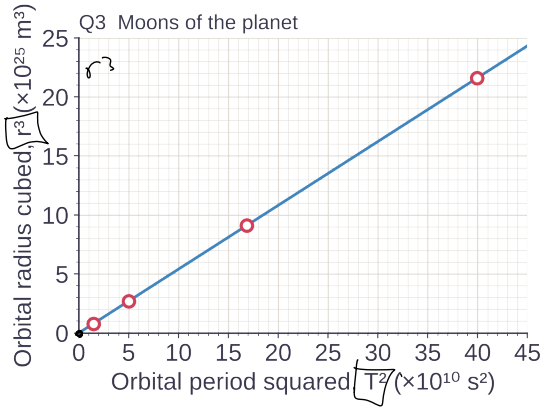
$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$

$r^3 = \frac{GM}{4\pi^2} \cdot T^2$

$r^3 = 5.41 \cdot 10^{14} \cdot (3.96 \cdot 10^4)^2$

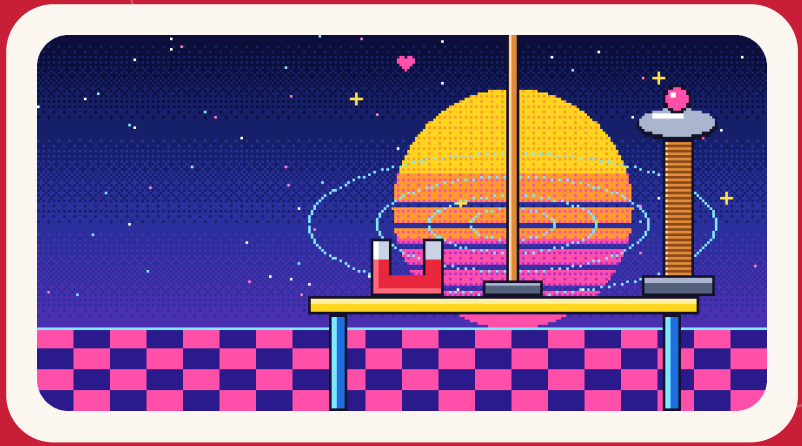
$r = \sqrt[3]{5.41 \cdot 10^{14} \cdot (3.96 \cdot 10^4)^2}$

$= 9.46 \cdot 10^7$ m $- 5.8 \cdot 10^7 = 3.66 \cdot 10^7$ m



BLOCK 2 OF 6 · 12:30 TO 1:20

Electromagnetism.



Julian + Tusho

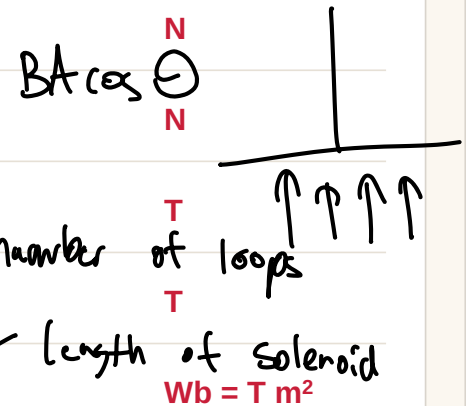
8 min of key ideas, then 7 questions (42 min)

MOST REQUESTED

Electromagnetism: formulas, units and traps

Every symbol has an SI unit. Convert to it before you substitute.

Electric field	$E = F/q = V/d$	$V\ m^{-1}$
Coulomb	$F = kq_1q_2/r^2$	N
Moving charge	$F = qvB \sin\theta$	N
Wire	$F = BIL \sin\theta$	N
Field of wire	$B = \mu_0 I / 2\pi r$	T
Solenoid	$B = \mu_0 nI$	T
Flux	$\Phi = B_\perp A$	$Wb = T\ m^2$
Faraday	$\varepsilon = -N\Delta\Phi/\Delta t$, $\varepsilon = BLv$	V



Common mistakes

✗ n vs N: in $B = \mu_0 nI$, n is turns PER METRE (N/L). In $\varepsilon = -N\Delta\Phi/\Delta t$, N is the number of turns

✗ cm and mm to metres first. 1 cm^2 = 1 × 10^{-4} m^2

✗ θ is between v (or I) and B. For flux, check plane vs normal

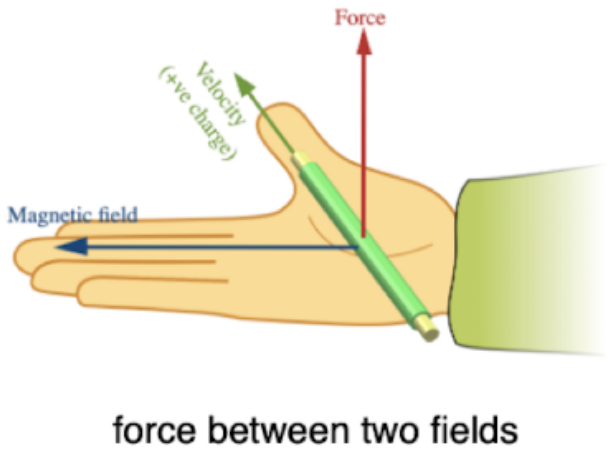
✗ Electron: do the hand rule, then reverse it

✗ Lenz opposes the CHANGE in flux, not the field

Two hand rules, two different jobs

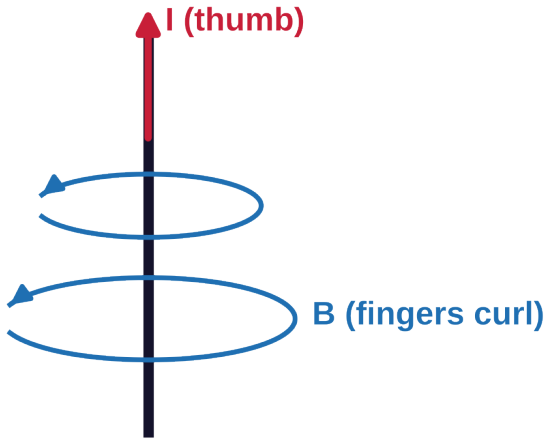
Use your RIGHT hand. Say the rule out loud as you do it.

Palm rule: which way is the FORCE?



Negative charge (electron): find the force, then reverse it.

Grip rule: which way is the FIELD?



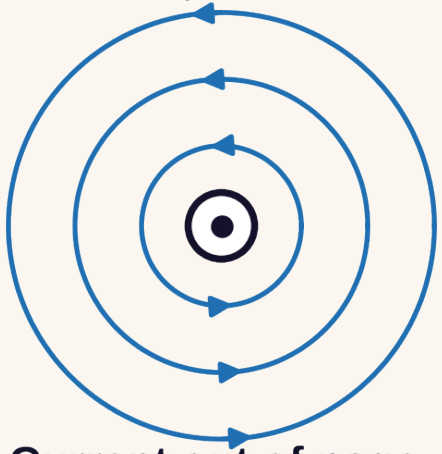
Seen from above: current out of page (•) gives an anticlockwise field

Solenoid: curl fingers with the current, thumb points to N.

Field patterns you must be able to draw

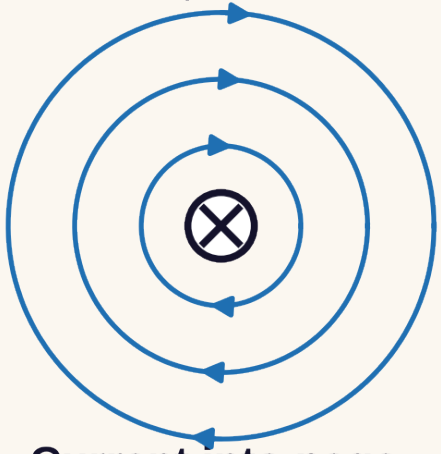
Dot (•) = out of the page, towards you. Cross (×) = into the page.

$B = \mu_0 I / 2\pi r$

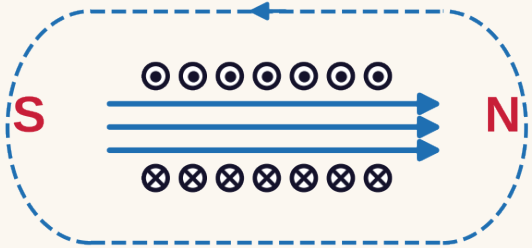


Current out of page: anticlockwise

$B = \mu_0 I / 2\pi r$



Current into page: clockwise



Solenoid: uniform inside
$B = \mu_0 n I$

Wire: $B = \mu_0 I/2\pi r$ **Solenoid: $B = \mu_0 n I$** **n = turns per metre**

QUESTION

4

Level 1

2 marks

Warm-up

WORKBOOK

Page 5

UP NEXT

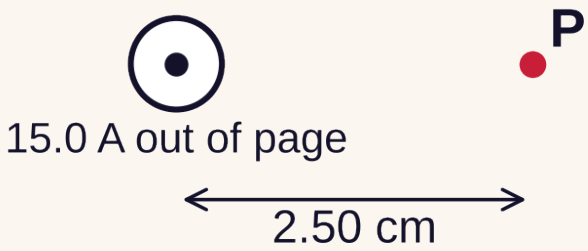
1:20 Break
1:30 Special relativity

Field near a straight wire

A long straight wire carries a current of 15.0 A directly out of the page. Point P is 2.50 cm to the right of the wire.

Determine the magnitude and direction of the magnetic field at P. [2]

Q4 View from above, looking at the page



Workbook page 5. Try it on your own first.

WORKING

4

Level 1

2 marks

Warm-up

WORKBOOK

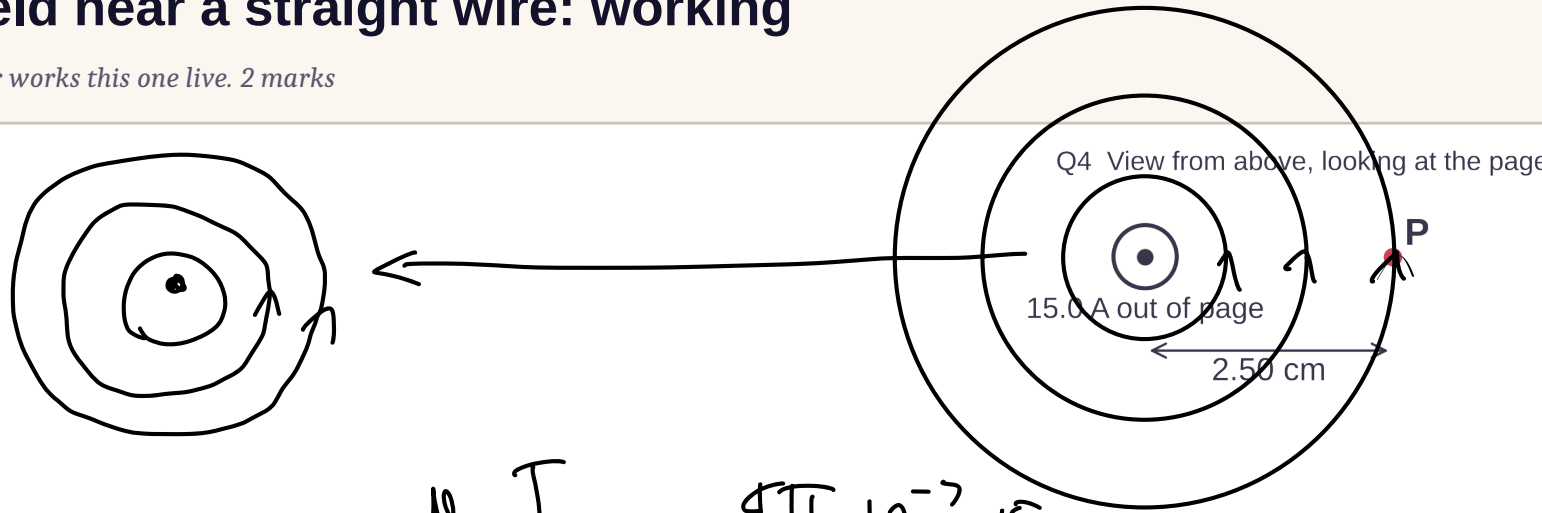
Page 5

UP NEXT

1:20 Break
1:30 Special relativity

Field near a straight wire: working

Tutor works this one live. 2 marks



$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi \cdot 10^{-7} \cdot 15}{2\pi \cdot (2.5 \cdot 10^{-2})} = 1.2 \cdot 10^{-4}\ \text{T}$$

QUESTION

5

Level 2

4 marks

Exam standard

WORKBOOK

Page 5

UP NEXT

1:20 Break
1:30 Special relativity

Proton crossing a field at an angle

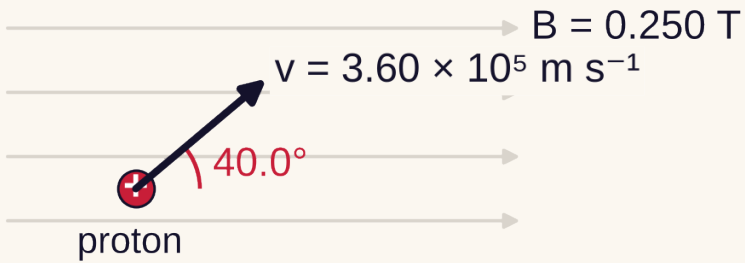
A proton moves in the plane of the page at 3.60×10^5 m s^{-1}. Its velocity is at 40.0° to a uniform 0.250 T magnetic field, which points to the right in the plane of the page.

a) Calculate the magnitude of the magnetic force on the proton. [2]

b) Determine the direction of the force at this instant. [1]

c) An electron moves with the same velocity. State how the force on it compares with the force on the proton. [1]

Q5 All vectors in the plane of the page



Workbook page 5. Try it on your own first.

WORKING

5

Level 2

4 marks

Exam standard

WORKBOOK

Page 5

UP NEXT

1:20 Break
1:30 Special relativity

Proton crossing a field at an angle: working

Tutor works this one live. Parts: a) [2] b) [1] c) [1]

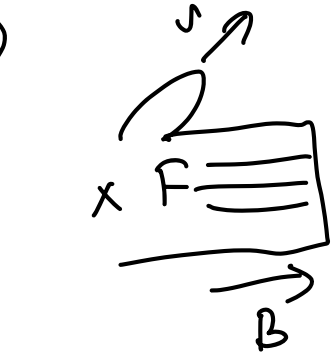
a)

$F = qvB\sin\theta$

$= 1.60\times10^{-19} \times 3.6\cdot10^{5} \cdot 0.25 \cdot \sin 40°$

$= 9.26\cdot10^{-15}\ N$

b)

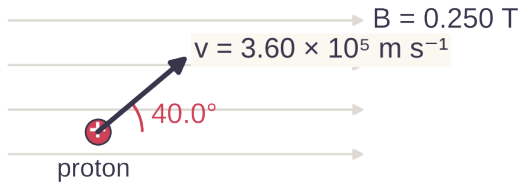


force into page

c) changes direction of force

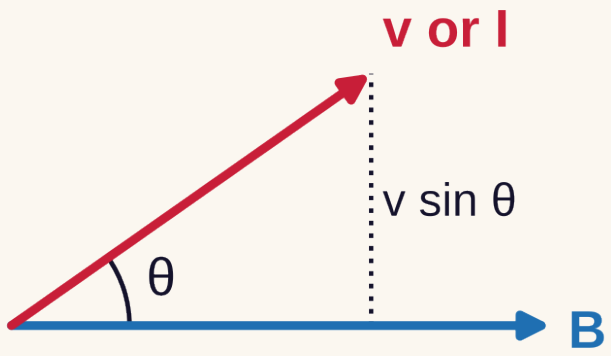
↳ out of page

Q5 All vectors in the plane of the page



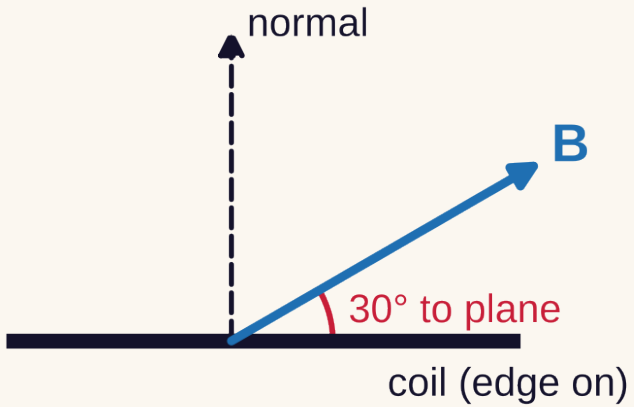
Angles in the formulas: the biggest trap

Two different angles. Always check which one the question gives you.



F = qvB sin θ **F = BIL sin θ**

θ is between the velocity (or current) and the field



Φ = B⊥A = BA sin(angle to plane)

= BA cos(angle to normal). Draw the normal first.

θ = 90°: maximum force **θ = 0°: no force** **plane ⊥ field: maximum flux**

QUESTION

6

Level 2

4 marks

Exam standard

WORKBOOK

Page 6

UP NEXT

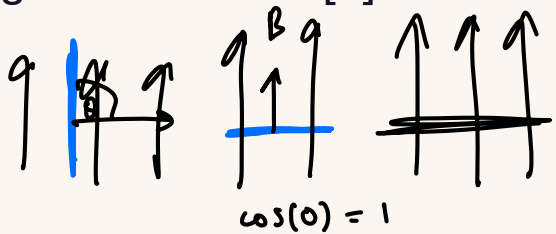
1:20 Break
1:30 Special relativity

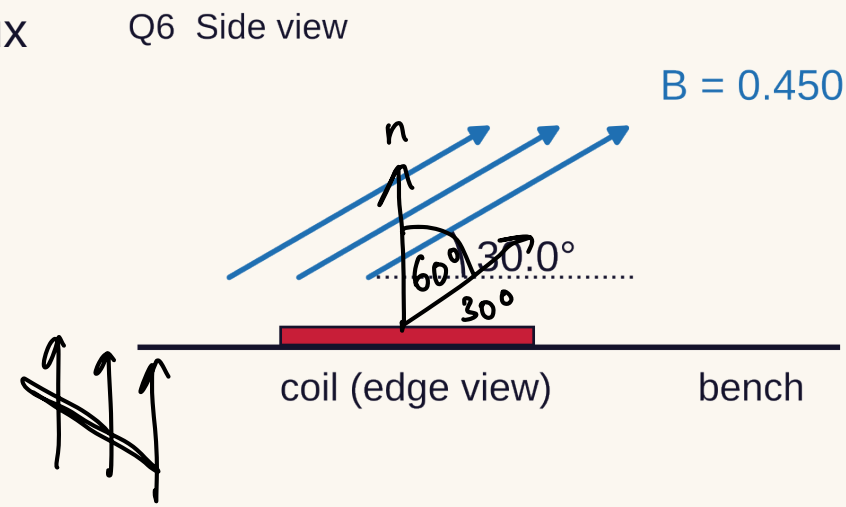
Tilting a coil: the angle trap

A square coil of 80 turns and side length 6.00 cm lies flat on a horizontal bench. A uniform 0.450 T magnetic field is directed at 30.0° above the horizontal. In 0.120 s the coil is rotated until its plane is perpendicular to the field.

a) Calculate the initial magnetic flux through one turn of the coil. [2]

b) Calculate the magnitude of the average emf induced in the coil during the rotation. [2]





Workbook page 6. Try it on your own first.

WORKING

6

Level 2

4 marks

Exam standard

WORKBOOK

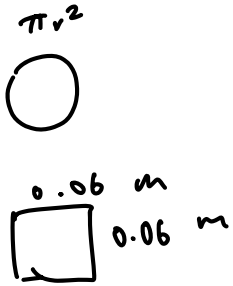
Page 6

UP NEXT

1:20 Break
1:30 Special relativity

Tilting a coil: the angle trap: working

Tutor works this one live. Parts: a) [2] b) [2]



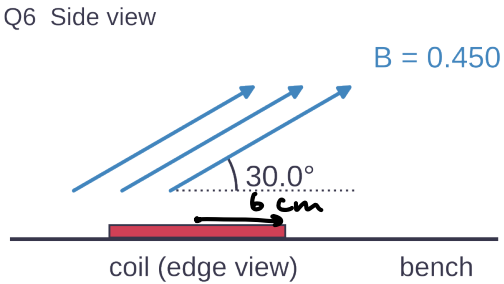
a) initial flux: $\phi = BA\cos\theta$

$\theta = 60^\circ$

$B = 0.450\ T$

$A = 0.06^2$

$\phi = 0.45 \times 0.06^2 \cos(60^\circ) = 8.1 \times 10^{-4}\ Wb$



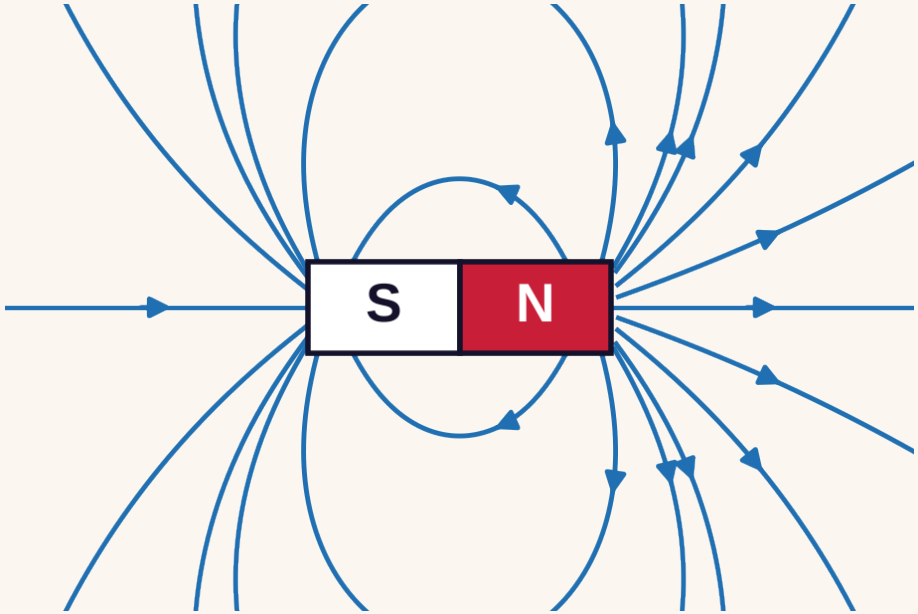
b) $emf = -N\frac{\Delta\phi}{\Delta t}$ θ changes

$= -N\frac{BA(\cos\theta_f - \cos\theta_i)}{\Delta t} = -80\frac{0.045 \times 0.06^2(\cos(0) - \cos(60))}{0.12}$

$= 0.540\ V$

Bar magnets

QCAA: sketch field lines due to currents, moving charges and magnets.



Out of N, into S

Outside the magnet the lines run from the N pole to the S pole. Inside, S to N, so every line is a closed loop

Never cross, closest at the poles

Line spacing shows strength: the field is strongest at the poles and weakens quickly with distance

Coils act like bar magnets

Grip rule: curl your fingers with the current, and your thumb points to the coil's N end. Lenz uses this

Faraday, then Lenz

Faraday tells you how big. Lenz tells you which way.

1
Flux changes

$\Phi = B\perp A$: field, area or angle changes

→

2
emf is induced

$\varepsilon = -N\Delta\Phi/\Delta t$ or $\varepsilon = BLv$

→

3
Current flows

$I = \varepsilon/R$ if the circuit is closed

→

4
Opposes it

Its own field fights the change in flux

Lenz in three questions

1. What is changing? (flux into the page is increasing)
2. Which way must the induced field point to oppose it? (out of the page)
3. Grip rule: which way does the current flow to make that field? (anticlockwise)

QUESTION

7

Level 2

5 marks

Exam standard

WORKBOOK

Page 6

UP NEXT

1:20 Break
1:30 Special relativity

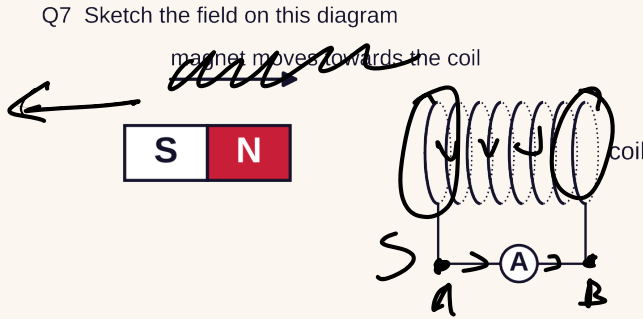
Bar magnet into a coil

The north pole of a bar magnet is pushed towards one end of a coil. The coil is connected to a sensitive ammeter.

a) On the diagram, sketch the magnetic field around the bar magnet. Show at least six field lines with their direction. [2]

b) Use Lenz's law to determine whether the end of the coil nearest the magnet becomes a north or a south pole while the magnet approaches. Justify your answer. [2]

c) State one change that would produce a larger induced current, and explain why it works. [1]



Workbook page 6. Try it on your own first.

WORKING

7

Level 2

5 marks

Exam standard

WORKBOOK

Page 6

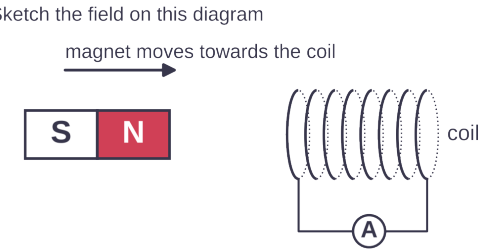
UP NEXT

1:20 Break
1:30 Special relativity

Bar magnet into a coil: working

Tutor works this one live. Parts: a) [2] b) [2] c) [1]

Q7 Sketch the field on this diagram



QUESTION

8

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 7

UP NEXT

1:20 Break
1:30 Special relativity

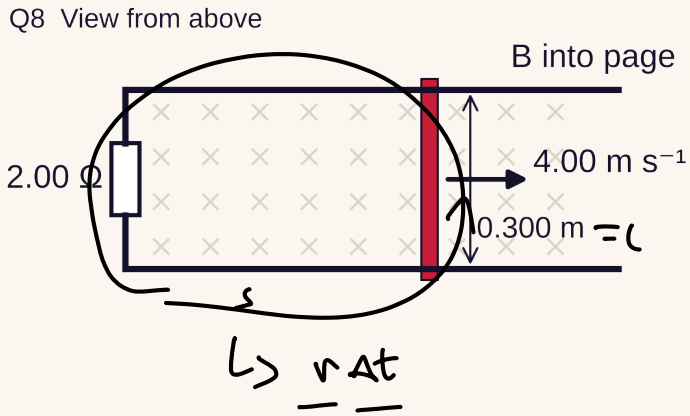
Rod sliding on rails

A metal rod of length 0.300 m slides to the right at a constant 4.00 m s^{-1} along two horizontal conducting rails. The rails are joined on the left by a 2.00 Ω resistor. A uniform magnetic field points into the page. A voltmeter across the rod reads 0.180 V. Ignore the resistance of the rod and rails.

a) Determine the magnetic field strength. [2]

b) Use Lenz's law to determine the direction of the current in the rod (towards the top or bottom of the page). Justify your answer. [2]

c) Determine the force needed to keep the rod moving at constant speed. [2]



Workbook page 7. Try it on your own first.

WORKING

8

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 7

UP NEXT

1:20 Break
1:30 Special relativity

Rod sliding on rails: working

Tutor works this one live. Parts: a) [2] b) [2] c) [2]

a) $A = l v \Delta t$

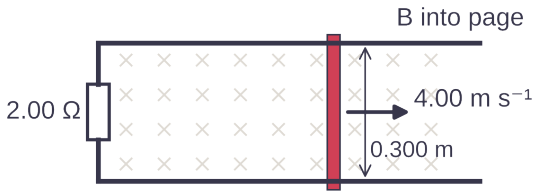
$\text{emf} = -N \frac{B A \cos\theta}{\Delta t}$ → $\theta = 0$

$= -\frac{B l v \Delta t}{\Delta t}$

$\text{emf} = Blv$

$B = \frac{\text{emf}}{lv} = \frac{0.18}{0.3 \cdot 4} = 0.15\ T$

Q8 View from above



b)

c) $I = \frac{V}{R} = \frac{0.18}{2} = 0.09\ A$

$\theta = 90°$

$F = BIL \sin\theta$

$= BIL = 0.15 \cdot 0.09 \cdot 0.3$

$= 4.05 \cdot 10^{-3}\ N$

Electric field vs magnetic field

Two different fields. Know the definitions and what each one can push.

Electric field (E)

A region where a charged object experiences a force

Pushes charges at rest AND moving: F = qE

Direction: the force on a POSITIVE charge. Lines start on + and end on −

Between parallel plates: uniform, E = V/d

Units: N C^{-1} (same as V m^{-1})

Magnetic field (B)

A region where a moving charge, a current or a magnet experiences a force

Pushes MOVING charges only: F = qvB sin θ, so F = 0 if v = 0 or v ∥ B

Lines are closed loops: out of N, into S outside a magnet

Made by currents and moving charges (and magnets)

Units: tesla (T)

A charge at rest in a magnetic field feels NO force **That is Q10 d)**

QUESTION

9

Level 3

5 marks

Hardest: new context

WORKBOOK

Page 8

UP NEXT

1:20 Break
1:30 Special relativity

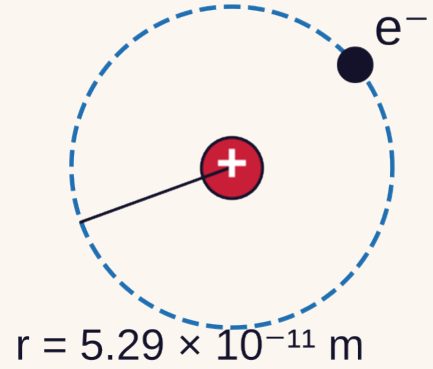
Inside a hydrogen atom

In the Bohr model, the electron in a hydrogen atom's ground state moves in a circle of radius 5.29×10^{-11} m around the proton. The electrostatic attraction provides the centripetal force. Use $1/(4\pi\varepsilon_0) = 8.99 \times 10^{9}$ N m^2 C^{-2}.

a) Show that the speed of the electron is about 2.2×10^{6} m s^{-1}. [3]

b) Hence calculate the kinetic energy of the electron, in eV. [2]

Q9 Not to scale



Workbook page 8. Try it on your own first.

WORKING

9

Level 3

5 marks

Hardest: new context

WORKBOOK

Page 8

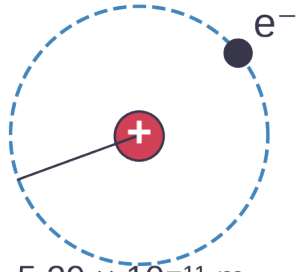
UP NEXT

1:20 Break
1:30 Special relativity

Inside a hydrogen atom: working

Tutor works this one live. Parts: a) [3] b) [2]

Q9 Not to scale



$r = 5.29 \times 10^{-11}$ m

QUESTION

10

Level 3

7 marks

Hardest: new context

WORKBOOK

Page 9

UP NEXT

1:20 Break
1:30 Special relativity

Holding a droplet with an electric field

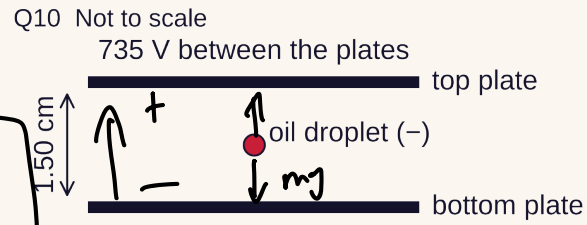
A tiny negatively charged oil droplet of mass 3.20×10^{-15} kg floats at rest between two horizontal metal plates 1.50 cm apart when the potential difference between them is 735 V.

a) Determine the magnitude of the charge on the droplet, and the number of excess electrons it carries. [3]

b) Determine which plate is positive. Justify your answer. [1]

c) The potential difference is increased to 980 V. Determine the magnitude and direction of the droplet's acceleration. [2]

d) Explain why a magnetic field could not hold this droplet at rest. [1]



Workbook page 9. Try it on your own first.

WORKING

10

Level 3

7 marks

Hardest: new context

WORKBOOK

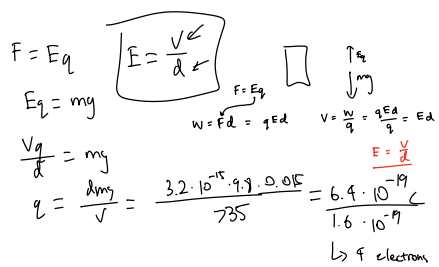
Page 9

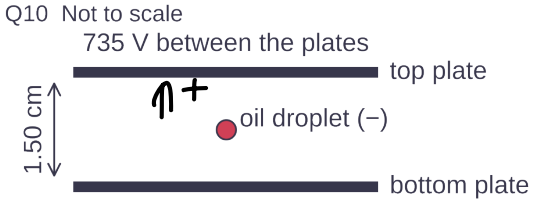
UP NEXT

1:20 Break
1:30 Special relativity

Holding a droplet with an electric field: working

Tutor works this one live. Parts: a) [3] b) [1] c) [2] d) [1]





$$F_{net} = Eq - mg$$

$$= \frac{Vq}{d} - mg$$

$$= \frac{980 \cdot 6.4 \cdot 10^{-19}}{0.015} - 3.2 \cdot 10^{-15} \cdot 9.9$$

$$= +1.05 \cdot 10^{-14}\ N \text{ upwards}$$

$$\frac{F}{m} = a$$

$$\frac{1.05 \cdot 10^{-14}}{3.2 \cdot 10^{-15}} = 3.27\ ms^{-2}$$

LOCUS

BREAK 1 · 30 SECONDS

Quick check-in

Vibe check, pace, and a shout out for any tutor who helped. Then go grab some water.

Anonymous · scan with your phone camera



SCAN ME

Up next: Special relativity

10 MIN BREAK

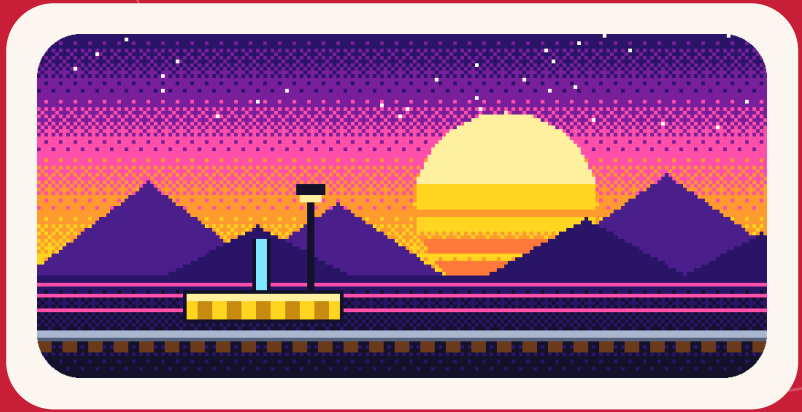
Break + Krillion

Back at 1:30 for special relativity

Stretch, drink some water, and look back at one question you got wrong.

BLOCK 3 OF 6 · 1:30 TO 1:55

Special *relativity.*



Himank + Imira

5 min of key ideas, then 3 questions (20 min)

Postulates of Special Relativity

1st postulate:

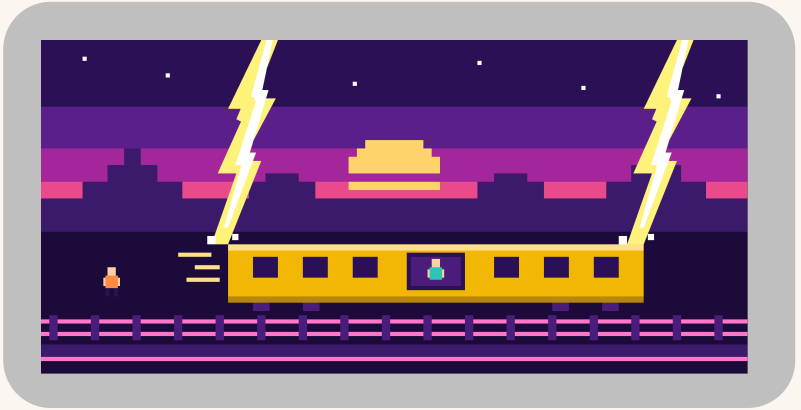
1. The laws of physics are the same for all inertial frames of reference.

- **No preferred frame of reference**
- **Experimental results are identical**

2nd postulate:

2. The speed of light in a vacuum is constant for all observers in any inertial frame of reference ($c = 3 \times 10^8\ ms^{-1}$).

Relativity of simultaneity



Alice: observes both lightning strikes at the same time

Bob: observes the rear lightning strike first

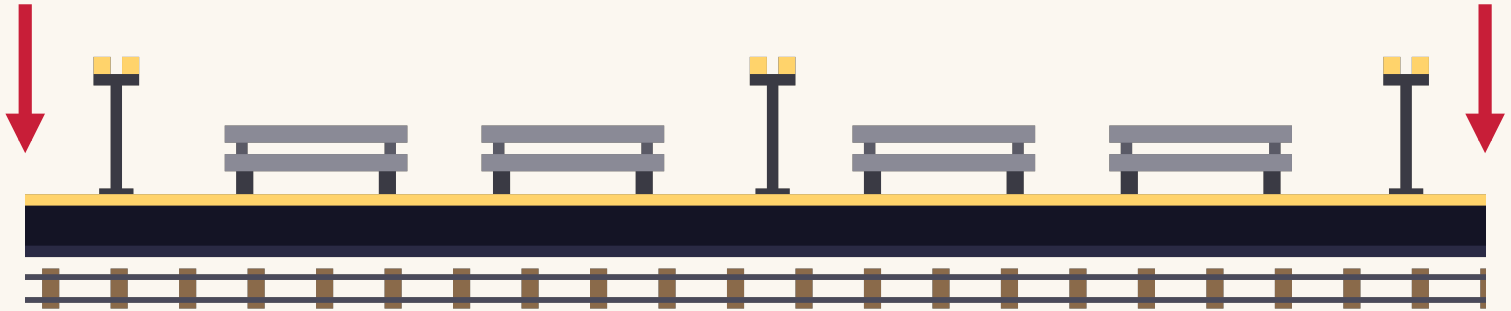
Who’s right?
Both!

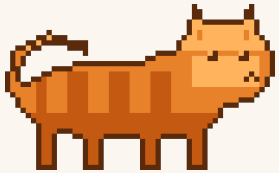
Describe the concept:

Two events that are simultaneous in one inertial frame are not necessarily simultaneous in another inertial frame. Simultaneity is not absolute.

Who measures proper time (t_0) ???

Scenario 1: How long does cat take to pass platform





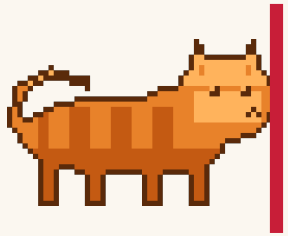


0.8c

Reference frames

Cat

Start + stop

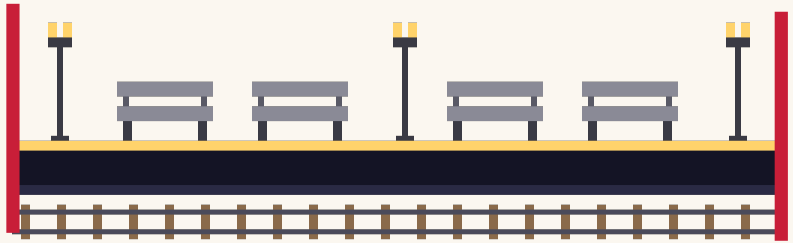


Same location → Proper time

t_0

Platform

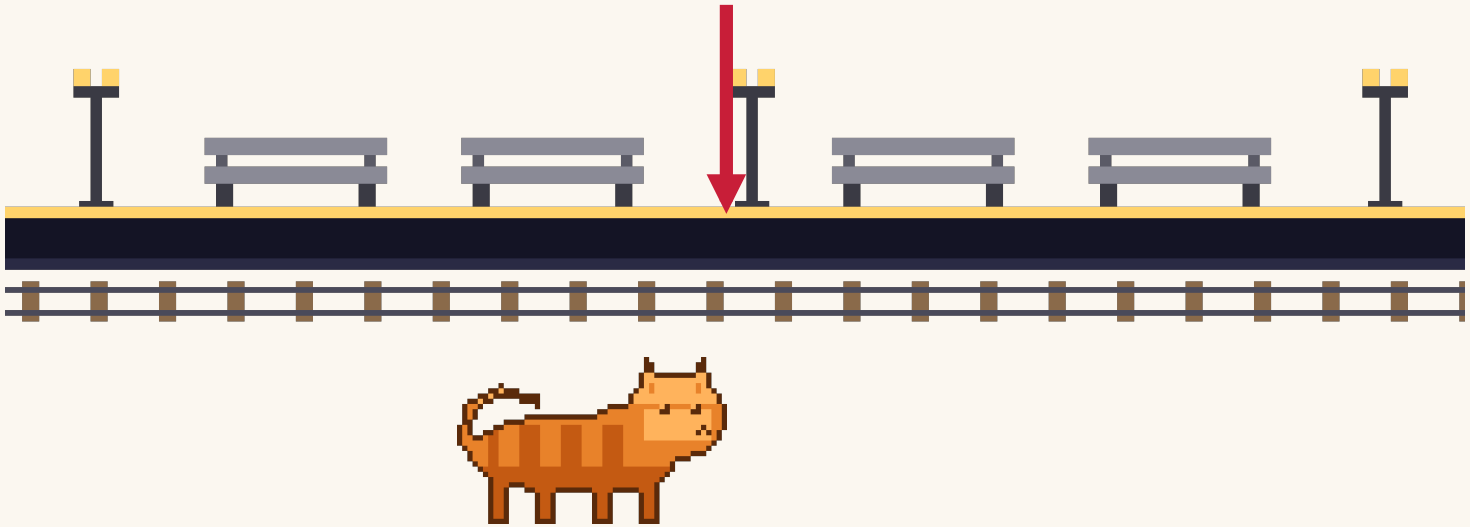
Start Stop



Different locations → Dilated time

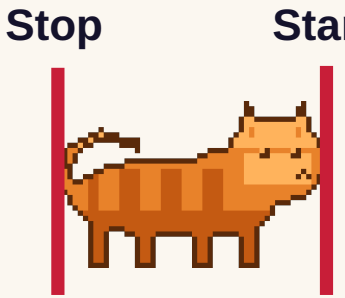
t

Scenario 2: How long does cat take to cross halfway



Reference frames

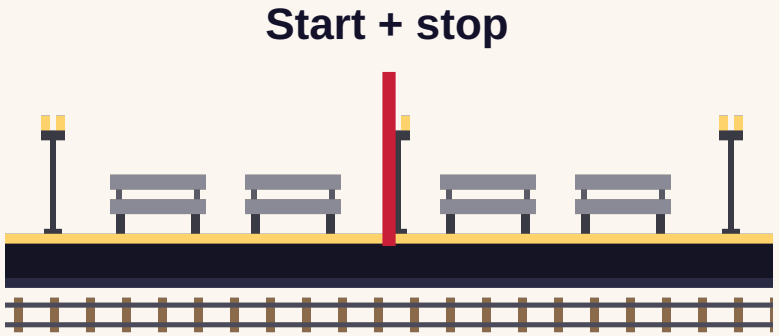
Cat



Different locations → **Dilated time**

t

Platform



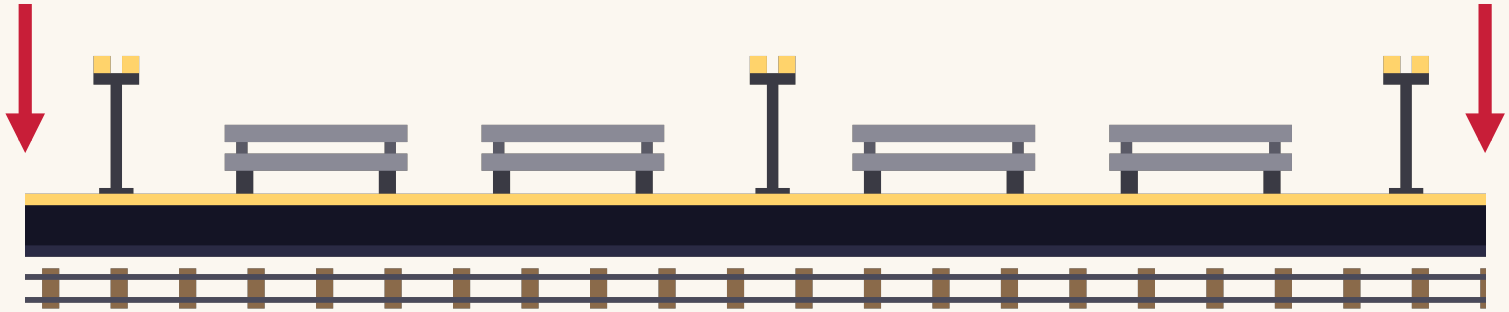
Same location → **Proper time**

t_0

Proper time: time interval between two events that occur at the same location in an inertial reference frame

Who measures proper length (L_0) ???

Scenario 1: How long does cat take to pass platform





0.8c

L_0

Reference frames

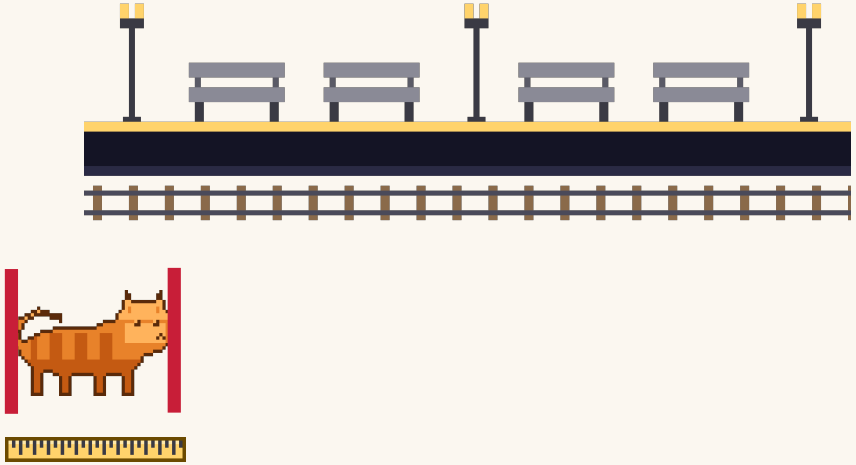
Cat

Points at rest relative to cat



Proper length

Platform



Contracted length

Proper length: distance between two points measured in an inertial reference frame at rest relative to both points

dilated (

proper (

$$t = \frac{t_0}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

Dilated time > Proper time

$t = \gamma t_0 \,, \quad L = \frac{L_0}{\gamma}$

contracted (

$$L = L_0 \sqrt{\left(1 - \frac{v^2}{c^2}\right)}$$

(proper

Contracted length < Proper length

$$\gamma = \frac{1}{\sqrt{\left(1 - \frac{v^2}{c^2}\right)}}$$

Lorentz Factor (≥1)

QUESTION

11

Level 1

2 marks

Warm-up

WORKBOOK

Page 10

UP NEXT

1:55 Quantum theory

2:20 Break

The speed limit

No spacecraft, however powerful, can be accelerated to the speed of light.

Explain why an object with mass cannot reach the speed of light. [2]

$$p = \frac{m_0 v}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{m_0 v}{\sqrt{1 - \frac{c^2}{c^2}}}$$

0

Workbook page 10. Try it on your own first.

WORKING

11

Level 1

2 marks

Warm-up

WORKBOOK

Page 10

UP NEXT

1:55 Quantum theory
2:20 Break

The speed limit: working

Tutor works this one live. 2 marks

Three paradoxes, one fix: think about frames

QCAA has asked all three: twins (2020), simultaneity (2022), ladder and barn (2025).

The twins

The travelling twin's clock is the moving clock, so she measures the proper time and ages less. Her clock reads less, so she is younger when she returns.

Ladder in the barn

Barn frame: the ladder is contracted and fits. Runner frame: the barn is contracted. Both are right because the frames disagree on whether the doors shut at the same time.



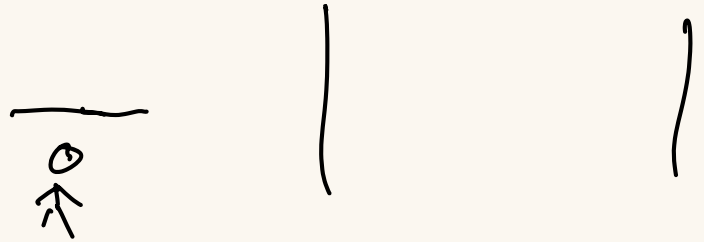
Light on a train

A flash in the middle of a carriage hits both ends together for a passenger. A platform observer sees the rear move towards the light, so it is hit first. Simultaneity is relative.



General framework for paradoxes

Step 1: Describe the paradox



Step 2: Explain what is observed in reference frame A

Step 3: Explain what is observed in reference frame B

Step 4: Use theory of special relativity (postulates, relativity of simultaneity, time dilation/length contraction, calculations)

Step 5: Conclusion

QUESTION

12

CF

4 marks

Complex familiar

WORKBOOK

Page 10

UP NEXT

1:55 Quantum theory

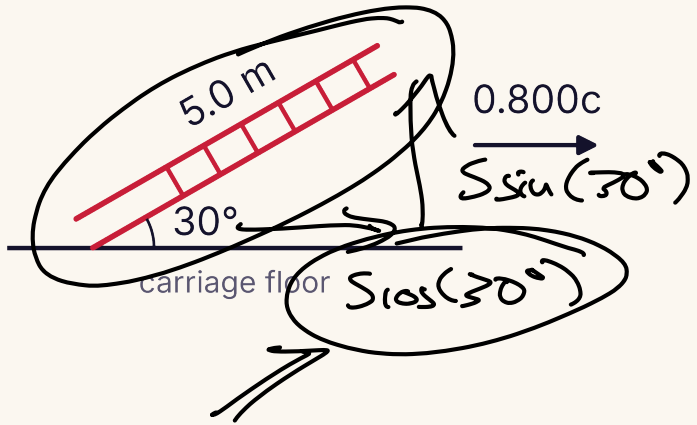
2:20 Break

The tilted ladder

A passenger on a train holds a 5.0 m ladder tilted at 30° above the carriage floor (both measured in the train's frame). The train passes a platform at 0.800c, and an observer on the platform measures the ladder.

a) Determine the length of the ladder as measured from the platform. [2]

b) Determine the angle the ladder makes with the horizontal as measured from the platform. [2]



$L = L_0\sqrt{1-(v/c)^2}$

$= 5\sqrt{1-(0.8)^2}$

$L = 5\cos(30)\sqrt{1-(0.8)^2}$

$= 2.6$

Workbook page 10. Try it on your own first.

WORKING

12

CF

4 marks

Complex familiar

WORKBOOK

Page 10

UP NEXT

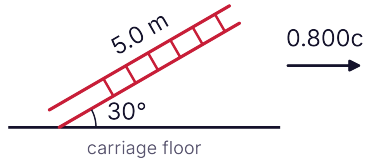
1:55 Quantum theory

2:20 Break

The tilted ladder: working

Tutor works this one live. Parts: a) [2] b) [2]

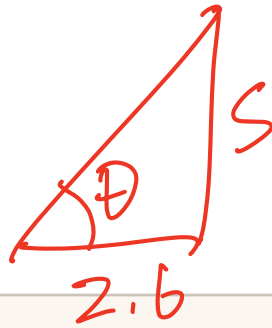




$r = \sqrt{2.6^2 + (5\sin(30))^2}$

$=$ ~

b)



$\theta = \tan^{-1}\left(\frac{5\sin(30^\circ)}{2.6}\right)$

$=$ ~

QUESTION

13

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 11

UP NEXT

1:55 Quantum theory

2:20 Break

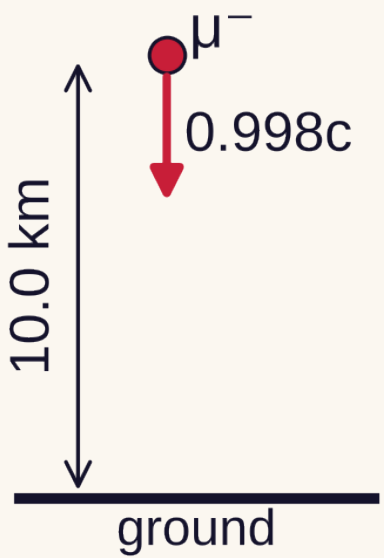
Muons that should not make it

Muons are created 10.0 km above the ground and travel straight down at 0.998c. The mean lifetime of a muon, measured at rest, is 2.20 μs.

a) Show that the Lorentz factor for these muons is about 15.8. [1]

b) Using Earth's frame, determine whether a typical muon reaches the ground. [2]

c) Using the muon's frame, determine the thickness of atmosphere the muon must cross, and explain why this frame reaches the same conclusion. [3]



Workbook page 11. Try it on your own first.

WORKING

13

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 11

UP NEXT

1:55 Quantum theory
2:20 Break

Muons that should not make it: working

Tutor works this one live. Parts: a) [1] b) [2] c) [3]

$y = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}}$

$= \frac{1}{\sqrt{1-0.998^2}}$

$= 15.82$

$t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}$

$t = 2.2\times10^{-6} \times 15.82$

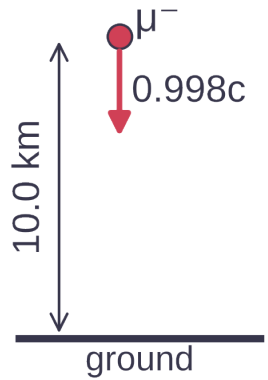
$= 34.8\ \mu s$

$d = vt$ ↓

$= 0.998 \times 3\times10^8$

$\times 34.8\times10^{-6}$

$= 1.04\times10^4$



$L = L_0\sqrt{1-\frac{v^2}{c^2}}$

$= 10000/15.82$

$= 632\text{m}$

$t_0 \times v = d$

$2.2\times10^{-6} \times (0.998c) = 659\text{m}$

Locus

BREAK 2 · 2 MINUTES

Halfway check-in

How it's going, plus a few quick questions to help us plan small classes next year.

Anonymous · scan with your phone camera



Up next: Standard Model

BLOCK 4 OF 6 · 1:55 TO 2:20

Quantum *theory.*



Himank + Julian

5 min of key ideas, then 3 questions (20 min)

Which formula, when?

Read what the question GIVES you, then pick the row.

Wavelength or frequency of light	$E = hf = hc/\lambda$
Light hits a metal, electrons come out	$E_k = hf - W$
Stopping voltage	$E_{k(max)} = qV_0$
Peak wavelength or temperature	$\lambda_{max} = b/T$
Electron jumps between levels	$\Delta E = E(upper) - E(lower) = hf$
Answer in eV, data in J (or reverse)	$1\ eV = 1.60 \times 10^{-19}\ J$

QUESTION

14

Level 1

2 marks

Warm-up

WORKBOOK

Page 12

UP NEXT

2:20 Break
2:30 Standard Model

Photoelectrons from potassium

Photons of energy 3.20 eV strike a potassium surface, which has a work function of 2.30 eV.

Calculate the maximum kinetic energy of the emitted photoelectrons in joules, and the stopping voltage. [2]

$E_K = 3.20\ eV$

$W = 2.30$

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

$E_n = hf - W$

$= 3.20 - 2.30$

$= 0.90\ eV$

$0.90 \times 1.60 \times 10^{-19} =$

Workbook page 12. Try it on your own first.

WORKING

14

Level 1

2 marks

Warm-up

WORKBOOK

Page 12

UP NEXT

2:20 Break
2:30 Standard Model

Photoelectrons from potassium: working

Tutor works this one live. 2 marks

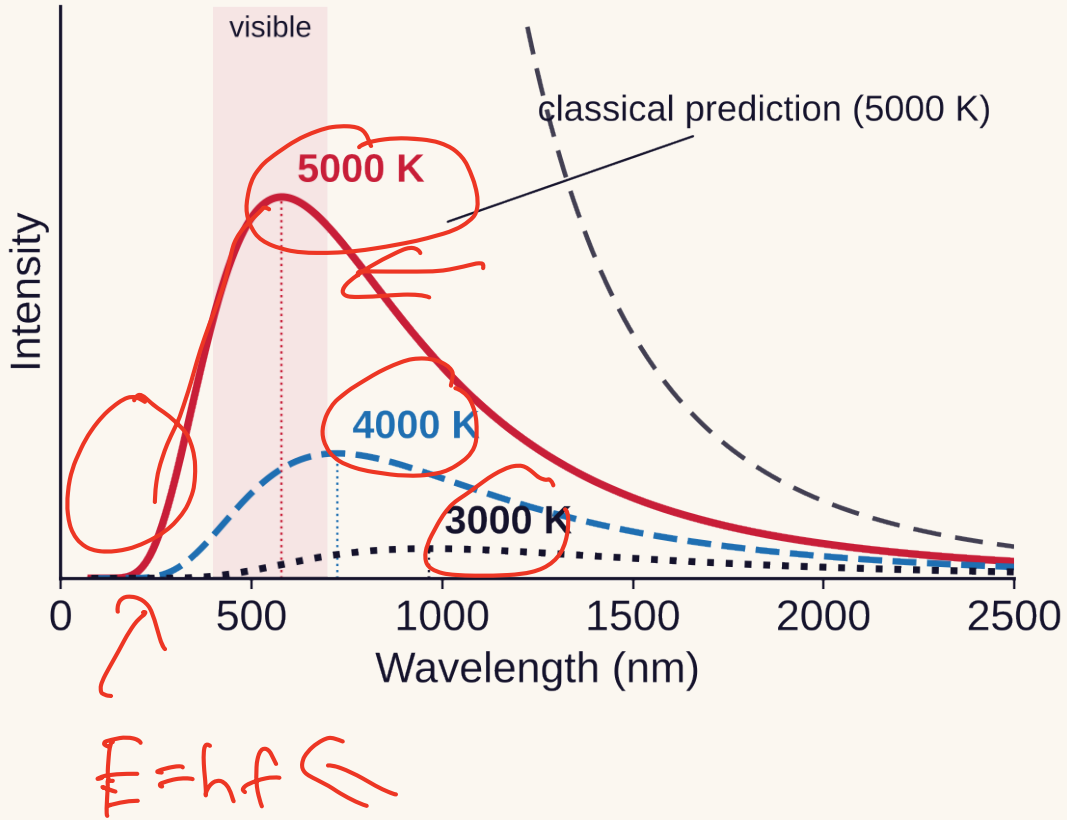
cutoff voltage $(V_0) = \frac{E_K}{q}$

$= \frac{1.44 \times 10^{-19}}{1.6 \times 10^{-19}}$

$= \boxed{0.90\,V}$

Black body radiation

Hotter means brighter at every wavelength, and a bluer peak.



Peak shifts left as T rises

λmax = b/T, b = 2.898 × 10^{-3} m K

Classical physics failed

Predicted intensity → ∞ at short λ: the ultraviolet catastrophe

Planck: energy comes in quanta

E = hf. High f needs big quanta, which are rarely emitted, so the curve falls to zero

QUESTION

15

Level 2

4 marks

Exam standard

WORKBOOK

Page 12

UP NEXT

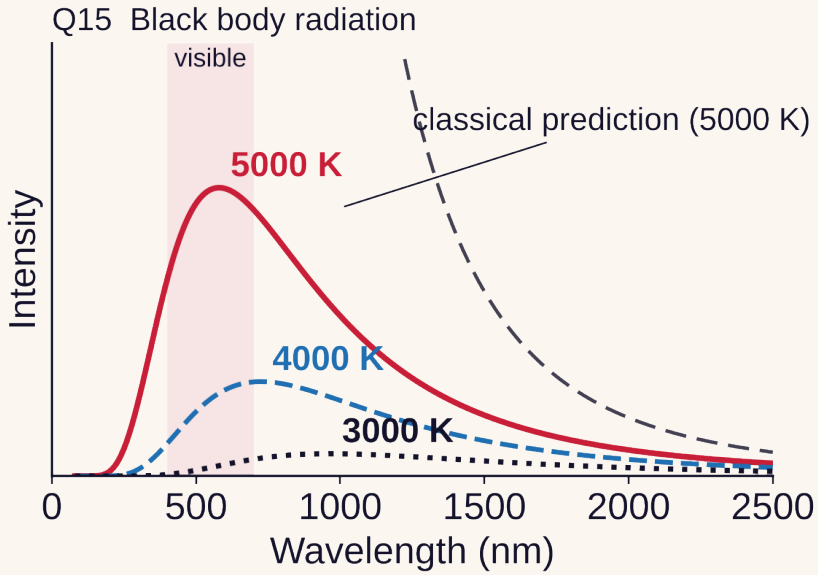
2:20 Break
2:30 Standard Model

Reading black body curves

The graph shows the measured intensity of radiation emitted by a black body at three temperatures. The dashed line shows the classical prediction for the 5000 K curve.

a) Describe how the shape of the curve changes as the temperature increases. [2]

b) Explain how Planck's idea of quantised energy resolved the difference between the classical prediction and the measured curve at short wavelengths. [2]



Workbook page 12. Try it on your own first.

WORKING

15

Level 2

4 marks

Exam standard

WORKBOOK

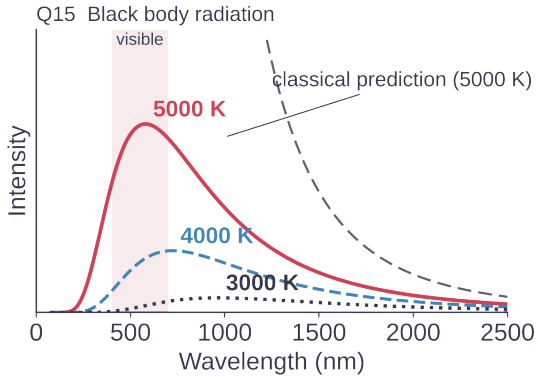
Page 12

UP NEXT

2:20 Break
2:30 Standard Model

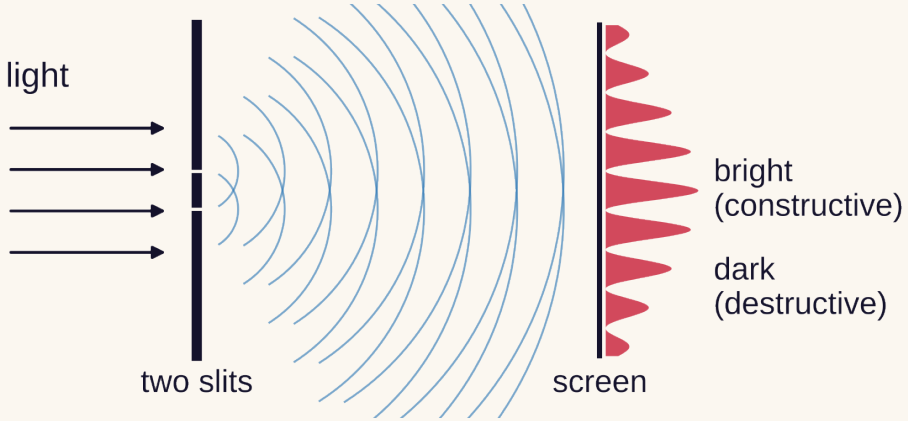
Reading black body curves: working

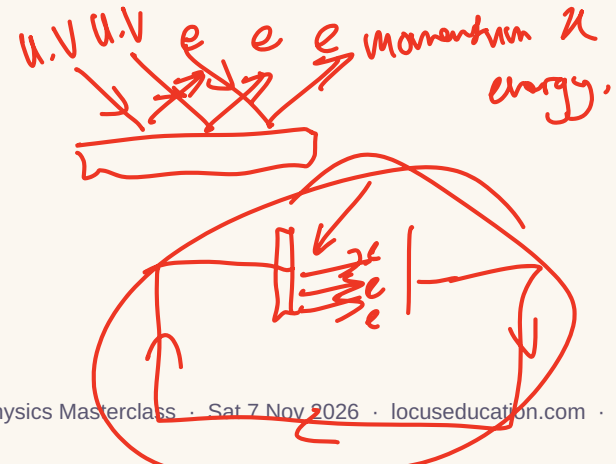
Tutor works this one live. Parts: a) [2] b) [2]



Wave or particle? The two key experiments

QCAA asks you to explain how each one is evidence.





- **Double slit: light is a WAVE**

  Light diffracts through both slits and interferes: bright fringes where waves add, dark where they cancel. Particles would only make two bands

- **Photoelectric effect: light is a PARTICLE**

  One photon frees at most one electron. Below the threshold frequency nothing is emitted, however bright the light. Ek(max) = hf − W

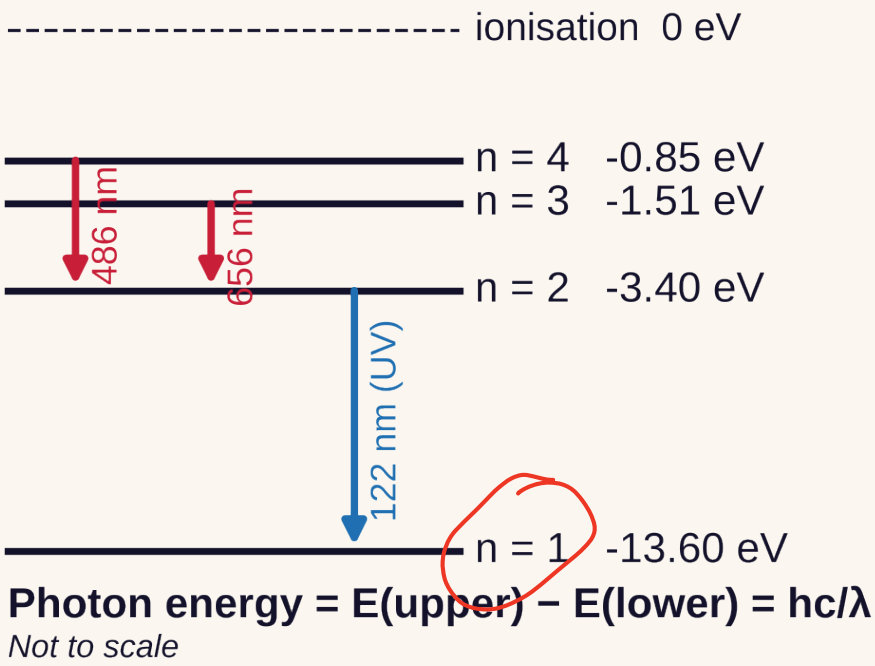
- **Both are true**

  Wave-particle duality: light shows wave behaviour in some experiments and photon behaviour in others



Energy level diagrams

Photon energy = the gap. Nothing else.



Photon energy = E(upper) − E(lower) = hc/λ

Not to scale

- **Emission: electron drops**

  Each different gap gives one line. Biggest gap, shortest wavelength

- **Count the lines**

  From level n, list every possible drop, not just the ones to the ground state

- **Absorption: photon must match a gap**

  An electron that collides can give part of its energy. A photon is absorbed only if it matches a gap exactly

QUESTION

16

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 13

UP NEXT

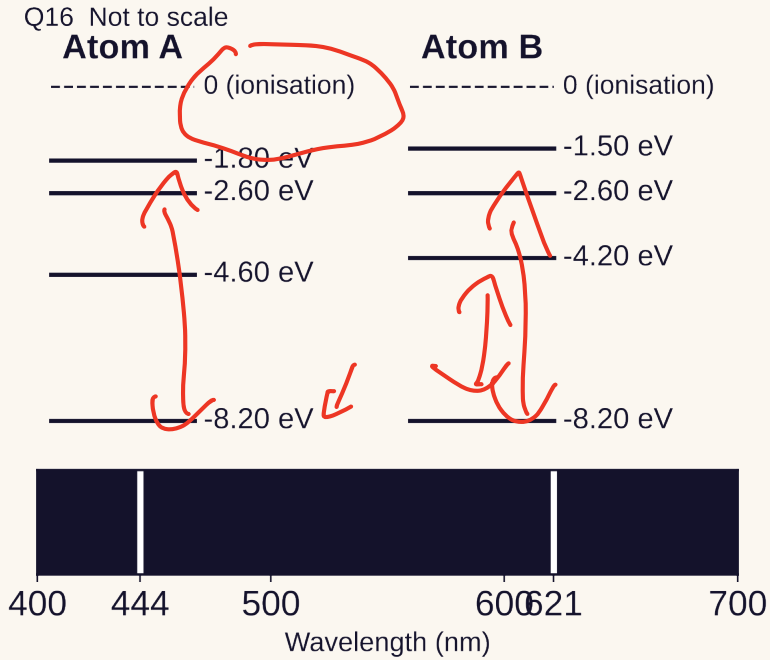
2:20 Break
2:30 Standard Model

Which atom made this spectrum?

A gas discharge tube produces a visible emission spectrum with lines at 444 nm and 621 nm only. The energy level diagrams for two possible atoms, A and B, are shown. Visible light is 400 nm to 700 nm.

a) Determine which atom is producing the spectrum. Show your working. [4]

b) Calculate the minimum frequency of a photon that could ionise this atom from its ground state. [2]



Workbook page 13. Try it on your own first.

WORKING

16

Level 3

6 marks

Hardest: new context

WORKBOOK

Page 13

UP NEXT

2:20 Break
2:30 Standard Model

Which atom made this spectrum?: working

Tutor works this one live. Parts: a) [4] b) [2]

400nm

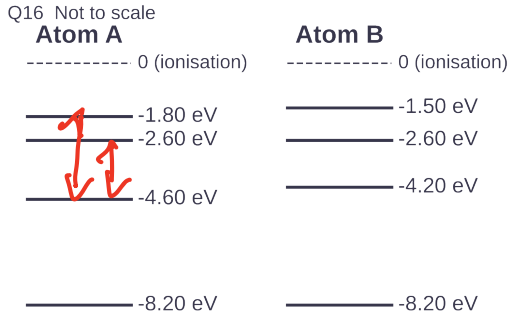
$E = \frac{hc}{\lambda} = 4.48 \times 10^{-19} J = 2.8 eV$

621nm
2eV

$8.2 eV = 1.31 \times 10^{-18} J$

$1.31 \times 10^{-18} J = hf$

$f = 1.98 \times 10^{15} Hz$



10 MIN BREAK

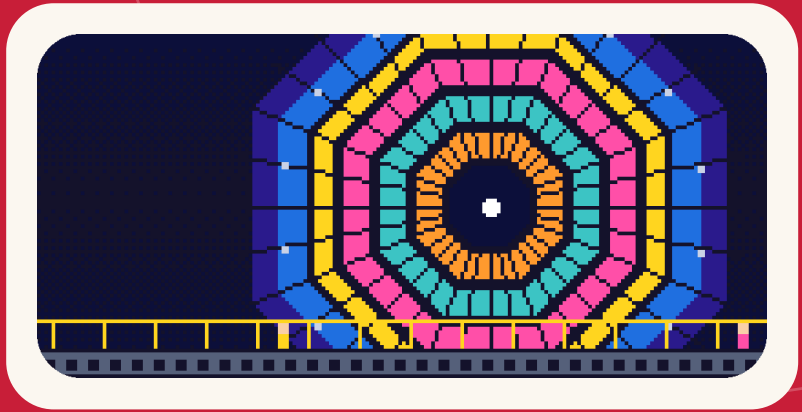
Break

Back at 2:30 for the Standard Model

Stretch, drink some water, and look back at one question you got wrong.

BLOCK 5 OF 6 · 2:30 TO 2:45

Standard *Model.*



Tusho + Imira

3 min of key ideas, then 3 questions (12 min)

The Standard Model on one slide

Quarks and leptons are matter. Gauge bosons carry the forces.

Quarks (feel all 4 forces)

u +⅔	**c** +⅔	**t** +⅔
d −⅓	**s** −⅓	**b** −⅓

Leptons (never strong)

e −1	**μ** −1	**τ** −1
ν_e 0	**ν_μ** 0	**ν_τ** 0

Gauge bosons

g	strong
γ	electromagnetic
W^+ W^- Z	weak

Hadrons

Baryon: 3 quarks, B = +1 (p = uud, n = udd)

Meson: quark + antiquark, B = 0 (π^+ = u + anti-d)

Antiquarks flip the charge sign

Every reaction, check 3 things

Charge · baryon number · lepton number

Antileptons count −1. Only the weak force (W, Z) changes quark flavour.

QUESTION

17

Level 1

2 marks

Warm-up

WORKBOOK

Page 14

UP NEXT

2:45 Exam technique
3:00 Finish

Reading quark content

The Ξ particle has quark content d s s. The K^0 particle has quark content d $\bar{s}$ (a down quark and an anti-strange quark). The down and strange quarks each have charge $-\frac{1}{3}e$.

Determine the charge of each particle, and classify each as a baryon or a meson. [2]

Workbook page 14. Try it on your own first.

WORKING

17

Level 1

2 marks

Warm-up

WORKBOOK

Page 14

UP NEXT

2:45 Exam technique
3:00 Finish

Reading quark content: working

Tutor works this one live. 2 marks

QUESTION

18

Level 2

3 marks

Exam standard

WORKBOOK

Page 14

UP NEXT

2:45 Exam technique
3:00 Finish

Contrast quarks and leptons

Quarks and leptons are both elementary particles in the Standard Model.

Contrast quarks and leptons in terms of the fundamental interactions each can experience. [3]

Workbook page 14. Try it on your own first.

WORKING

18

Level 2

3 marks

Exam standard

WORKBOOK

Page 14

UP NEXT

2:45 Exam technique

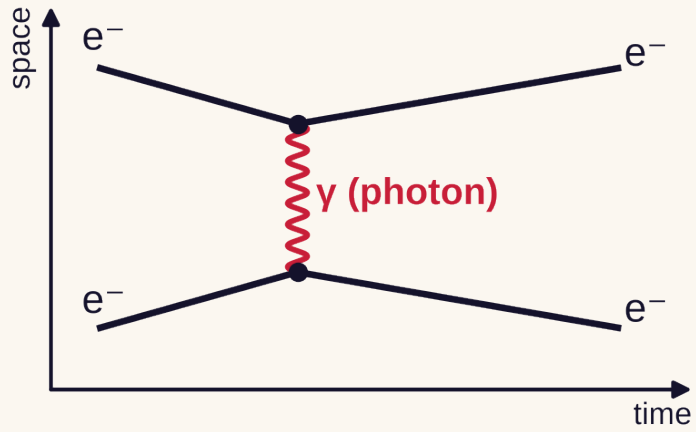
3:00 Finish

Contrast quarks and leptons: working

Tutor works this one live. 3 marks

Reading reaction diagrams (QCAA style)

Time runs left to right. Space is up the page.



Two electrons repel by exchanging a photon

Straight lines are particles

Quarks, hadrons and leptons move along the time axis. Label every line

The wavy line is the exchange boson

Photon (γ) for electron/electron and electron/positron. W^- or W^+ for decays (weak)

Every vertex balances

Charge, baryon number and lepton number are conserved at each vertex

QUESTION

19

Level 2

3 marks

Exam standard

WORKBOOK

Page 14

UP NEXT

2:45 Exam technique

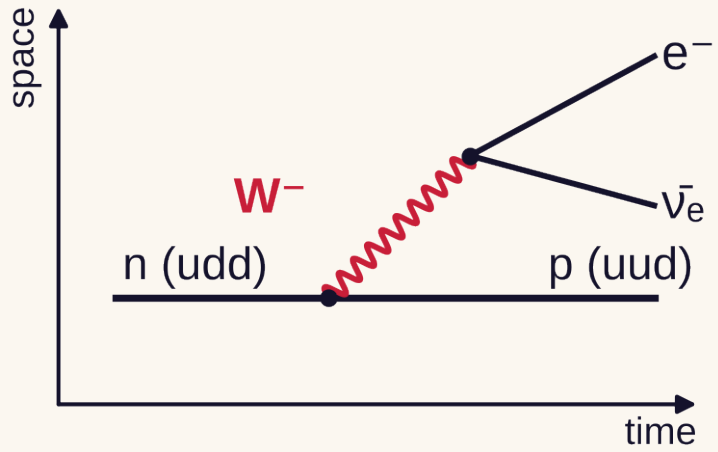
3:00 Finish

Neutron decay diagram

The reaction diagram represents the decay of a free neutron into a proton, an electron and an electron antineutrino.

a) Describe the interaction shown, including the change at the quark level and the exchange particle. [2]

b) Show that lepton number is conserved in this decay. [1]



Workbook page 14. Try it on your own first.

WORKING

19

Level 2

3 marks

Exam standard

WORKBOOK

Page 14

UP NEXT

2:45 Exam technique

3:00 Finish

Neutron decay diagram: working

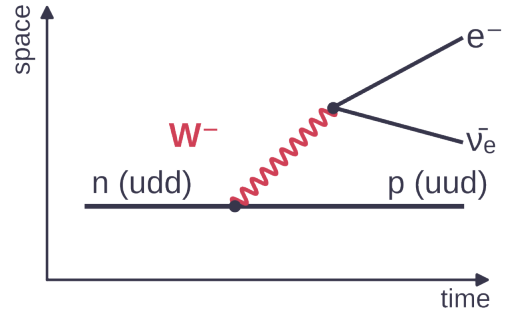
Tutor works this one live. Parts: a) [2] b) [1]

- Significance of symmetry:

→ Every symmetry is associated with a conservation law

(time reversal, charge reversal, crossing)

(mass, charge, baryon #, lepton #)



BLOCK 6 OF 6 · 2:45 TO 3:00

Exam *technique.*



Tusho + Imira

3 min of key ideas, then 2 questions (12 min)

How QCAA gives the marks

From the real 2020 and 2021 marking guides.

Recognise

1 mark

Name the physics or write the formula: 'magnetic force F = BIL', 'Newton's third law'.

Reason

1 to 3 marks

Substitute with units, rearrange, show each link of the chain. Working earns marks even if the answer is wrong.

Result

1 mark

Answer with units. QCAA does not penalise sig figs, but the answer line tells you what they want.

Explain questions: cause → law → effect

One idea per sentence. 'Contrast' needs 'whereas'. 'Explain' needs a because. A labelled diagram can earn a mark.

QUESTION

20

Level 2

5 marks

Exam standard

WORKBOOK

Page 15

UP NEXT

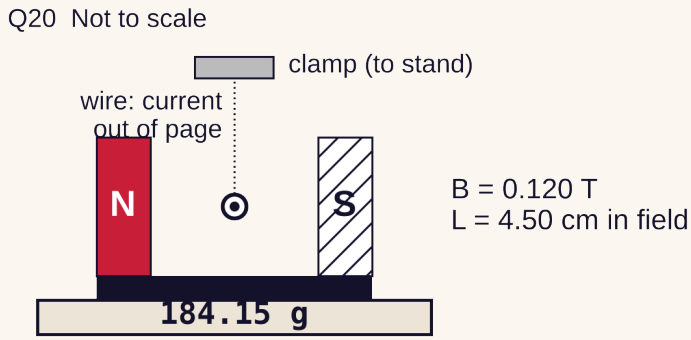
3:00 Finish

Wire on a balance

A U-shaped magnet sits on an electronic balance. A horizontal straight wire, held by a clamp that does not touch the magnet, passes between the poles perpendicular to the field, with 4.50 cm of wire in the 0.120 T field. With no current, the balance reads 182.40 g. When a current flows, the reading rises to 184.15 g.

a) Explain why the balance reading increases when the current flows. [2]

b) Determine the current in the wire. Show your working. [3]



Workbook page 15. Try it on your own first.

WORKING

20

Level 2

5 marks

Exam standard

WORKBOOK

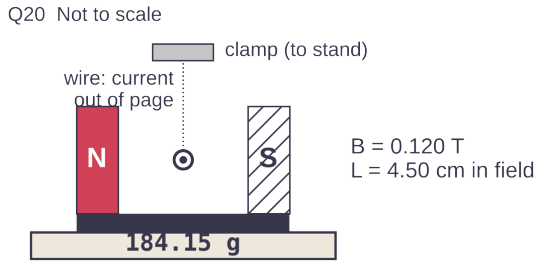
Page 15

UP NEXT

3:00 Finish

Wire on a balance: working

Tutor works this one live. Parts: a) [2] b) [3]



QUESTION

21

Level 3

7 marks

Hardest: new context

WORKBOOK

Page 16

UP NEXT

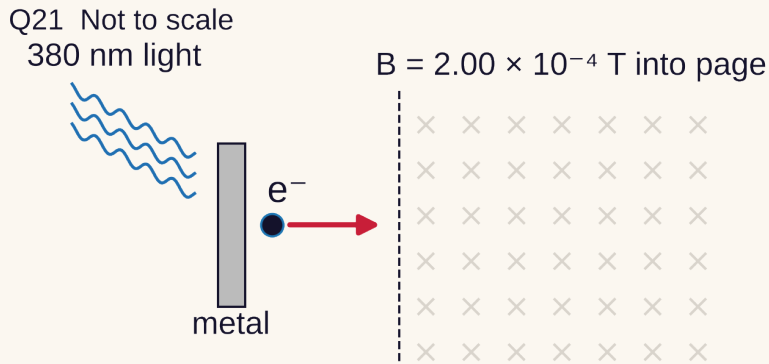
3:00 Finish

Photoelectron in a magnetic field

Light of wavelength 380 nm falls on a metal surface with a work function of 2.40 eV. The fastest photoelectrons emitted travel to the right into a uniform 2.00×10^{-4} T magnetic field directed into the page, perpendicular to their velocity.

a) Determine the maximum radius of the photoelectrons' circular path in the field. Show your working. [5]

b) Determine whether the photoelectrons curve towards the top or the bottom of the page. Justify your answer. [2]



Workbook page 16. Try it on your own first.

WORKING

21

Level 3

7 marks

Hardest: new context

WORKBOOK

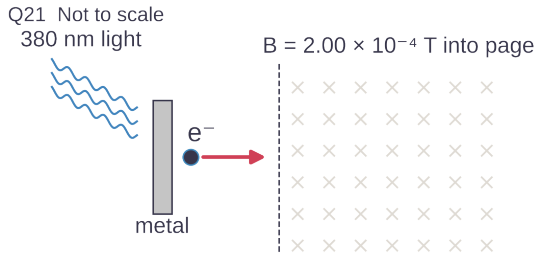
Page 16

UP NEXT

3:00 Finish

Photoelectron in a magnetic field: working

Tutor works this one live. Parts: a) [5] b) [2]



Locus

THAT'S A WRAP

Final feedback

Last one, we promise. Tell us what worked and what we should do better next time.

Anonymous · scan with your phone camera



SCAN ME

Good luck on Monday. You've got this.

@locustutoring

THAT'S A WRAP

You're *ready.*

Monday 9 November	Paper 1 at 9am · Paper 2 at 12:30pm
Sunday	Redo every question you circled today. Then stop and sleep.
In the exam	Formula first, then substitution, then units. Every step is a mark.

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