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Activity

Practice-for-exam questions

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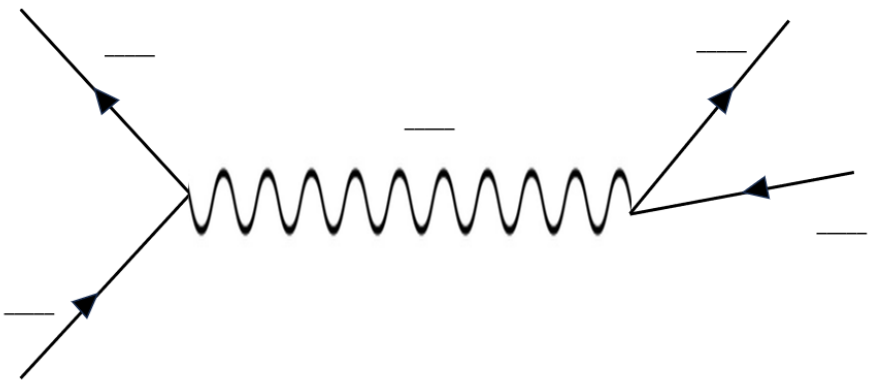
Use the questions below either in class or for individual work after students have read the articles in the magazine. Although the questions state the values of constants required, some of the questions require additional data — students should either make reasonable estimates of quantities or look up values using a data book or website. Students should clearly communicate any assumptions made. Suggested outline answers to questions are provided in a separate document.

Understanding Feynman diagrams

1 **a** When considering a Feynman diagram what is the meaning of an upwards pointing, or downwards pointing, arrow on a straight line towards an interaction?

b Name the different exchange particles and the corresponding forces.

2 **a** Label this Feynman diagram for a beta minus decay with the symbols for the particles involved in the interaction:



b Draw both the Feynman diagrams for an antineutrino interacting with a proton via the weak interaction:

$$p + \bar{\nu}_e \rightarrow n + e^+$$

Observing gravitational waves

1 Gravitational waves are only detectable from very massive accelerating objects. Although a full treatment of gravitational waves requires Einstein's theory of gravity (general relativity), we can still use Newtonian mechanics as a good approximation to many massive systems that emit gravitational waves.

Assume that two black holes of masses 20.0 $M_\odot$ and 50.0 $M_\odot$ are orbiting around their common centre of mass. The distances to that point are 75.0 AU and 30.0 AU respectively.

$1\ AU\ 1.50 \times 10^{11}\ m,\ G = 6.67 \times 10^{-11}\ N\ m^2 kg^{-2}, 1\ M_\odot = 1.99\ \times 10^{30} kg$

Assume that you can use Newton's law of universal gravitation to answer these questions:

a Calculate the gravitational force between these two black holes.

b Calculate the orbital period of the black holes about their common centre of mass.

c If the black holes are $9.50 \times 10^9 AU$ away from the Earth, how long would it take for the effects of the gravitational waves to arrive and be detected by the LIGO experiment?

Dating the Earth

1 Technetium-99m (Tc-99m, a meta-stable excited state of Technetium-99 that decays into the ground state by emitting gamma rays) is a nuclear isotope commonly used for medical purposes due to producing easily detectable gamma rays and its relatively short half-life of 6.04 hours — long enough to track certain bodily process but short enough not to cause lasting damage in the body.

a Calculate the decay constant of Tc-99m.

b What percentage of the injected isotope would remain in the body after 24 hours?

c How long would it take for the activity of the isotope to drop to less than 0.1% of its original activity?

Extension:

d Tc-99m decays into Tc-99, which has a half-life of about 210 000 years and decays by beta emission. Suppose that 50.0 μg of Tc-99m is injected into a patient's body. After 4 days, about 99.999% of the original Tc-99m has decayed into Tc-99. Calculate the activity of the Tc-99. Comment on whether the Tc-99 represents a risk to the patient.

2 A fossilised tree is found to contain the isotope carbon-14, which decays by beta emission with a half-life of 5730 years. Given that the fossil contains about 0.05% of this isotope compared to a modern specimen, approximately how old is the tree?

Methods for measuring *g* with a falling object

1 Scientists want to perform measurements of the acceleration due to gravity on a series of extraterrestrial bodies. Describe at least two methods for doing this. Include details of the measurements to be taken, and how the scientists should analyse their data, including any graphs they should draw and any calculations they need to carry out.

2 A series of measurements have been made on a moving object. Given the data below calculate the missing variables.

a The object starts from rest and accelerates uniformly, taking 25 seconds to travel a distance of 100 metres. Find the final speed and the acceleration.

b An object initially travelling at a steady speed accelerates uniformly at 5 m s^{-2} for 3 seconds. The object reaches a final speed of 20 m s^{-1}. Find the initial speed and the distance travelled while the object was accelerating.

c An object initially travelling at 12 m s^{-1} accelerates uniformly to a final speed of 20 m s^{-1}. It travels 10 metres while doing so. Find the acceleration of the object and the time it took to travel through this distance.