Exam Techniques, Intuition and Questions

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Rundown of today's lesson

- Exam Techniques
- Revision Techniques
- This week's problems
- Other Questions

Exam Techniques

Let us first talk about some exam techniques. Exam techniques are very important because:

- People who get high marks are not necessarily smart.
- You can basically boost your results by learning a few techniques.
- These techniques cannot be really taught - they are basically what I have learnt throughout the years.
- By that I mean the best techniques are always individualised - I can only give you some ideas as in how you can approach problems. Come up with your own.

Exam Techniques

The techniques I am going to talk about:

1. Diagrams
2. Intuition Check
3. POE
4. Units and Dimensional Analysis

Diagrams

Why diagrams?

- Physics is all about the real world - you need to visualise what is going on.
- In DSE often that is given - but if there are no diagrams (like in MCQ) you should draw your own.
- Even when you know what you are doing they are still a good intuition check.

Diagrams

Example

Identical charges of strength q is fixed on the corners of a regular hexagon. An electron is put at the centre of the polygon. Find the resultant force on the electron. What is the resultant force on the electron when one of the charges is removed?

Diagrams

Solution

Draw a hexagon! You will find that the problem is symmetric - there is no resultant force in the first case. The second part is equivalent to adding a negative charge at that point. The resultant force is:

$$\mathbf{F} = \frac{1}{4\pi\epsilon_0}\frac{qe}{r^2}\mathbf{e_r} \tag{1}$$

where $\mathbf{e_r}$ *is the radial vector.*

Intuition Check

Physical intuition forms the backbone for any scientific inquiry. This cannot be taught but you can practice/ train your intuition by:

- Reading
- Thinking
- Doing Questions
- Talking to your friends

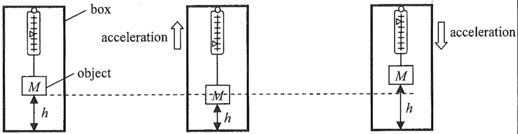
Let us look at a few examples to illustrate this.

Intuition Check

Example

4. Read the following description about **accelerometers** and answer the questions that follow.

An accelerometer is a device for measuring acceleration. The following example illustrates the principle of a simple accelerometer. An object of mass M is suspended by a spring balance inside a box. If the box is at rest without acceleration, the object is h above the bottom of the box (Figure 4.1). When the box accelerates upward, h decreases (Figure 4.2). Likewise, when the box accelerates downward, h increases (Figure 4.3). Since it is known that the tension of the spring balance is directly proportional to its extension, we can therefore determine the magnitude and direction of the box's acceleration by measuring h.



at rest without acceleration
Figure 4.1

accelerating upward
Figure 4.2

accelerating downward
Figure 4.3

Intuition Check

Example

Before looking at the question what should you instantly think?

- What kind of questions am I dealing with?
- What is the equation that I would most likely use?
- Why does the reading change when the lift accelerates?
- What is causing that?

Solution

- *Classical Mechanics*
- $\mathbf{F} = m\mathbf{a}$
- *Net force is different.*
- *You probably would not need to know - Hooke's Law.*

Intuition Check

Example

27.

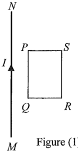


Figure (1)

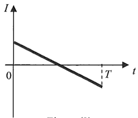


Figure (2)

A long straight current-carrying wire MN and a rectangular coil $PQRS$ are fixed in the same plane as shown in Figure (1). The current I is taken as positive when it flows from M to N and it varies with time t as shown in Figure (2). The direction of the induced current in the coil during the time interval $0 - T$ is

A. first anti-clockwise and then clockwise.
B. first clockwise and then anti-clockwise.
C. anti-clockwise throughout.
D. clockwise throughout.

- Ask yourself the same questions as before.
- Can think as the current in opposite direction growing superimposed on static existing system!
- Why - system is linear!

Intuition Check

Example

A rollercoaster is performing a vertical circular loop. Suppose the track is smooth. Find the minimum initial speed (at the bottom) for the rollercoaster to perform a complete loop given that the radius of the vertical loop is R. (Hint: The question is not as easy as it looks - think about the centripetal force when the rollercoaster is at its higher point!)

Intuition Check

Example

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Solution

- *What am I trying to do?*
- *What can I use?*
- *Why is there a hint? Something must be fishy?*

Intuition Check

Solution

We know that it is not as simple as energy conservation (from the hint). Centripetal force at the top is given by

$$F_{cent} = mg + N = m\frac{v^2}{R}$$

When the force is minimum the normal force is zero. Hence,

$$v_{top} = \sqrt{gR}$$

Now we use energy conservation to give

$$\frac{1}{2}mv^2 + mgh = const \tag{2}$$

$$\implies v_0 = \sqrt{5gR}$$

POW - Power of Elimination

Why do we need POW?

- Everyone knows how to do this.
- Gives you statistically the best chance to score a point whether you know that answer or not.
- Useful in ALL subjects (if you know what you are doing).

POW - Power of Elimination

Example

6. Two small identical blocks slide down from rest on smooth incline planes from the same height H as shown in Figure (1) and Figure (2) below. Their respective speeds at the bottom of the incline planes are denoted by v_1 and v_2 and the respective times taken to reach the bottom are t_1 and t_2. Which of the following is correct ? Neglect air resistance.

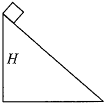


Figure (1)

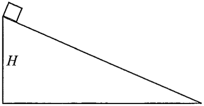


Figure (2)

A. $v_1 > v_2$ and $t_1 = t_2$
B. $v_1 > v_2$ and $t_1 < t_2$
C. $v_1 = v_2$ and $t_1 = t_2$
D. $v_1 = v_2$ and $t_1 < t_2$

Instantly think extreme situations!

POW - Power of Elimination

Example

*11. An astronaut inside a spacecraft moving in a circular orbit around the Earth is apparently weightless because

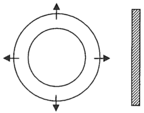
A. the astronaut is too far from the Earth to feel the Earth's gravitational force.
B. the astronaut and the spacecraft are both moving with the same acceleration towards the Earth.
C. the Earth's gravitational force on the astronaut is balanced by the reaction force of the spacecraft's floor.
D. the Earth's gravitational force on the astronaut is balanced by the centripetal force.

What is even A doing here? The astronaut is floating - not C. What is centripetal force?

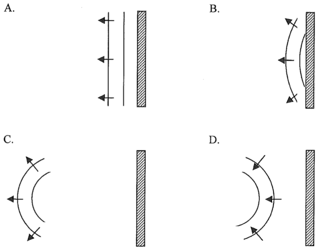
POW - Power of Elimination

Example

13.



The above figure shows two circular pulses produced by drops of water falling on a ripple tank. The pulses are then reflected by a straight barrier. Which diagram best shows the reflected pulses ?

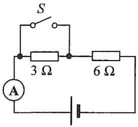


This is so obvious - the other cases are so improbable!

POW - Power of Elimination

Example

24.



In the above circuit, the cell has constant e.m.f. and a fixed internal resistance. When S is closed, the ammeter reads 3.0 A. When S is open, which of the following is a possible reading of the ammeter ?

A. 1.6 A
B. 2.0 A
C. 2.4 A
D. 3.2 A

Note option D here makes no sense - the equivalent resistance must drop for this to happen!

Dimensional Analysis

Why do physicists need this?

- To check their answers.
- If dimensionally it does not make sense then it is not physical.
- Forms a powerful way of analysing actual physical problems! See Stoke's Law (not Theorem).

Dimensional Analysis

We usually analyse the dimensions by checking three main quantities.

1. Mass M
2. Time T
3. Length L

Dimensional Analysis

Example

How does the period of a pendulum τ depend on the length l, the mass of bob m and the gravitational constant g?

Solution

Assume

$$\tau \propto l^{\alpha} g^{\beta} m^{\gamma}$$

We know that

$$dim(\tau) = T$$

$$dim(l) = L$$

$$dim(g) = LT^{-}2$$

$$dim(M) = M$$

Dimensional Analysis

Solution

$$\tau = l^{\alpha} g^{\beta} m^{\gamma}$$

Compare the dimensions:

$$T : 1 = -2\beta$$

$$L : 0 = \alpha + \beta$$

$$M : 0 = \gamma$$

Therefore $\beta = -\frac{1}{2}$, $\alpha = \frac{1}{2}$, $\gamma = 0$, *this gives,*

$$\tau \propto \sqrt{\frac{l}{g}}$$

Actual answer is

$$\tau = 2\pi\sqrt{\frac{l}{g}} \tag{3}$$

Dimensional Analysis

Example

Say I am calculating some acceleration and come up with this expression.

$$a = g \ln(L_A L_B / L_C)$$

What is wrong?

Dimensional Analysis

Solution

$$a = g \ln(L_A L_B / L_C)$$

I know instantly I have made some mistakes somewhere - the quantity inside log should have no dimensions!

Studying Techniques

Do I even need studying techniques? Yes - but come up with your own! Everyone is different. Here are some advice I can give you:

- Writing a summary page.
- Try and explain it to someone - like your dog.
- Feynmann Method
- Past papers - aim to finish earlier?

Last week's problems

- I was so busy last week.
- These questions are something that I came up in 5 minutes.
- They cover something that I struggled with - even now!

Monday's Problem

Example

Describe how transformer work. How can you improve the performance of a transformer - and why?

Monday's Problem

Example

Describe how transformer work. How can you improve the performance of a transformer - and why?

Solution

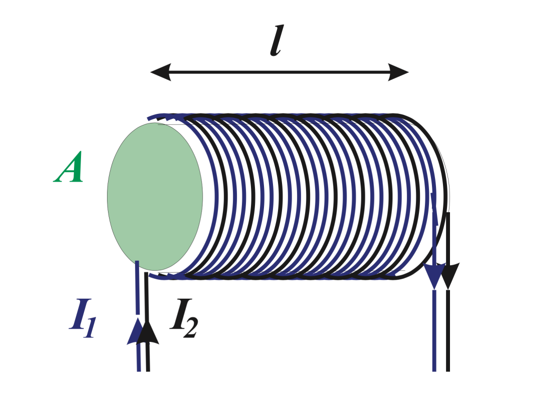
This is something you should recall from textbooks/notes (we call this bookwork). Mainly I am looking for how well you phrase your answer.

Monday's Problem

Example

Describe how transformer work. How can you improve the performance of a transformer - and why?

Solution



Monday's Problem

Example

Describe how transformer work. How can you improve the performance of a transformer - and why?

Solution

- *Ideal transformer formed by two transformers wounding around ferromagnetic core.*
- *Current I_1 is time-varying, generates time-varying magnetic field in core.*
- *Changing magnetic flux induces sinusoidal emf in the second wounding coil.*
- *This generates a current in second coil I_2.*
- *Different number density of the coils give different voltages.*

Monday's Problem

Example

Describe how transformer work. How can you improve the performance of a transformer - and why?

Solution

- *To improve performance - need to first identify main loss of energy - dissipation as heat.*
- *Solutions can be reducing R of copper wire, introduce lamination, increasing* μ *of ferromagnetic core, etc.*
- *Justify each point.*

Thursday's Problem

Example

Describe what happens to a metallic ball tied to the wall by a string between two oppositely charged plates.

Thursday's Problem

Solution

- *Imagine ball starts at a plate - ball is charged as the same sign as the plate.*
- *Electrical Repulsion drives ball away from plate.*
- *Meanwhile, ball is attracted to the other plate.*
- *When ball hits the plate it discharges and becomes charged with the opposite charge.*
- *Same thing happens again...*

Tuesday's Problem

Example

Design an experiment to measure the wavelength of *a laser* using diffraction experiments. You are given with a diffraction grating of a known slit separation, a double slit, a single slit (which you may use or not use), a screen, a measuring tape and a ruler with 0.5mm readings. Mention the related error and uncertainties you might come across. (6-8 points)

Tuesday's Problem

It is generally really difficult to get all the points in an experimental physics question. But generally remember the points:

- What set-up should I build? What am I given with?
- Think hard about measurements at each step - what are the associated errors and uncertainties?
- Is there a simpler set-up that I can use?

Tuesday's Problem

Return to the question:

Example

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Remember that you are trying to do an experiment. You should have at least seen the set-up before.

Tuesday's Problem

Solution

What I know:

- *Double slit and diffraction grating equations.*
- *I can measure distances.*
- *I might need a coherent source - but I am given with a laser!*

Tuesday's Problem

Solution

Two-slit experiment:

- *Align laser beam on an optical rail. Shine light perpendicularly on the two-slits aperture.*
- *Set up a screen distance D from the aperture.*
- *Record the separation of fringes on the screen.*
- *Measure the distance from the aperture to the screen using a measuring tape.*
- *Use equation:*

$$\Delta x = \frac{\lambda D}{a} \tag{4}$$

where a is the fringe separation. You can measure it using a ruler (usually it is of order $\sim 10^{-6} m$ *- you will only be able to measure it using a microscope.*

Tuesday's Problem

Solution

Grating experiment:

- *Same as before.*
- *However this time need to determine the mid-point - usually not ideal.*
- *Measure centre fringe to nth-order separation using ruler.*
- *Use equation:*

$$d \sin\theta = n\lambda \tag{5}$$

d being the slit separation in grating (given). Angle θ can be found by using simple trigonometry:

$$\tan\theta = \frac{x}{D}$$

where x is the separation on the screen.

Tuesday's Problem

Solution

Errors and Uncertainties:

- *Mainly from measurement of distances using the ruler and measuring tape.*
- *Approximation used:* $D \gg x$*. Is this true? (Fraunhofer vs Frensel)*
- *Small angle approximation - how good is it?*
- *Coherent light source - what if I used a lamp - then need to add single-slit.*
- *How far should the distance be between the single and double-slit?*
- *Alignment of mirrors - is it important?*

Tuesday's Problem

Some final words:

- Read and understand the experimental set-ups covered in the course.
- Read more books.
- Calm down - it should not be that hard...

Friday's Problem

Example

What is angular momentum? Why is it quantised in the Bohr model?

This is actually for fun - you should not know this...

Friday's Problem

Definition

Angular momentum $\mathbf{L}$ is defined as

$$\mathbf{L} = \mathbf{r} \times \mathbf{p} \tag{6}$$

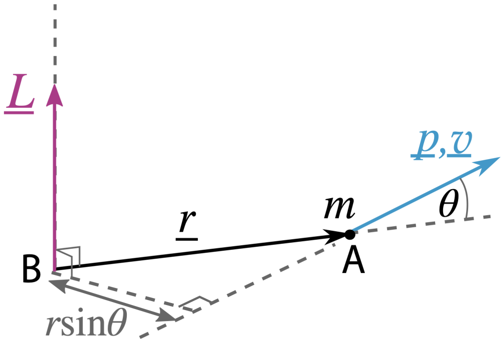
where $\mathbf{r}$ is the radial vector and $\mathbf{p}$ is the momentum.

Friday's Problem

Why do you need angular momentum?

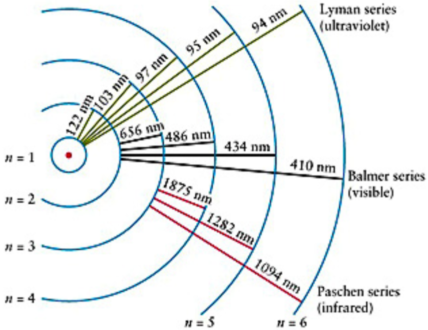
- Angular momentum is conserved if there is no external torque (c. f. NII)
- Forms the backbone of classical mechanics.
- If you think about it it actually comes from the fact that we have rotational invariance...

Friday's Problem



Friday's Problem

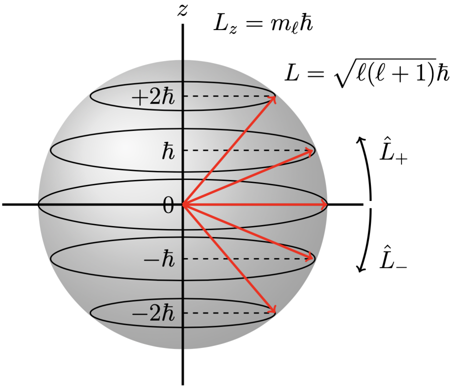
How does this model come from then?



It is actually a hypothesis...

Friday's Problem

In fact the whole structure comes from operators...



Friday's Problem

Main takeaways:

- Don't stop learning and say I don't need this for the exam.
- If you are generally interested in the subject you will score better.
- I don't suggest reading material outside of the course at this stage but don't be afraid to try if you really want to know more!

Question Time

References

Diagrams are obtained from:

- *IA Rotational Mechanics and Special Relativity*, Course Notes, Dr Lisa Jardine-Wright
- *IB Electromagnetism*, Course Notes, Dr Oleg Brandt
- *IB Quantum Physics*, Course Notes, Prof Stafford Withington
- *2014 HKDSE Physics Paper*

Other diagrams are from my personal collection.