Ideas in Context Questions (from pupils)

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Some of these questions are quite similar to each other, or to problems on the other examples sheet. If I have only given an answer with no working, look for working somewhere else...

1. **Work out the momentum of the tram when it has 25 people in it who all weigh 75 kg, whilst the tram is travelling st top speed.**

   momentum = mass × velocity
   $= [50000 + 25 \times 75]$ kg × 80 km h^{-1}
   = 4150000kg km h^{-1}
   (= 1153000kg m s^{-1} – You work it out!)

2. **The tram with a total weight [MASS] nof 50280 kg reaches the top of the hill which is 100 m high. Calculate the GPE of the tram.**

   GPE= mgh = 50280 kg × 10 N kg^{-1} × 100 m
   = 5.03 MJ

3. **At the bottom of the hill the tram is travelling at 80 km h^{-1} with a weight [MASS] of 50280 kg. Work out its kinetic energy.**

   KE $= \frac{1}{2}mv^2$
   =12.4 MJ

4. **How do regenerative brakes work?**

   Good question! According to Wikipedia, regenreative brakes simply use the motor in reverse to slow the tram down. The motor is designed to act as a generator when it is used in this way, and the electricity generated in this way is stored, either in special batteries on the tram or by sending it back through the rails (but I think batteries would be better in this case, since putting power back into the rails might cause problems for other trams on the line!)

   The regenerative brakes normally are only used when the speed is quite large – normal friction brakes are used to bring the tram to a stop, or for emergency braking.

5. **The tram's power lines are rated at 750 V, 10 kW. Find the current it draws.**

   Assuming that we are drawing the maximum rated power (for example going up that hill), we know that $P = IV$ so $I = P/V$. This gives a current of 13.3 A.

1. **The tram's route is 3 miles long. If it travelled at an average speed of 70 mph, how long will it take to get around the route?**

   $v = \frac{s}{t}$ so $t = \frac{s}{v} = \frac{3 \text{ miles}}{70 \text{ mph}}$
   giving 0.0429 hours, or 2 min 34 seconds. *Is this reasonable?* Yes—you expect to go about a mile per minute at 60 mph, so at 70 mph, a 3 mile journey should take somewhat less than 3 mins.

2. **The tram takes 2 hours to get around a different route. If it travelled at an average speed of 70 mph, what distance was the route?**

   140 miles – that's quite a long track! Maybe it will only actually get 1 mile away if the track is a circle!

3. **What is the difference between an a.c. current and a d.c. current?**

4. **The mass of the tram is 3 tonnes, and it climbs a hill which is 7 m high. What is its change in gravitational potential energy?**

   210000 J.

5. **How do generators generate the electicity in the power station?**

   Power stations convert some form of energy into electrical energy. There are loads of different ones. Wind & tidal get electrical energy from kinetic, photovoltaics use sublight to create electrical energy, but most rely on heating something up (usually water) and driving it through a turbine. The water can be heated in a number of ways – you can burn something like coal, or maybe use biofuels to be greener. Also nuclear reactions could be used to generate heat.

   Of these, all but solar use turbines to generate the electricity. These are like motors in reverse, and rely on the fact that a wire which moves in a magnetic field gets a current induced in it by electromagnetic induction. More usually, generators use fixed coils of wire, and a moving magnet, which is attached to a turbine and rotates. There is an alternating current set up in the coils, and that's how the electricity is generated.

How much electrical energy is created when the tram slows from full speed to stationary? As we mentioned, the brakes can't be 100% efficient, but for this calculation, let's assume they are, so that no energy is lost to friction, and we get straight conversion from kinetic to electrical via the regenerative brakes. Thus, we need to know the kinetic energy of the tram at full speed, which is worked out elsewhere (in this question, it's not clear whether we're talking about a full or empty tram).

1. **The supertram has a top speed of 80 km h^{-1}. How fast is this in metres per second?**

   If we travel 80 km in one hour (this is 80000 m), we shall go 80000/60 m in one minute, and 80000/60/60 m in one second. This turns out as 22.2 m s^{-1}.

2. **An empty supertram has a mass of about 50000 kg. What is its weight in newtons (N)?**

   Assuming $g = 10$ m s^{-2}, 500000 N. (OK, g is more like 9.81 m s^{-2}, but I cheat!)

3. **The hill is x metres high. How much gravitational potential energy would an empty tram have at the top of this hill?**

   GPE = work done in lifting tram up hill = force needed × distance lifted
   = 500000 N × x = 500000x J.

4. **Suggest a reason why the tram will run on d.c. power.**

   See previous answer on other sheet.

5. **Assuming the tram is full and the weight of an average person is 75 kg, how much momentum will the tram have when travelling at top speed?**

   I've done this already, too.

1. **As speed equals 80 km h^{-1}, how far on average could the tram travel in 3 hours?**

   240 km

2. **What is the resistance of the overhead cable if the voltage is 750 V and the current is 300 A?**

   This isn't a good question. We might naively use ohm's law to get a resistance, but it isn't a fair resistance. Think about it. We have the voltage *across the tram* and the current through the cable/tram circuit. We can tell the resistance of the tram, but the question doesn't allow us to work out anything about the cables. See also the later question on this, about how the driver controls the current.

3. **Calculate the change in gravitational potential energy for the tram going down a hill of 10 m, given that the weight [MASS] of the tram is 50000 kg.**

   5000000 J.

4. **A transformer is placed in the depot to reduce the voltage. Is this a step-up or step-down transformer?**

   Step-down.

5. **The transformer at the depot has 13 turns on the primary coil and 4 on the secondary coil. Given that the a.c. voltage across the primary coil is 750 V, what is the output voltage across the secondary coil?**

   This isn't a very good tranformer, as you need more than 4 turns to get a decent magnetic field linkage (i.e. a good efficiency)! It's also the wrong way around: in the depot, the output voltage is 750 V. Anyhow, as posed, the answer to the question is 230.8 V (this is close to the mains voltage – is that what was intended?)

1. **How much gravitational potential energy does the tram make going up the steepest hill that has a slope of about 1 in 10?**

   The tram doesn't 'make' energy (otherwise is would be a handy way to beat global warming!) It transfers energy from either it's motion (kinetic stores) or from the power supply via the motor (electrical) into stored gravitational potential energy. Also, all hills having a slope of 1 in 10 have are equally steep. The question can't be answered without a bit more information: how far up the hill are we going?

2. **How much kinetic energy is created?**

   As the first question was incomplete, I don't know what you mean by this.

3. **What is the work done of the tram?**

   Also an impossible question!

4. **What is the current in the cables used to power the super tram?**

   This is also impossible! (depends on speed of tram, steepness of hill, mass of tram)

5. **What is the resistance of the cable?**

   Also impossible.

The next set of problems have answers already; how kind!

1. **Calculate the energy of the supertram going full speed.**

   Is this empty or full? Done elsewhere, anyway.

2. **Give reasons why the supertram is better than buses.**

   Trams run on tracks; could be safer. Electical energy could be greener (but then again, maybe they are hydrogen fuel cell buses!) Quieter - but this could also be a danger to pedestrians. Good for old cities where it's difficult for buses to get around corners of medieval streets. Also no emissions / pollution which could damage buildings.

3. **An empty supertram brakes from 80 km h^{-1} to 35 km h^{-1} to enter a station. What is the change in momentum?**

   625000 kg m s^{-1}

4. **Give an advantage of the supertram.**

   It is fast?

5. **Why is having the tram's power supply from the national grid a bad thing compared to having a separate power supply?**

   It won't work in power cuts?

1. **What is the momentum of the supertram when it is empty and travelling at top speed?**

   1110000 kg m s^{-1}

2. **If an empty supertram is travelling up a slope with a vertical height of 3 m, what would the change in gravitational potential enrgy be?**

   1500000 J.

3. **The electricity used to power the supertram is from the national grid, and this needs to be stepped down before use. Give 3 examples of the number of coils on the primary and secondary coils which could be used.**

   The key thing here is that the ratio must be the same. So we are going for a ratio of 40000 V down to 750 V. We need the same ratio of turns on the primary:secondary coils.
   We could just use 40000 on the primary and 750 on the secondary.
   Or 120000 on the primary and 2250 on the secondary.
   Or 80 on the primary and 15 on the secondary, but this will probably be too few for a decent transformer.

4. **If an empty tram is steadily accelerating at a rate of 2 m s^{-2} what is the net force on the tram?**

   $F = ma$
   =100000 N.

5. **When an empty tram is travelling at full speed, what is its kinetic energy?**

   12.3 MJ.

1. **By how much would the voltage from the national grid have to be stepped down before it would safely power a tram?**

   I don't know. But in the case of the supertram, a voltage of 750 V is used.

2. **What is the momentum of an empty tram travelling at top speed?**

   1110000 kg m s^{-1}

3. **An empty train A, with a velocity of 40 km h^{-1}, collided with a stationary tram B. After the collision, tram A is stationary. What is the velocity of tram B in kilometres per hour?**

   Conservation of momentum implies that B must carry off all of A's momentum, so it must have a speed of 40 km h^{-1} after the collision. I pity the passengers, as the impulses (changes in momentum) would be huge in this collision!

4. **How much kinetic energy does an empty tram travelling at 50 km h^{-1} have?**

   4.82 MJ.

5. **The transformer in the substation has 60 turns on its secondary coil. If the voltage is stepped down from 40000 V to 750 V, how many turns must be on the primary coil?**

   3200.

1. **Why is an a.c. current used?**

   To reduce transmission losses.

2. **What is the total mass of the tram given that an average person has a mass of 65 kg and it is at full capacity?**

   66250 kg m s^{-1}.

3. **What is the momentum of the tram?**

   Depends on speed; not enough information.

4. **Calculate the change in gravitational potential energy as the tram goes up a slope of about 1 in 10.**

   Depends how far up the hill you go; not enough information.

5. **Why is the electricity converted to d.c. before the tram uses it?**

This is a safety thing; see other sheet answers.

1. **How much does a full supertram weigh? (Assume a passenger to have a mass of 70 kg.)**

   67500 kg.

2. **What would a full supertram's momentum be when pulling away from a stop to reach top speed?**

   Zero when pulling away from a stop. Is this a trick question?

3. **Why isn't all gravitational potential energy converted into kinetic energy?**

   There will be losses due to friction

4. **Suggest how the tram driver controls the flow of electricity?**

   Uses a variable resistor of some sort to control the current flow by $I = \frac{V}{R}$.

5. **Two supertrams are on the tracks. Is their current shared out or equal?**

   If two trams are on the tracks, they are in parallel. They therefore don't necessarily have the same current (they have the same voltage). I should therefore say the current is 'shared'. This is useful, since it means that one can draw more power than the other, for example if it is going up a hill.

1. **What is a regenerative brake?**

   See the explanation about how regenerative brakes work. It's really the motor used to slow the tram.

2. **What is the momentum if there are 75 people on board, with an average mass of 69.5 kg, and the tram is travelling at 60 km h^{-1}?**

   920200 kg m s^{-1}.

3. **If 20 people then got off, and the average mass changed to 64 kg, but the speed stayed the same, what would the percentage momentum change be?**

   New momentum = 892000kg m s^{-1}. Percantage change is therefore -3.06%.

4. **How many coils would be needed to step down the national grid voltage of 40000 V to the supertram voltage of 750 V?**

   We don't know the absolute number of coils, only the ratio - there is a previous question on this, giving 3 possible answers.

5. **What are the advantages of having a regenerative brake?**

   Surely it's better than losing everything to friction each time you have to stop! There is an increase in efficiency.

1. **Explain why if there are two trams on the rail at one time, the circuits switch to parallel?**

   Don't forget that each tram completes its branch of the circuit by making a connexion between the rail and the overhead cable. If there are two or more trams on the rail at one time, each will form one branch of the overall circuit – the trams will therefore be connected in parallel.

2. **Explain the reasoning for using AC current instead of DC.**

   Power losses are much lower with AC, especially for long transmission distances.

3. **Calculate the momentum of an empty supertram travelling at 80 km h^{-1}.**

   1110000 kg m s^{-1}

4. **Why is the momentum change so great after the tram pulls away?**

   The change in momentum is large because the tram is heavy and it has to undergo a large change in velocity to get up to full speed.

5. **Approximately how long would the tram take to travel six kilometres?**

At full speed, the tram would take $4\frac{1}{2}$ minutes to travel 6 km.

1. **Calculate the work done by the tram climbing the steepest slope for 100 m.**

   Steepest slope on route is 1 in 10. Taking $g = 10$ m s^{-2}, the work done *on* the tram is 5000000 J = 5 MJ.

2. **Calculate the momentum of the tram at full speed.**

   Empty tram: 1110000 kg m s^{-1}

3. **Calculate the distance travelled in 20 minutes at full speed.**

   20 minutes is one third of an hour. In one hour at full speed, the tram would travel 80 km, so in 20 minutes, 26.7 km would be covered.

4. **How far would the tram go if it travelled for 30 minutes at an average speed of 40 km h^{-1}?**

   20 km.

5. **Calculate the change in momentum if the tram were to accelerate to its full speed from standing still [in 10 seconds]?**

   I've put some brackets in [], as that information is only needed if you want to know the force. Change in momentum is 1110000 kg m s^{-1}.

1. **What is the formula used to calculate work done?**

   work done = force × distance moved in the direction of the force

2. **What are regenerative brakes?**

   See the explanation about how regenerative brakes work. It's really the motor used to slow the tram.

3. **What is the equation to work out the GPE?**

$$V(\mathbf{r}) = \int_{|\mathbf{x}-\mathbf{r}|=0}^{\infty} \mathbf{F}(\mathbf{x})\, d\mathbf{x}$$

Wish you hadn't asked? That's the equation for the GPE in any situation, for Newtonian gravity. However, near to the Earth, things are simpler because the gravitational field is (nearly) uniform, and so we gan write an equation for changes in GPE quite simply:

change in GPE = mass × acceleration due to gravity × change in height

4. **What units do you use for GPE?**

   Another very broad question... Any unit which has dimensions of energy is fine, e.g. the joule (J). But so long as we have dimensions of M L^2 T^{-2}, we're fine (e.g. tonne square kilometers per year per year!)

5. **What is a step-up/step-down generator?**

   I think you mean transformer here.

1. **Calculate the momentum change.**

   When what happens? (Impossible.)

2. **Calculate the change in gravitational potential energy.**

   Impossible.

3. **Work out the power used to run the supertram.**

   Impossible.

4. **Draw a graph showing the constant speed of the tram.**

   Trivial straight line graph for each of speed, acceleration (zero) and distance (increasing).

5. **Calculate kinetic energy.**

   Impossible.

The next set have answers provided again.

1. **How long would it take to go 50 km at top speed?**

   $37\frac{1}{2}$ minutes.

2. **The tram goes up a hill for 100 m, with a force of 2000 N. How much work is done?**

   I guess this is the height reached, so the work done would be 200000 J. If this is the distance travelled, you need to know the slope as well.

3. **The tram hits a smaller, stationary tram, having a mass of 30000 kg, at 10 m s^{-1}. Assuming the brakes aren't on, what is the momentum of the second tram after the collision?**

   We need some further information to answer this one – do the trams stick together, or does the firs tram come to a standstill. . . ?

4. **What is the momentum of a tram carrying half its maximum passeger load going at half of full speed?**

   Assuming a person hass mass of 70 kg, the momentum is 97800 kg m s^{-1}.

5. **Assuming that the tram is full to start with, that it is going full speed, and that at every stop, 14 passengers get off, what will be the momentum of the tram after 12 stops.**

   At this point, 12 lots of 14 people will have got off (168 people). This leaves 82 people on the tram, so if each has mass of 70 kg, the momentum is now 1239000 kg m s^{-1}.

1. **What are the functions of step-up and step-down tranformers? When and why are they used?**

   Step-up and step-down transformers are used to change the voltage of an ac supply.

2. **Name two differences between parallel and series circuits regarding (a) potential difference and (b) current.**

3. **Assume the tram is carrying half its maximum capacity of people, who have an average mass of 80 kg. What will the momentum of**

the tram be if it is travelling at 60 km h^{-1}?

4. **What is the difference between AC and DC electrical current?**

   See previous answer.

5. **When the tram brakes it converts its kinetic energy into electrical energy. Explain why not all of the electrical energy is stored in batteries or fed back into the tram circuit.**

   There will be some losses of energy in the motor when it is being used as a generator in regenerative braking, since no generator can capture all of the magnetic field from the magnet in the coils.

1. **Why does the current have to be changed from ac to dc to go into rails and cables?**

   This is to do with safety, and is discussed in one of the other answers.

2. **If the tram has the maximum number of people sitting and half the maximum number of people standing, with each person weighing 80 kg, what would be the momentum of the tram?**

   At maximum speed, the momentum would be 1410000 kg m s^{-1}.

3. **What other ways, apart from overhead cables, could electricity be transferred to the tram?**

   Hmmm... Each tram could carry a battery, which is charged at the end of the day, or maybe power could be trasmitted via microwaves (this is a new technology, and probably would not work). We could perhaps use some kind of induction scheme, with a current loop in the road under the tram which induces a current in loops inside tram.

4. **What are the advantages of having the circuit in parallel when more than one supertram is on the tracks in the same circuit?**

   I've answered this question in one of the other answers. For a parallel circuit, the current through the trams can be different, meaning that, for the same votage of 750 V, the trams can draw different currents and therefore different powers (this is useful if, for example, one is going along the flat and one is going up a hill).

5. **Draw a distance-time graph for tram if it travels for 20 minutes at a constant speed of 50 km h^{-1}.**

   This will be a straight line with a gradient of 50 833 m per minute. The final distance would be 16.7 km.

1. **How much momentum will an empty tram have when it is travelling at 40 km h^{-1}?**

   556000 kg m s^{-1}.

2. **At the top of the hill and empty tram with mass 50000 kg travels a distance of 20 m downwards. How much kinetic energy is gained by the tram between the top and bottom of the hill?**

   I think your 20 m is the vertical distance downward, so the KE gained is 10000000 J or 10 MJ.

3. **What is the momentum of a full tram at full speed, assuming an average person has a mass of 75 kg?**

   1530000 kg m s^{-1}.

4. **The a.c. electricity is prodiced by generators. What is the name of the process used to generate electricity?**

   Electromagnetic induction.

1. **When the supertram is empty, calculate the work done if it travels 200 m up the steepest hill.**

   I guess you mean a horizontal distance of 200 m, which (with a gradient of 1 in 10) corresponds to a vertical distance of 20 m. This would need 10 MJ of energy.

2. **Calculate the same with a full load.**

   If each person has mass of 70 kg, this would need 13.5 MJ.

3. **Using the voltages given for the national grid and that used on the supertram system, calculate the number of turns on the primary and secondary coils.**

   Using the voltages given, we can't work this out; only the ratio can be determined (see previous question on this).

4. **At maximum velocity, what is the momentum of the supertram when it has (a) no load (b) half load (c) full load?**

   1110000 kg m s^{-1} for no load; if each person has a mass of 70 kg, 1305000 kg m s^{-1} for a half load, 1500000 kg m s^{-1} for full load.

5. **At full velocity and with full load, how much kinetic energy does the supertram have?**

   If each person has a mass of 70 kg, the KE is 16700000 J = 16.7 MJ.

1. **What is the relationship between power, current and voltage?**

   $P = IV$

2. **Why is an AC current used in mains electricity?**

   To reduce losses in transmission, and to allow voltages to be stepped up and down conveninently via transformers.

3. **What 3 things affect the size of the induced voltage in a power station?**

   The strength of the magnet used for electromagnetic induction in the generator, the speed of the generator and the number of turns in the generator's coils.