1. Heat (3+2+1+2 = 8M)
   a. Kenny is using a solar heater to heat up some liquid of mass 10kg to determine its specific heat capacity. It is given that the energy received by the solar heater is 1000W, and its efficiency is 69%. In 1 hour, the temperature of the liquid rises from 25°C to 50°C, determine the specific heat capacity of the liquid. State an assumption in your calculation.
   b. Kenny now uses a setup with an immersion heater to measure the liquid's specific latent heat of vaporization as shown below in figure 1a.

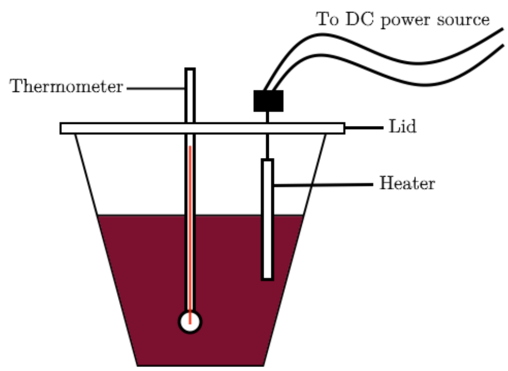
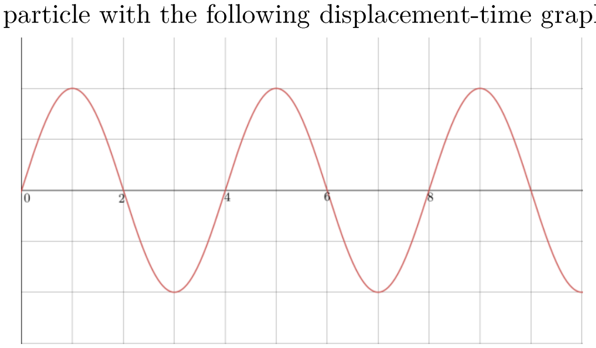


Figure 1a

      i. State **TWO** mistakes in the experimental setup
      ii. Suggest a material that the cup should be made of, explain your answer
      iii. After fixing the errors. The heater with power 1.6kW is switched on for one minute and 10g of liquid is boiled away, find its specific latent heat of vaporization.

2. Motion I (2+2+2+2=8M)
   a. Consider a particle with the following displacement-time graph



      i. Sketch its velocity-time graph and its acceleration-time graph

      ii. Given that its displacement, $x = A\sin(\omega t)$, deduce the net force of the particle $\mathrm{F}(t)$ as a function of x, where A, ω are constants. The particle has a mass of m.

b. When will the particle reach its maximum velocity and acceleration?

c. It was later found that the particle is a part of a string. Tony claims that this motion (called Simple Harmonic Motion) violates the law of energy conservation as the kinetic energy of the particle is completely lost when it is stationary when $x = A$. Is Tony correct? Explain your answer.

3. Motion II (2+3+2 =7M)

   a. There is a fire and a fat man is about to jump from the burning building. He is 12m above the ground level, calculate the time it takes for him to land onto a trampoline ring on the ground level.

   b. When the man, with mass 115kg touches the trampoline, it takes him 0.5s to become completely stationary. Calculate the average force acting on the man by the trampoline during this period. Hence explain why the trampoline can be used to save him from dying during the fall.

   c. It is not advisable for the man to jump onto the trampoline if he is even higher up in the building due to safety concerns, explain why.

4. Motion III (2+3+2+2=9M)

   Boxes A and B are in contact as shown. Box A has mass 3kg, box B has mass 1kg, the ground surface is frictionless. The system is acted on by a force F.

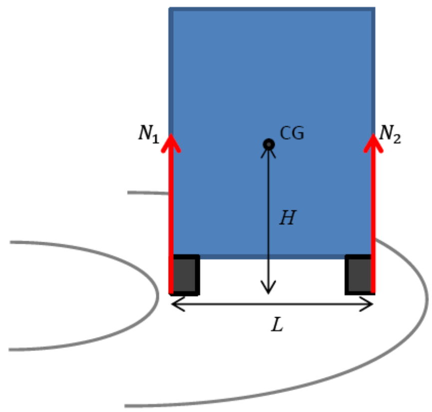
   a. Draw a free body diagram for both boxes; note that the surfaces of the two boxes are rough.

   b. Suppose the frictional force on B due to A is equal to 0.8 times the normal reaction force on B by A. Find the minimum magnitude of force F such that box B does not fall down and find the corresponding acceleration of the system.

   c. The force is maintained for 10 seconds, find the average power delivered.

   d. Suppose the ground surface is not smooth, how will the minimum magnitude of F be affected if B still does not fall down. Explain your answer.

5. Motion IV (4+2+1=7M)



A bus of mass m is turning around a circular corner (to the left) at some speed v as shown above. The radius of the circle is r. The bus has a width of L and the height from its center of gravity (CG) to the ground is H. N_1 and N_2 are the normal reaction forces exerted on the left and right respectively. Assume that the normal reaction forces are exerted on the edge of the tyres.

Given: Total frictional force on both tyres to make the turn

$$f = \frac{mv^2}{r}; \text{ directed towards centre of the circle}$$

a. By considering moment at the center of gravity of the bus, show that:

$$N_1 = m\left(\frac{g}{2} - \frac{Hv^2}{LR}\right) \quad \text{and} \quad N_2 = m\left(\frac{g}{2} + \frac{Hv^2}{LR}\right)$$

b. Express the largest value of v, in terms of suitable variables and constants, such that the bus can turn around the corner without flipping over. Assume the frictional force is large enough such that the bus flips over before it slips.

c. It is given that the bus is travelling around the corner at v_{max} found in (b) on Earth. State what would happen to the bus if the bus is travelling around the same bend, at the same speed, but on the moon? (Gravity on the moon is $\frac{1}{6}$ times that on Earth)

6. Motion V (2+6)

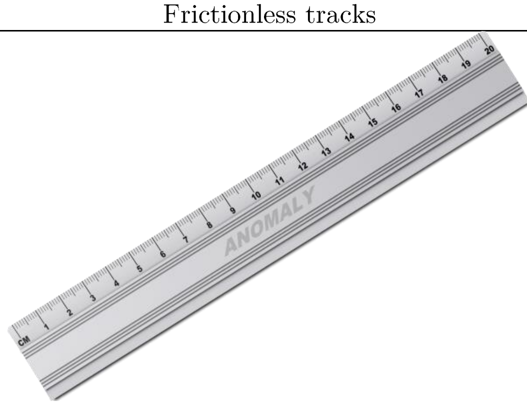
Figure 6a

Figure 6a depicts a pull-back toy car with mass m. It has a spring inside it to store energy.

a. State the energy conversions involved when the toy car is pulled back and released.
b. You are given frictionless track pieces, markers, ruler and a stopwatch. With the provided apparatus, use an experiment to find out the max amount of energy that can be stored inside the spring of the toy car. State a precaution that should be taken in the experiment.

Frictionless tracks

Markers

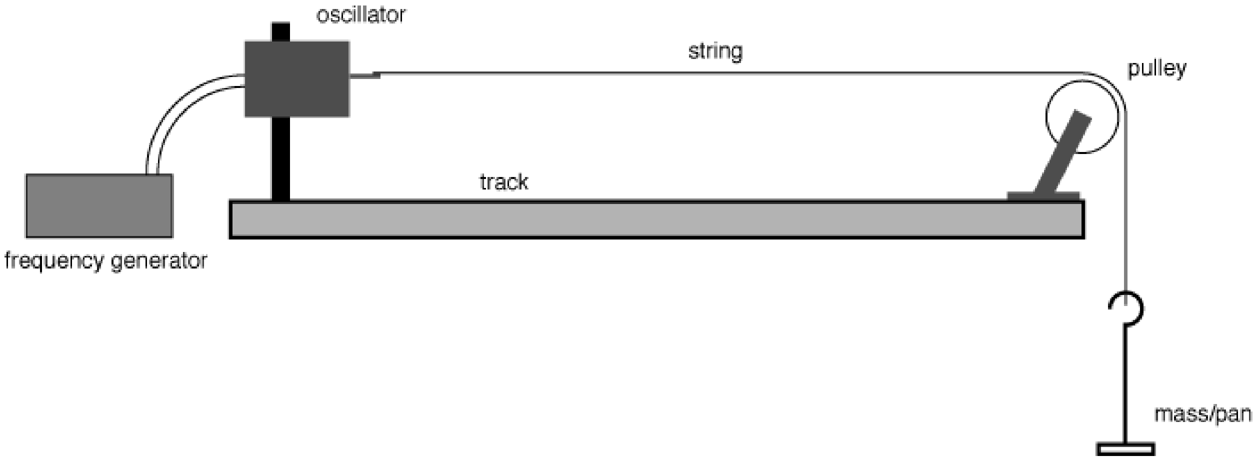


Ruler

Stopwatch

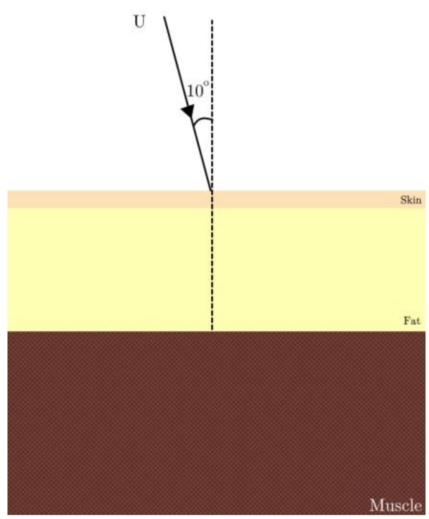
7. Wave Motion I (3+2+2+2=9M)

   A stationary wave is set up as shown



   a. The frequency generator is then turned on. It is found that stationary waves can be formed at 24Hz and 28Hz, but not at any frequency in between. Find the fundamental frequency, f_0 of the string. It is given that the string is 1.5m in length and the pulley is a fixed end.
   b. Explain the formation of the stationary wave.
   c. A very low pitched sound can also be heard during the process, explain why.
   d. More mass is now added to the right side, state and explain what would happen to the fundamental frequency of the string.

8. Wave Motion II (1+3+2+2=8M)



   An ultrasound ray U enters the human body at an angle of incidence of 10^{o} during ultrasound imaging process

   a. State the meaning of ultrasound.
   b. Calculate the angle of refraction of the ultrasound ray and hence complete the light ray in the above figure. Speed of ultrasound in air = 340 ms^{-1}; Speed of ultrasound in Skin and Fat = 1500 ms^{-1}

c. Explain why it is important to keep the ultrasound transducer (emits ultrasound waves) normal to the human body during imaging.

d. Suppose the ultrasound scanner is now normal to the human body. A ultrasound ray is emitted into the body, then reflects at the fat-muscle boundary and returns to the skin-air boundary in 50 μs, calculate the total thickness of the skin and fat layers.

9. Wave motion III (1+2+2+2+2+1=10M)

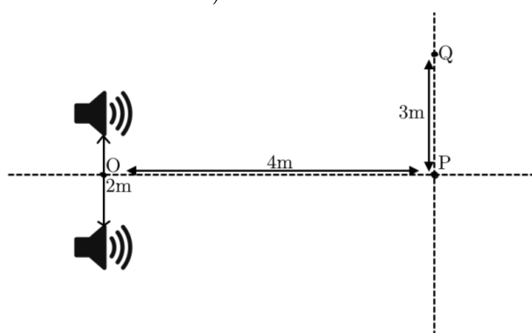


Figure 8a

In Figure 8a, two loudspeakers , which are coherent sources are placed 2m away from each other. O is the mid-point of the 2 speakers, while P is equidistant from the 2 speakers and 4m away from O. Q is a point 3m from P. OP and PQ are perpendicular to each other.

a. What is meant by coherent sources?

b. A loud sound can be heard at Q, explain its formation.

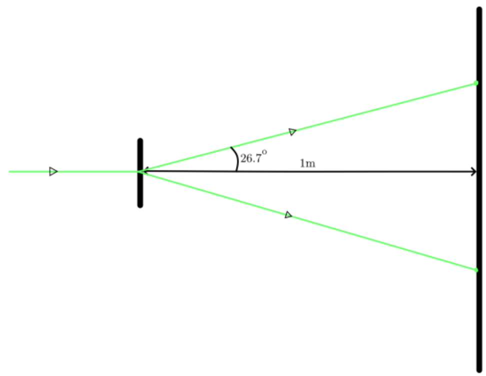
c. Q is the first order maximum. Calculate the frequency of the sound emitted. Take speed of sound in air = $340ms^{-1}$

d. The frequency of the sound is now halved, explain what would happen to the sound at Q.

e. Jeff now walks from P towards O, and eventually walks beyond O with a microphone, sketch a graph of volume against time. Jeff reaches O at t_1. Mark t_1 on the axis of your graph.

f. When using the formula $\Delta y = \frac{D\lambda}{a}$, Jeff could not obtain the correct value of length PQ. Explain why this is the case.

10. Wave motion IV (2+1+2+2+1+2=10M)
    a. A beam of light from a laser points toward a single slit, with a screen placed a certain distance behind. Explain why the light spot of the screen is much larger but dimmer than the original beam itself.
    b. The single slit is replaced with a diffraction grating with 500 lines per mm as shown below in figure 9a, the screen is placed 1m away from the grating, the angle of the 2nd order maximum is measured to be 26.7° as shown in figure 9a



       i. Why is the 2nd order maximum used in measurements instead of the first order?
       ii. Calculate the wavelength of the light used. (Note: the light might not be green in colour)
       iii. Calculate the total number of bright spots observed on the screen.
       iv. Sometimes, the laser beam is not perfectly normal to the diffraction grating, what can be done to reduce the error?
    c. White light is now used instead of the laser in 9(b), show that the 3rd order spectrum will partially coincide with the 2nd order spectrum.