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Table of Contents (the real thing)

Intro

Your brain on Physics. Here you are trying to *learn* something, while here your *brain* is doing you a favor by making sure the learning doesn't *stick*. Your brain's thinking, "Better leave room for more important things, like which wild animals to avoid and whether naked snowboarding is a bad idea." So how *do* you trick your brain into thinking that your life depends on knowing physics?

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think like a physicist

In the beginning ...

1

Physics is about the world around you and how everything in it works. As you go about your daily life, you're **doing** physics all the time! But the thought of actually **learning** physics may sometimes **feel** like falling into a bottomless pit with no escape! Don't worry... this chapter introduces how to **think like a physicist**. You'll learn to step into problems and to use your **intuition** to spot **patterns** and '**special points**' that make things much easier. By **being** part of the problem, you're one step closer to getting to the solution...

Physics is the world around you	2
You can get a feel for what's happening by being a part of it	4
Use your intuition to look for 'special points'	6
The center of the earth is a special point	8
Ask yourself "What am I ALREADY doing as I reach the special point?"	9
Where you're at - and what happens next?	11
Now put it all together	13

Go to the start of
the problem then
BE a part of it!

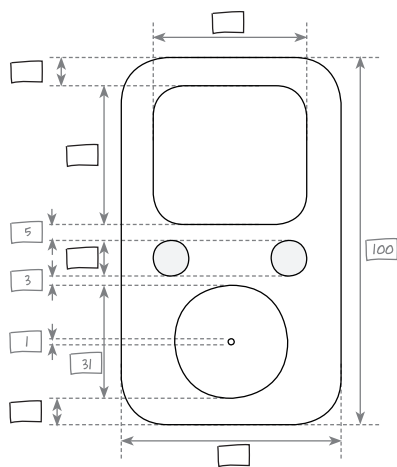


making it all MEAN something

Units and measurements

2

How long is a piece of string? Physics is based on making **measurements** that tell you about **size**. In this chapter, you'll learn how to use **units** and **rounding** to avoid making mistakes - and also why **errors** are OK. By the time you're through, you'll know when something is **significant** and have an opinion on whether size really **is** everything.



It's the best music player ever, and you're part of the team!	18
So you get on with measuring the myPod case	19
When the myPod case comes back from the factory, it's way too big	20
There aren't any UNITS on the blueprint	22
You'll use SI units in this book (and in your class)	25
You use conversion factors to change units	29
You can write a conversion factor as a fraction	30
Now you can use the conversion factor to update the blueprint	33
What to do with numbers that have waaaay too many digits to be usable	36
How many digits of your measurements look significant?	37
Generally, you should round your answers to three significant digits	39
You ALREADY intuitively rounded your original myPod measurements!	42
Any measurement you make has an error (or uncertainty) associated with it	43
The error on your original measurements should propagate through to your converted blueprint	44
STOP!! Before you hit send, do your answers SUCK?!	47
When you write down a measurement, you need the right number of significant digits	51
Hero or Zero?	52

Length



Time



Mass



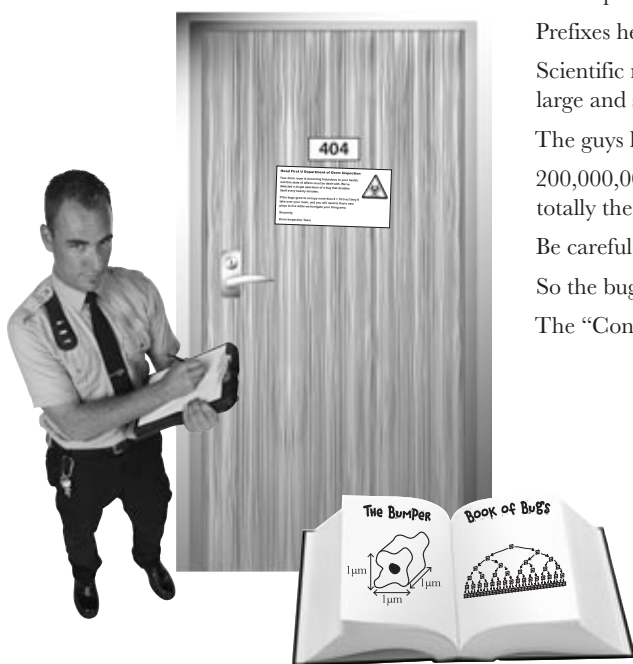
scientific notation, area, and volume

3

All numbers great and small

In the real world, you have to deal with all kinds of numbers, not just the ones that are easier to work with. In this chapter, you'll be taking control of unwieldy numbers using scientific notation and discovering why rounding a large number doesn't mean having to write a zillion zeros at the end. You'll also use your new superpowers to deal with units of area and volume - which is where scientific notation will save you lots of grief (and time) in the future!

A messy college dorm room	56
So how long before things go really bad?	57
Power notation helps you multiply by the same number over and over	61
Your calculator displays big numbers using scientific notation	63
Scientific notation uses powers of 10 to write down long numbers	64
Scientific notation helps you with small numbers as well	68
You'll often need to work with area or volume	72
Look up facts in a book (or table of information)	73
Prefixes help with numbers outside your comfort zone	74
Scientific notation helps you to do calculations with large and small numbers	76
The guys have it all worked out	81
200,000,000 meters cubed bugs after only 16 hours is totally the wrong size of answer!	83
Be careful converting units of area or volume	84
So the bugs won't take over ... unless the guys sleep in!	86
The "Converting units of area or volume" Question	87

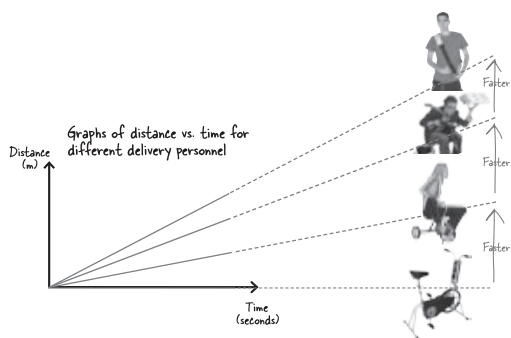


equations and graphs

Learning the lingo

4

Communication is vital. You're already off to a good start in your journey to truly think like a physicist, but now you need to **communicate your thoughts**. In this chapter, you're going to take your first steps in two universal languages - **graphs** and **equations** - pictures you can use to *speak a thousand words* about experiments you do and the physics concepts you're learning. *Seeing is believing.*



You need to work out how to give the customer their delivery time	97
If you write the delivery time as an equation, you can see what's going on	98
Use variables to keep your equation general	99
You need to work out Alex's cycling time	101
When you design an experiment, think about what might go wrong!	105
Conduct an experiment to find out Alex's speed	108
Write down your results... in a table	109
Use the table of distances and times to work out Alex's speed	111
Random errors mean that results will be spread out	113
A graph is the best way of taking an average of ALL your results	114
Use a graph to show Alex's time for ANY distance	117
The line on the graph is your best estimate for how long Alex takes to cycle ANY distance	118
You can see Alex's speed from the steepness of the distance-time graph	120
Alex's speed is the slope of the distance-time graph	122
Now work out Alex's average speed from your graph	123
You need an equation for Alex's time to give to the web guys	125
Rearrange the equation to say " Δ time = something"	126
Use your equation to work out the time it takes Alex to reach each house	129
So just convert the units, and you're all set...right?	131
Include the cooking time in your equation	133
A graph lets you see the difference the stop lights made	137
The stop lights change Alex's average speed	139
The "Did you do what they asked you" Question	146

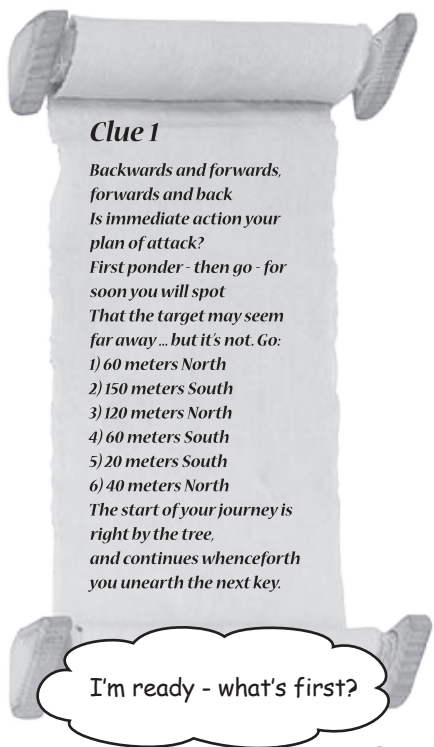
dealing with directions

5

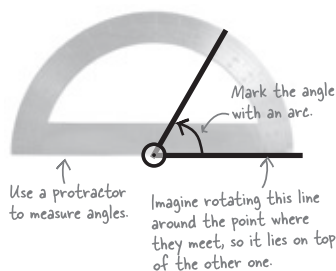
Vectors

Time, speed, and distance are all well and good, but you really need DIRECTION too if you want to get on in life.

You now have multiple physics superpowers: You've mastered graphs and equations, and you can estimate how big your answer will be. But **size** isn't everything. In this chapter, you'll be learning about **vectors**, which give **direction** to your answers and help you to find **easier shortcuts** through complicated-looking problems.



The treasure hunt	150
Displacement is different from distance	155
Distance is a scalar; displacement is a vector	157
You can represent vectors using arrows	157
You can add vectors in any order	162
The "Wheat from the chaff" Question	166
Angles measure rotations	168
If you can't deal with something big, break it down into smaller parts	170
Velocity is the 'vector version' of speed	174
Write units using shorthand	175
You need to allow for the stream's velocity too!	176
If you can find the stream's velocity, you can figure out the velocity for the boat	177
It takes the boat time to accelerate from a standing start	180
How do you deal with acceleration?	181
Vector, Angle, Velocity, Acceleration = WINNER!!!	187



Displacement, Velocity, and Acceleration

What's going on?

6

It's hard to keep track of more than one thing at a time.

When something falls, its displacement, velocity, and acceleration are all important at the same time. So how can you pay attention to all three without missing anything? In this chapter, you'll increase your experiment, graph, and slope superpowers in preparation for bringing everything together with an equation or two.

Just another day in the desert ...	204
How can you use what you know?	207
The cage accelerates as it falls	210
'Vectorize' your equation	211
You want an instantaneous velocity, not an average velocity	213
You already know how to calculate the slope of a straight line...	218
A point on a curved line has the same slope as its tangent	218
The slope of something's velocity-time graph lets you work out its acceleration	226
Work out the units of acceleration	227
Success! You worked out the velocity after 2.0 s - and the cage won't break!	231
Now onto solve for the displacement!	234



Equations of motion (part 1)

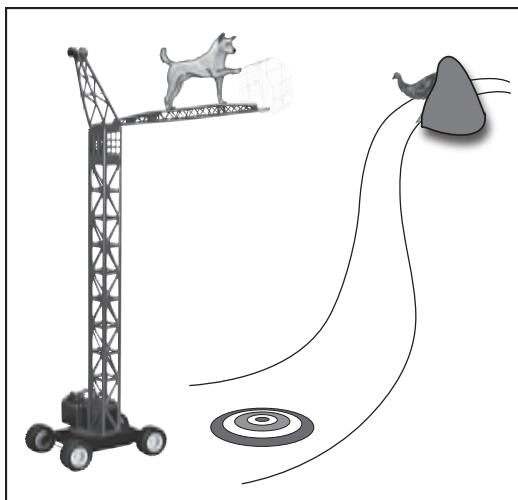
Playing With Equations

7

It's time to take things to another level.

So far, you've done experiments, drawn graphs of their results, and worked out equations from them. But there's only so far you can go since sometimes your graph isn't a straight line. In this chapter, you'll expand your math skills by making **substitutions** to work out a key **equation of motion** for a curved displacement-time graph of a falling object. And you'll also learn that **checking** your GUT reaction to an answer can be a good thing.

How high should the crane be?	238
Graphs and equations both represent the real world	240
You're interested in the start and end points	241
You have an equation for the velocity - but what about the displacement?	244
See the average velocity on your velocity-time graph	249
Test your equations by imagining them with different numbers	251
Calculate the cage's displacement!	253
You know how high the crane should be!	254
But now the Dingo needs something more general	255
A substitution will help	256
Get rid of the variables you don't want by making substitutions	259
Continue making substitutions ...	261
You derived a useful equation for the cage's displacement!	264
Check your equation using Units	265
Check your equation by trying out some extreme values	268
Your equation checks out!	273
So the Dingo drops the cage ...	274
The "Substitution" Question	275
The "Units" or "Dimensional analysis" Question	276

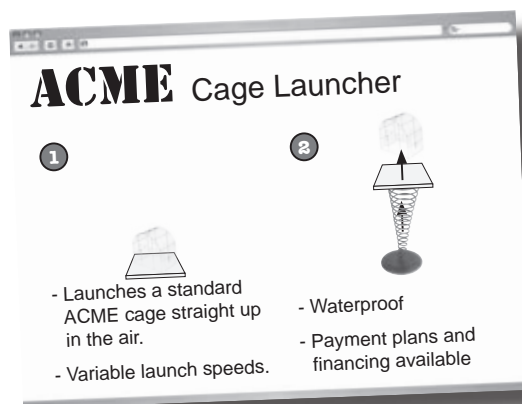


equations of motion (part 2)

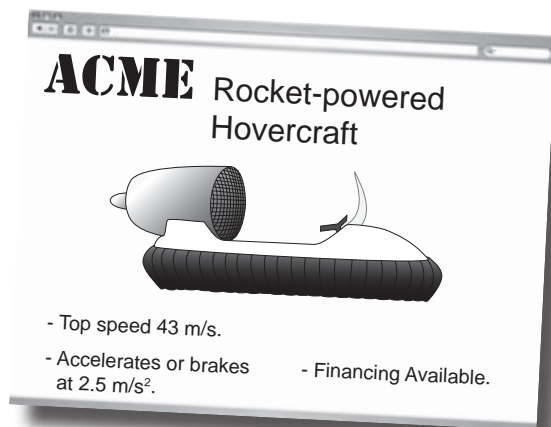
Up, up, and... back down

8

What goes up must come down. You already know how to deal with things that are falling **down**, which is great. But what about the other half of the bargain - when something's launched **up** into the air? In this chapter, you'll add a third key **equation of motion** to your armory which will enable you to **deal with** (just about) **anything**! You'll also learn how looking for a little **symmetry** can turn impossible tasks into manageable ones.



Now ACME has an amazing new cage launcher	284
The acceleration due to gravity is constant	286
Velocity and acceleration are in opposite directions, so they have opposite signs	288
You can use one graph to work out the shapes of the others	293
Is a graph of your equation the same shape as the graph you sketched?	298
Fortunately, ACME has a rocket-powered hovercraft!	305
You can work out a new equation by making a substitution for t	308
Multiply out the parentheses in your equation	311
You have two sets of parentheses multiplied together	312
You need to simplify your equation by grouping the terms	315
You can use your new equation to work out the stopping distance	317
There are THREE key equations you can use when there's constant acceleration	318
You need to work out the launch velocity that gets the Dingo out of the Grand Canyon!	321
You need to find another way of doing this problem	326
The start of a beautiful friendship	330
The "Sketch a graph" or "Match a graph" Question	331
The "Symmetry" and "Special points" Questions	332



triangles, trig and trajectories

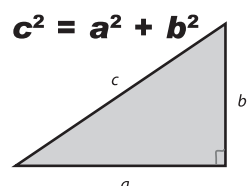
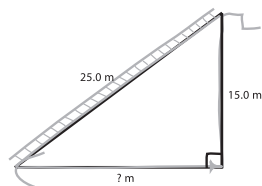
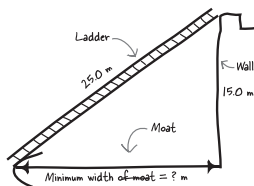
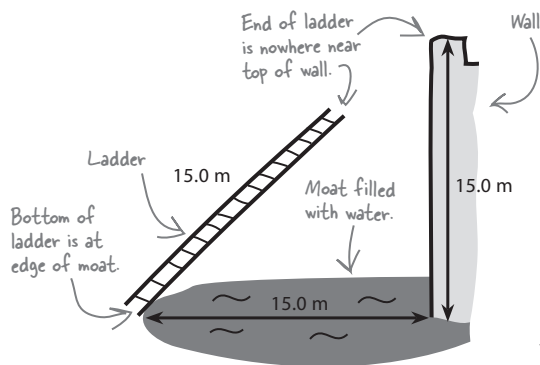
Going two-dimensional

9

So you can deal with one dimension. But what about real life?

Real things don't just go up or down - they go sideways too! But never fear - you're about to gain a whole new bunch of **trigonometry** superpowers that'll see you spotting **right-angled triangles** wherever you go and using them to **reduce complicated-looking problems into simpler ones that you can already do.**

Camelot - we have a problem!	336
How wide should you make the moat?	339
Looks like a triangle, yeah?	340
A scale drawing can solve problems	342
Pythagoras' Theorem lets you figure out the sides quickly	343
Sketch + shape + equation = Problem solved!	345
Camelot ... we have ANOTHER problem!	348
Relate your angle to an angle inside the triangle	351
Classify similar triangles by the ratios of their side lengths	354
Sine, cosine and tangent connect the sides and angles of a right-angled triangle	355
How to remember which ratio is which?	357
Sine Exposed	358
Calculators have $\sin(\theta)$, $\cos(\theta)$ and $\tan(\theta)$ tables built in	360
Uh oh. Gravity...	367
The cannonball's velocity and acceleration vectors point in different directions	369
Gravity accelerates everything downwards at 9.8 m/s^2	370
The horizontal component of the velocity can't change once you've let go	371
The horizontal component of a projectile's velocity is constant	372
The same method solves both problems	375
The "Projectile" Question	376
The "Missing steps" Question	387



Start with a sketch → Look for familiar shapes (triangles, rectangles, etc) → Use an equation that tells you about this kind of shape

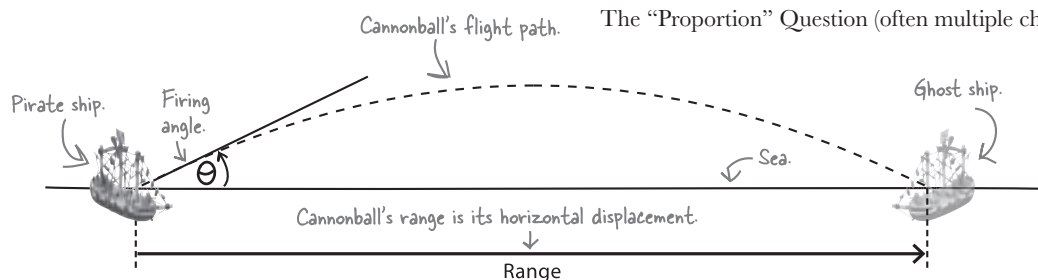
10

momentum conservation

What Newton Did

No one likes to be a pushover. So far, you've learned to deal with objects that are already moving. But what makes them go in the first place? You know that something will move if you push it - but *how* will it move? In this chapter, you'll overcome **inertia** as you get acquainted with some of **Newton's Laws**. You'll also learn about **momentum**, why it's **conserved**, and how you can use it to solve problems.

The pirates be havin' a spot o' bother with a ghost ship ...	392
What does the maximum range depend on?	395
Firing at 45° maximizes your range	396
You can't do everything that's theoretically possible - you need to be practical too	397
Sieges-R-Us has a new stone cannonball, which they claim will increase the range!	400
Massive things are more difficult to start and stop	402
Newton's First Law	403
Mass matters	404
A stone cannonball has a smaller mass - so it has a larger velocity. But how much larger?	407
Here's your lab equipment	410
How are force, mass and velocity related?	411
Vary only one thing at a time in your experiment	414
Mass \times velocity - momentum - is conserved	418
A greater force acting over the same amount of time gives a greater change in momentum	420
Write momentum conservation as an equation	421
Momentum conservation and Newton's Third Law are equivalent	422
You've calculated the stone cannonball's velocity, but you want the new range!	429
Use proportion to work out the new range	430
The "Proportion" Question (often multiple choice)	434



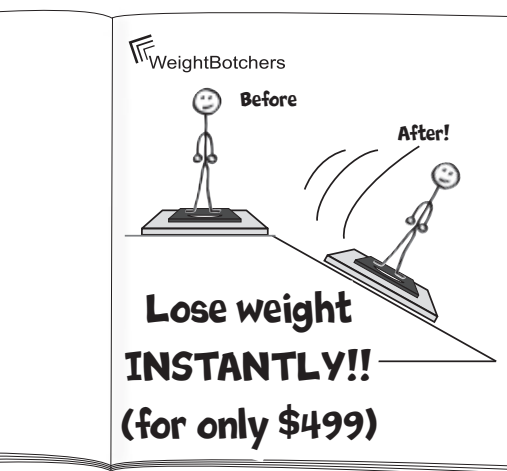
weight and the normal force

Forces for courses

11

Sometimes you have to make a statement forcefully.

In this chapter, you'll work out **Newton's 2nd Law** from what you already know about momentum conservation to wind up with the key equation, $F_{\text{net}} = ma$. Once you combine this with spotting **Newton's 3rd Law force pairs**, and drawing **free body diagrams**, you'll be able to deal with (just about) anything. You'll also learn about why mass and **weight** aren't the same thing, and get used to using the **normal force** to support your arguments.



WeightBotchers are at it again!	438
Is it really possible to lose weight instantly?!	439
Scales work by compressing or stretching a spring	440
Mass is a measurement of “stuff”	442
Weight is a force	442
The relationship between force and mass involves momentum	444
If the object's mass is constant, $F_{\text{net}} = ma$	446
The scales measure the support force	449
Now you can debunk the machine!	451
The machine reduces the support force	452
Force pairs help you check your work	454
You debunked WeightBotchers!	456
A surface can only exert a force perpendicular (or normal) to it	458
When you slide downhill, there's zero perpendicular acceleration	461
Use parallel and perpendicular force components to deal with a slope	463
The “Free body diagram” Question	466
The “Thing on a slope” Question	467

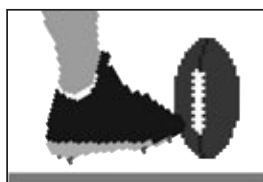
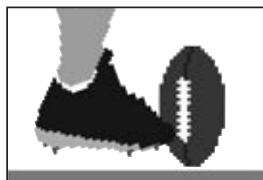
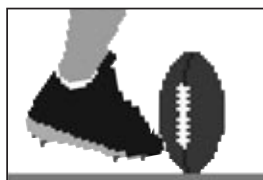
using forces, momentum, friction and impulse

Getting on with it

12

It's no good memorizing lots of theory if you can't apply it.

You already know about equations of motion, component vectors, momentum conservation, free body diagrams and Newton's Laws. In this chapter, you'll learn how to fit all of these things together and apply them to solve a much **wider range** of physics problems. Often, you'll spot when a problem is **like** something you've seen before. You'll also add more realism by learning to deal with **friction** - and will see why it's sometimes appropriate to act on **impulse**.



It's ... SimFootball!	472
Momentum is conserved in a collision	476
But the collision might be at an angle	477
A triangle with no right angles is awkward	479
Use component vectors to create some right-angled triangles	480
The programmer includes 2D momentum conservation ...	483
In real life, the force of friction is present	484
Friction depends on the types of surfaces that are interacting	488
Be careful when you calculate the normal force	489
You're ready to use friction in the game!	491
Including friction stops the players from sliding forever!	492
The sliding players are fine - but the tire drag is causing problems	493
Using components for the tire drag works!	497
Friction Exposed	498
The "Friction" Question	499
How does kicking a football work?	500
$F\Delta t$ is called impulse	502
The game's great - but there's just been a spec change!	506
For added realism, sometimes the players should slip	509
You can change only direction horizontally on a flat surface because of friction	510
The game is brilliant, and going to X-Force rocks!	511
Newton's Laws give you awesome powers	512

torque and work

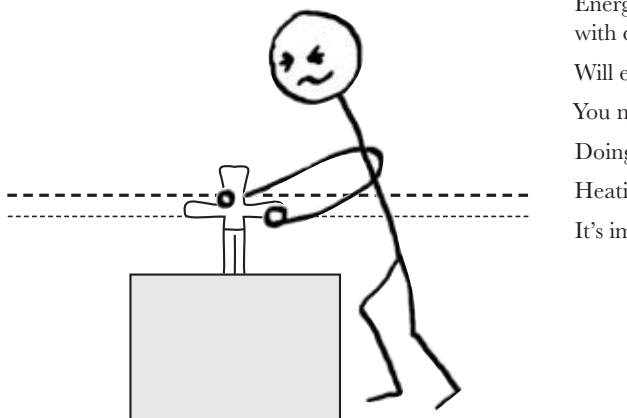
Getting a lift

13

You can use your physics knowledge to do superhuman feats.

In this chapter, you'll learn how to harness torque to perform amazing displays of strength, by using a lever to exert a much larger force than you could on your own. However, you can't get something for nothing - **energy** is always **conserved** and the amount of **work** you do to give something **gravitational potential energy** by lifting it doesn't change.

Half the kingdom to anyone who can lift the sword in the stone ...	516
Can physics help you to lift a heavy object?	517
Use a lever to turn a small force into a larger force	519
Do an experiment to determine where to position the fulcrum	521
Zero net torque causes the lever to balance	525
Use torque to lift the sword and the stone!	530
The "Two equations, two unknowns" Question	533
So you lift the sword and stone with the lever ... but they don't go high enough!	535
You can't get something for nothing	537
When you move an object against a force, you're doing work	538
The work you need to do a job = force \times displacement	538
Which method involves the least amount of work?	539
Work has units of Joules	541
Energy is the capacity that something has to do work	542
Lifting stones is like transferring energy from one store to another	542
Energy conservation helps you to solve problems with differences in height	545
Will energy conservation save the day?	547
You need to do work against friction as well as against gravity	549
Doing work against friction increases internal energy	551
Heating increases internal energy	552
It's impossible to be 100% efficient	553



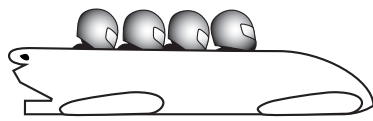
14

energy conservation Making your life easier

Why do things the hard way when there's an easier way?

So far, you've been solving problems using equations of motion, forces and component vectors. And that's great - except that it sometimes takes a while to crunch through the math. In this chapter, you'll learn to spot where you can use **energy conservation** as a shortcut that lets you solve complicated-looking problems with relative ease.

The ultimate bobsled experience	560
Forces and component vectors solve the first part... but the second part doesn't have a uniform slope	563
A moving object has kinetic energy	565
The kinetic energy is related to the velocity	567
Calculate the velocity using energy conservation and the change in height	569
You've used energy conservation to solve the second part	571
In the third part, you have to apply a force to stop a moving object	571
Putting on the brake does work on the track	573
Doing work against friction increases the internal energy	574
Energy conservation helps you to do complicated problems in a simpler way	579
There's a practical difference between momentum and kinetic energy	581
The "Show that" Question	584
The "Energy transfer" Question	585
Momentum conservation will solve an inelastic collision problem	587
You need a second equation for an elastic collision	587
Energy conservation gives you the second equation that you need!	589
Factoring involves putting in parentheses	591
You can deal with elastic collisions now	592
In an elastic collision, the relative velocity reverses	593
There's a gravity-defying trick shot to sort out ...	594
The initial collision is inelastic - so mechanical energy isn't conserved	596
Use momentum conservation for the inelastic part	597
The "Ballistic pendulum" Question	599



15

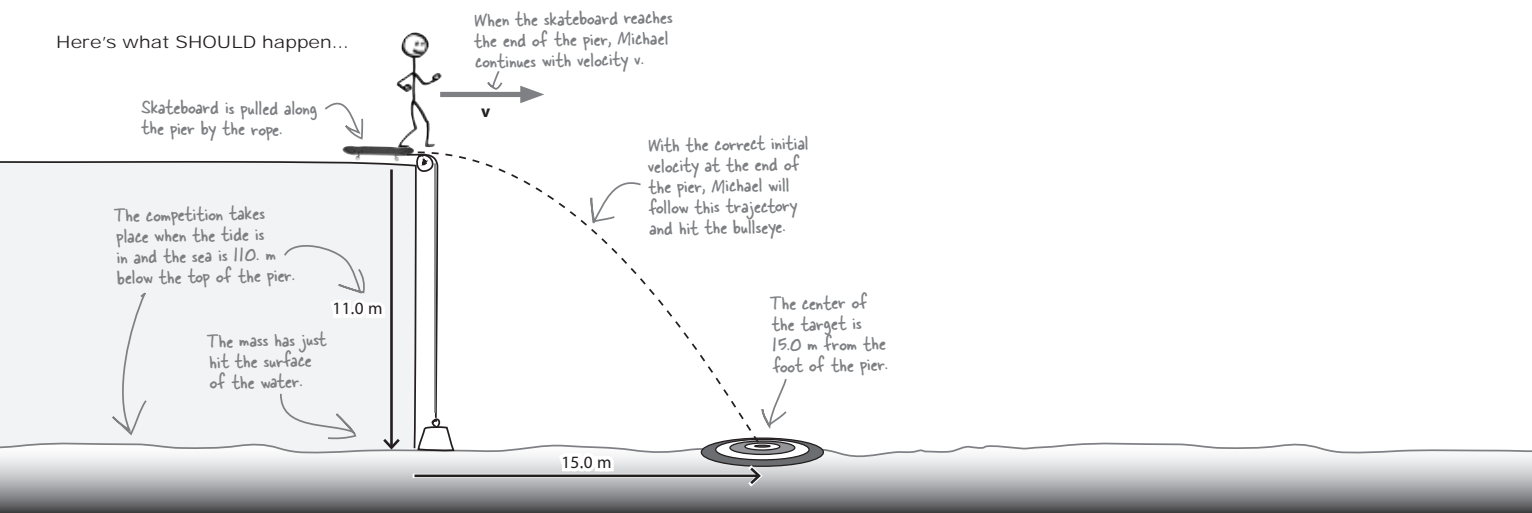
tension, pulleys and problem solving

Changing direction

Sometimes you need to deal with the tension in a situation

So far, you've been using forces, free body diagrams and energy conservation to solve problems. In this chapter you'll take that further as you deal with ropes, **pulleys**, and yes, **tension**. Along the way, you'll also practise looking for familiar signposts to help navigate your way through complicated situations.

It's a bird... it's plane...no, it's a guy on a skateboard?!	604
Always look for something familiar	605
Michael and the stack accelerate at the same rate	608
Use tension to tackle the problem	611
Look at the big picture as well as the parts	617
But the day before the competition ...	619
Using energy conservation is simpler than using forces	621
There goes that skateboard...	626



circular motion (part 1)

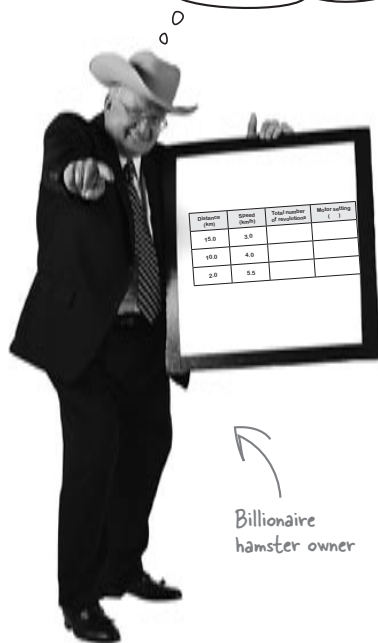
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From α to ω

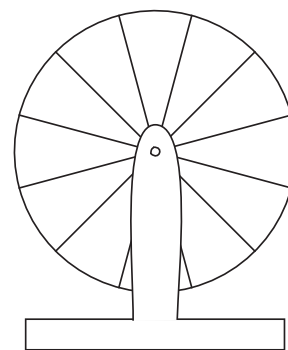
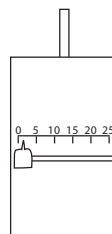
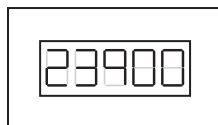
You say you want a revolution? In this chapter, you'll learn how to deal with **circular motion** with a crash course in **circle** anatomy, including what the **radius** and **circumference** have to do with pies (or should that be π s). After dealing with **frequency** and **period**, you'll need to switch from the **linear** to the **angular**. But once you've learned to use **radians** to measure angles, you'll know it's gonna be alright.

Limber up for the Kentucky Hamster Derby	632
You can revolutionize the hamsters' training	633
Thinking through different approaches helps	635
A circle's radius and circumference are linked by π	637
Convert from linear distance to revolutions	639
Convert the linear speeds into Hertz	641
So you set up the machine ... but the wheel turns too slowly!	643
Try some numbers to work out how things relate to each other	645
The units on the motor are radians per second	646
Convert frequency to angular frequency	651
The hamster trainer is complete!	652
You can increase the (linear) speed by increasing the wheel's radius	657
The "Angular quantities" Question	660

Hey kiddo, this Kentucky Hamster Derby is big business, and we gotta get the training schedule absolutely spot on!



Billionaire hamster owner



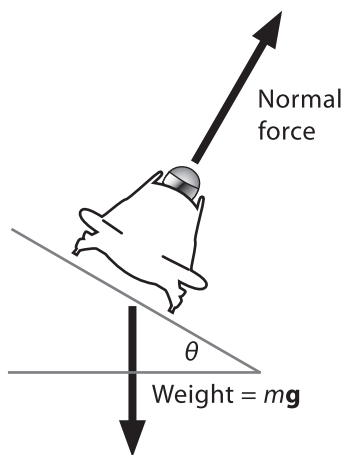
circular motion (part 2)

Staying on track

17

Ever feel like someone's gone off at a tangent? That's exactly what happens when you try to move an object along a **circular** path when there's not enough **centripetal force** to enable this to happen. In this chapter, you'll learn exactly what centripetal force is and how it can keep you on track. Along the way, you'll even solve some pretty serious problems with a certain Head First space station. So what are you waiting for? Turn the page, and let's get started.

The astronauts are tired of floating. They want gravity... in space!



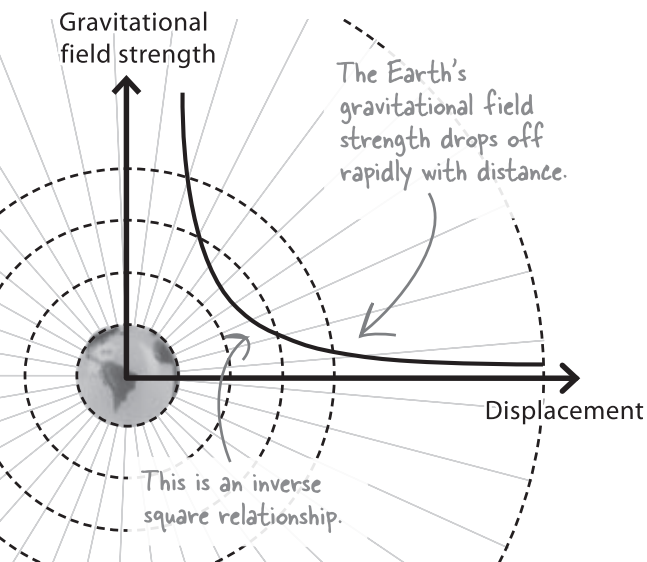
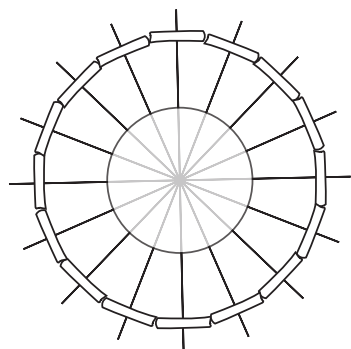
Houston ... we have a problem	664
When you're in freefall, objects appear to float beside you	666
What's the astronaut missing, compared to when he's on Earth?	667
Can you mimic the contact force you feel on Earth?	669
Accelerating the space station allows you to experience a contact force	671
You can only go in a circle because of a centripetal force	674
Centripetal force acts towards the center of the circle	677
The astronaut experiences a contact force when you rotate the space station	678
What affects the size of centripetal force?	679
Spot the equation for the centripetal acceleration	681
Give the astronauts a centripetal force	683
The floor space is the area of a cylinder's curved surface	686
Let's test the space station...	689
The "Centripetal force" Question	692
The bobsled needs to turn a corner	694
Angling the track gives the normal force a horizontal component	697
When you slide downhill, there's no perpendicular acceleration	698
When you turn a corner, there's no vertical acceleration	699
How to deal with an object on a slope	700
The "support force" required for a vertical circle varies	704
Any force that acts towards the center of the circle can provide a centripetal force	707
The "Banked curve" Question	711
The "Vertical circle" Question	712

gravitation and orbits

18

Getting away from it all

So far, you've been up close and personal with gravity - but what happens to the attraction as your feet leave the ground? In this chapter, you'll learn that gravitation is an **inverse square law**, and harness the power of **gravitational potential** to take a trip to **infinity**... and beyond. Closer to home, you'll learn how to deal with **orbits** - and learn how they can revolutionize your communication skills.



Party planners, a big event, and lots of cheese	716
What length should the cocktail sticks be?	717
The cheese globe is a sphere	719
The surface area of the sphere is the same as the surface area of the cheese	720
Let there be cheese...	723
The party's on!	725
To infinity - and beyond!	726
Earth's gravitational force on you becomes weaker as you go further away	729
Gravitation is an inverse square law	735
Now you can calculate the force on the spaceship at any distance from the Earth	741
The potential energy is the area under the force-displacement graph	743
If $U = 0$ at infinity, the equation works for any star or planet	745
Potential Energy Exposed	746
Use energy conservation to calculate the astronaut's escape velocity	747
We need to keep up with our astronaut	751
The centripetal force is provided by gravity	754
With the comms satellites in place, it's Pluto (and beyond)	757
The "gravitational force = centripetal force" Question	758

Oscillations (part 1)

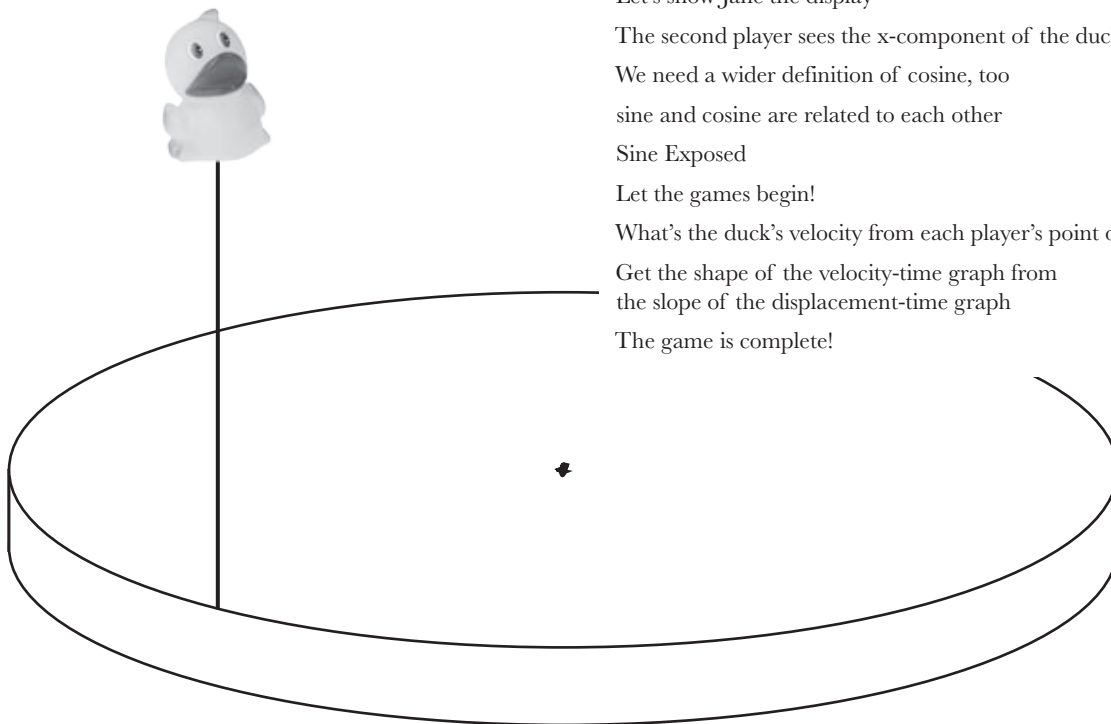
Round and round

19

Things can look very different when you see them from another angle.

So far you've been looking at circular motion from above - but what does it look like from the side? In this chapter, you'll tie together your **circular motion** and **trigonometry** superpowers as you learn extended definitions of **sine** and **cosine**. Once you're done, you'll be able to deal with anything that's moving around a circle - whichever way you look at it.

Welcome to the fair!	762
Reproduce the duck on the display	763
The screen for the game is TWO-DIMENSIONAL	769
So we know what the duck does... but where exactly is the duck?	773
Any time you're dealing with a component vector, try to spot a right-angled triangle	774
Let's show Jane the display	782
The second player sees the x-component of the duck's displacement	783
We need a wider definition of cosine, too	784
sine and cosine are related to each other	785
Sine Exposed	787
Let the games begin!	788
What's the duck's velocity from each player's point of view?	789
Get the shape of the velocity-time graph from the slope of the displacement-time graph	790
The game is complete!	794

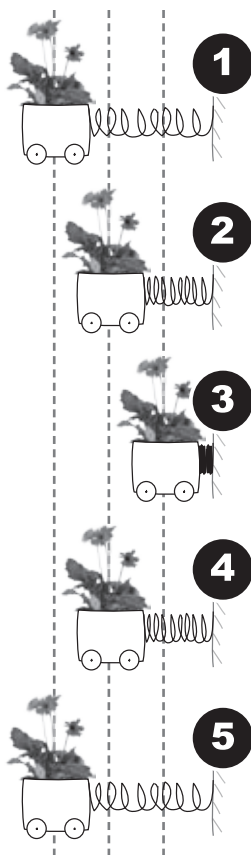


20

Oscillations (part 2)

Springs 'n' swings

What do you do when something just happens over and over? This chapter is about dealing with **oscillations**, and helps you see the big picture. You'll put together what you know about graphs, equations, forces, energy conservation and periodic motion as you tackle springs and pendulums that move with **simple harmonic motion** to get the ultimate "I rule" experience ... without having to repeat yourself too much.



Get rocking, not talking	798
The plant rocker needs to work for three different masses of plant	798
A spring will produce regular oscillations	799
Displacement from equilibrium and strength of spring affect the force	801
A mass on a spring moves like a side-on view of circular motion	805
A mass on a spring moves with simple harmonic motion	806
Simple harmonic motion is sinusoidal	809
Work out constants by comparing a situation-specific equation with a standard equation	810
The "This equation is like that one" Question	813
Anne forgot to mention something ...	815
The plants rock - and you rule!	821
But now the plant rocker's frequency has changed ...	822
The frequency of a horizontal spring depends on the mass	824
Will using a vertical spring make a difference?	824
A pendulum swings with simple harmonic motion	830
What does the frequency of a pendulum depend on?	831
The pendulum design works!	833
The "Vertical spring" Question	835
The "How does this depend on that" Question	836

think like a physicist

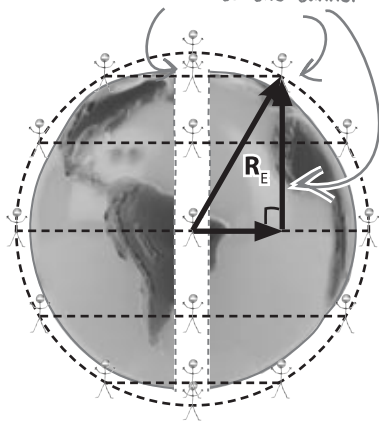
It's the final chapter

21

It's time to hit the ground running. Throughout this book, you've been learning to **relate** physics to **everyday life** and have absorbed **problem solving** skills as you've gone along. In this final chapter, you'll use your new set of **physics tools** to dig into the problem we started off with - the bottomless pit through the center of the earth. The key is the question: "How can I use what I know to work out what I don't know (yet)?"

You've come a long way!	840
Now you can finish off the globe	841
The round-trip looks like simple harmonic motion	842
But what time does the round-trip take?	843
You can treat the Earth like a sphere and a shell	845
The net force from the shell is zero	850
The force is proportional to the displacement, so your trip is SHM	853
The "Equation you've never seen before" Question	855
You know your average speed - but what's your top speed?	857
Circular motion from side-on looks like simple harmonic motion	858
You can do (just about) anything!	861

You can project this component of the orbit's radius onto the tunnel.



leftovers

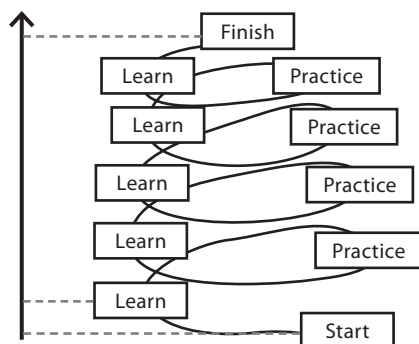
The Top Six Things (we didn't cover)



No book can ever tell you everything about everything.

We've covered a lot of ground, and given you some great thinking skills and physics knowledge that will help you in the future, whether you're taking an exam or are just curious about how the world works. We had to make some really tough choices about what to include and what to leave out. Here are some topics that we didn't look at as we went along, but are still **important** and **useful**.

Better at physics



#1 Equation of a straight line graph, $y = mx + c$	864
#2 Displacement is the area under the velocity-time graph	866
#3 Torque on a bridge	868
#4 Power	870
#5 Lots of practice questions	870
#6 Exam tips	871

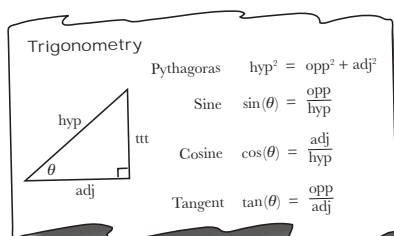
equation table

Point of Reference



It's difficult to remember something when you've only seen it once.

Equations are a major way of describing what's going on in physics. Every time you use equations to help **solve a problem**, you naturally start to become familiar with them without the need to spend time doing rote memorization. But before you get to that stage, it's good to have a place you can **look up** the equation you want to use. That's what this **equation table** appendix is for - it's a point of reference that you can turn to at any time.



Mechanics Equations Table	874
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