ROBERT F. O'CONNELL

SELECTED PUBLICATION LIST

PDF's given on following list

7. R. F. O'Connell and C. O. Carroll, "Internal Conversion Coefficients: General Formulation for all Shells and Application to Low Energy Transitions," Phys. Rev. 138, B1042 (1965).

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Exact analytical results (in the case of a point nucleus with no screening) for the internal conversion coefficients for any shell are presented. These results simplify considerably at threshold values of the gamma-ray energy. Numerical results, at threshold, are obtained for the K, $L(L_{\mathrm{I}}, L_{\mathrm{II}}, L_{\mathrm{III}})$ and $M(M_{\mathrm{I}}, M_{\mathrm{II}}, M_{\mathrm{III}}, M_{\mathrm{IV}}, M_{\mathrm{V}})$ shells, for 19 values of Z in the range $5 \leqslant Z \leqslant 95$, and for the first five electric and magnetic multipoles. The results for the K shell agree with those obtained by Spinrad. It is shown that the theshold results are actually correct to order P (momentum of electron in units of its mass). The effects of finite nuclear size are also considered.

28. R. F. O'Connell and J. J. Matese, "Effect on a Constant Magnetic Field on the Neutron Beta Decay Rate and its Astrophysical Implications," Nature 222, 649 (1969).

RECENT advances in the production of large magnetic fields in the laboratory[1,2] have generated interest in the effect of intense magnetic fields on various phenomena[3,4]. The largest field that can be produced in the laboratory[1,2] at present is about 10^6 G, which is considerably lower than the quantum critical field value[5] of $H_c = m^2c^3/e\hbar = 4{\cdot}4 \times 10^{13}$ G; but the "cosmic laboratory" may be a source of much stronger fields and it has been suggested[6] that magnetic fields as large as 10^{14}–10^{16} G may exist in neutron stars. Hoyle[7] has cited the possibility of a large primordial magnetic field, and Brownell and Callaway[8] speculate that neutron stars and the dense early universe may be ferromagnetic. One of us (R. F. O.) has examined[9] various effects of a large magnetic field and has indicated an effect of magnetic fields which has been often ignored in astrophysical investigations, namely, that the rates of all elementary particle processes will be affected. Pursuing this idea, we examine here the effect of a magnetic field on the β decay rate of a neutron. This is a fundamental process in many astrophysical phenomena and in particular it is very important[10] in a problem of current interest, that is, the production of He in the "big-bang" expansion of the universe[11]. In addition, our calculations should be applicable to other elementary particle processes. We present here only the main ideas; the calculation details will be published elsewhere[12].

47. R. F. O'Connell and S. N. Rasband, "Lense-Thirring Type Gravitational Forces Between Disks and Cylinders," Nature 232, 193 (1971).

BECAUSE of the widespread interest in measuring forces between spinning cylinders and disks[1,2] and the speculative nature of the conclusions reached in previous discussions, we have made a quantitative calculation of the magnitude of the forces. As in earlier calculations[3], our approach is based on a weak field low velocity (EIH) approximation to general relativity. By methods familiar from potential theory in electrodynamics we first compute the first order corrections to a flat space metric due to the presence of a spinning cylinder.

58. R. F. O'Connell, "Spin, Rotation and C, P, and T Effects in the Gravitational Interaction and Related Experiments," Invited Lecture, in Experimental Gravitation: Proceedings of Course 56 of the International School of Physics "Enrico Fermi" Varenna, Italy, 1972, ed. B. Bertotti (Academic Press, 1974), p.496.

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1. – Introduction.

The importance of the role of general relativity in the study of modern astrophysics is widely accepted. This fact, combined with the continued development of more sophisticated experimental techniques, has led to intense interest in experiments to test the theories of EINSTEIN and others. Our main aim here is to consider experimental tests of

i) the gravitational theories (particularly that of Einstein's) of rotating and spinning bodies and

ii) possible parity (P), time (T) and charge conjugation (C) violating terms in the gravitational interaction.

69. B. M. Barker and R. F. O'Connell, "Nongeodesic Motion in General Relativity," Gen. Relativ. Gravit. 5, 539 (1974).

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ABSTRACT

The equations of motion of a spinning body in the gravitational field of a much larger mass are found using both the Corinaldesi-Papapetrou spin supplementary condition (SSC) and the Pirani SSC. These equations of motion are compared with our previous result derived from Gupta's quantum theory of Gravitation. It is found that the spin-dependent terms differ in each of the above three results due to a different location of the center of mass of the spinning body. As expected, these terms are not affected by the choice of either Schwarzschild or isotropic coordinates. Finally, for the presently planned Stanford gyroscope experiment, we find the maximum secular displacement of the orbit of the gyro with respect to the orbit of its non-rotating housing to be of the order of (10^{-7} cm/year)t, a result much smaller than Schiff's result which is proportional to time squared.

78. B. M. Barker and R. F. O'Connell, "The Gravitational Two Body Problem With Arbitrary Masses, Spins, and Quadrupole Moments," Phys. Rev. D 12, 329 (1975).

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We find the precession of the spin and the precession of the orbit for the two-body problem in general relativity with arbitrary masses, spins, and quadrupole moments. One notable result which emerges is that, in the case of arbitrary masses m_1 and m_2, the spin-orbit contribution to the *spin* precession of body 1 is a factor $(m_2+\mu/3)/(m_1+m_2)$ times what it would be for a test body moving in the field of a fixed central mass (m_1+m_2). Here μ denotes the reduced mass $m_1 m_2/(m_1+m_2)$. This contrasts with the result of Robertson for the *periastron* precession where the corresponding factor is unity. These results may be of interest for binary neutron stars and, in particular, for binary pulsars such as PSR1913+16.

79. B. M. Barker and R. F. O'Connell, "Relativistic Effects in the Binary Pulsar PSR 1913+16," Astrophys. J. Lett. 199, L25 (1975).

RELATIVISTIC EFFECTS IN THE BINARY PULSAR PSR 1913+16

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ABSTRACT

The relativistic precession of both the spin and the periastron of the pulsar 1913+16, in the gravitational field of its companion, are analyzed.
Subject headings: binaries — black holes — neutron stars — pulsars — relativity

The discovery of the pulsar PSR 1913+16 in a binary system (Hulse and Taylor 1975) provides a unique opportunity for studying various gravitational and relativistic effects. Up to now such studies were invariably carried out on "test bodies" in the gravitational field of a "large mass" (essentially a one-body problem). We have now carried out a detailed analysis of the gravitational two-body problem with arbitrary masses, spins, and quadrupole moments (Barker and O'Connell 1975). Here, we apply these results to find the precession of the spin and precession of the orbit of PSR 1913+16 in the gravitational field of its companion.

One notable result which emerges is that, in the case of arbitrary masses m_1 and m_2, the spin-orbit contribution to the *spin* precession of body 1 is a factor $(m_2 + \mu/3)/(m_1 + m_2)$ times what it would be for a test body moving in the field of a fixed central mass $(m_1 + m_2)$. Here μ denotes the reduced mass $m_1m_2/(m_1 + m_2)$. This contrasts with the result of Robertson (1938) for the *periastron* precession where the corresponding factor is unity.

93. R. F. O'Connell and E. P. Wigner, "On the Relation Between Momentum and Velocity for Elementary Systems," Phys. Lett. 61A, 353 (1977).

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We investigate how the quantum mechanical position operator can be defined for elementary systems so that the connection, postulated by the special theory of relatively, between velocity (the time derivative of the position) and momentum remains valid.

96. R. F. O'Connell and E. P. Wigner, "Position Operators for Systems Exhibiting the Special Relativistic Relation Between Momentum and Velocity," Phys. Lett. 67A, 319 (1978).

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We have previously shown that if the position operator is defined as in ref. [21,the movement of the *mean* position of a free particle obeys the classical equation u = P/P_0 where P_0 is the total energy, including the rest mass. Conversely, it will be demonstrated here that the validity of this equation implies that, for spinless particles, the position operator is that of ref. [2]. For spin 1/2 particles, however, another choice is also possible (eq. (7)). The corresponding value of the orbital angular momentum in the latter case is unity, whereas for the state of ref. [2] it is zero.

137. M. Hillery, R. F. O'Connell, M. O. Scully, and E. P. Wigner, "Distribution Functions in Physics:Fundamentals", Physics Reports 106 (3), 121 (1984).

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This is the first part of what will be a two-part review of distribution functions in physics. Here we deal with fundamentals and the second part will deal with applications. We discuss in detail the properties of the distribution function defined earlier by one of us (EPW) and we derive some new results. Next, we treat various other distribution functions. Among the latter we emphasize the so-called *P* distribution, as well as the generalized *P* distribution, because of their importance in quantum optics.

145. J. L. Greenstein, R. J. W. Henry and R. F. O'Connell, "Further Identification of Hydrogen in GRW + 70° 8247", Ap. J. (Lett.) 289, L25 (1985).

FURTHER IDENTIFICATIONS OF HYDROGEN IN Grw +70°8247

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ABSTRACT

Numerous spectra of the magnetic white dwarf Grw +70°8247 were obtained with the double CCD spectrograph at Palomar with signal-to-noise ratio above 100. Five weak absorptions in the blue and four in the red are produced by hydrogen in a strong magnetic field. We compute new, precise, multiparameter, variational energy levels yielding intensity and wavelength, from 100 to 600 MG. We search for those Zeeman components with wavelengths nearly constant with field. Two such, which are relatively sharp and strong π transitions, explain the Minkowski band, 4137 Å (known since 1938), as the $2s0-4f0$ and the 5855 Å band as the $2s0-3p0$. Both have minimum wavelengths at $B \approx 300$ MG. Their absorptions resemble band heads degraded to the red, as observed. The mixed nature of the $4f0$ level results in an intensity ratio $(2s0-4f0)/(2s0-3p0) = 0.58$ at 280 MG, high for a line *forbidden* at zero field. Profiles computed for a pole-on dipole, near $\log B_p = 8.5$, fit the two observed lines. Other hydrogen transitions (including the core of Lyα) are consistent with that field strength. Six models with a variety of B_p and inclination are illustrated to show the quality of fit to the observations.

Subject headings: stars: individual — stars: magnetic — stars: white dwarfs — Zeeman effect

149. R. F. O'Connell, "The Gyroscope Experiment", Physics To-Day 38, 104 (Feb. 1985).

The gyroscope experiment

The article by Barbara Levi (May, page 20) on the "Orbiting test of general relativity" is misleading in several respects. A subsequent letter by C. W. F. Everitt (August, page 84) partially clarified the situation in one respect but then confused it in other ways.

Referring to the work of B. M. Barker (University of Alabama) and myself, Everitt quoted a 1974 paper of mine, completely ignoring many relevant subsequent contributions. In addition, Everitt said: "R. F. O'Connell (and) B. M. Barker applied the analogy of spin-orbit and spin-spin coupling to investigate higher-order terms affecting the gyroscope experiment as well as a variety of astrophysical phenomena." I would like to point out that

154. G. W. Ford, J. T. Lewis, and R. F. O'Connell, "Quantum Oscillator in a Blackbody Radiation Field", Phys. Rev. Lett. 55, 2273 (1985).

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The quantum Langevin equation is used to calculate an *exact* expression for the *free energy* of a quantum oscillator interacting, via dipole coupling, with a blackbody radiation field. In particular, we obtain a temperature-dependent shift in the free energy. This result may then be used to obtain corresponding results for the energy, the partition function, and other thermodynamic quantities.

179. G. W. Ford, J. T. Lewis, and R. F. O'Connell, "The Quantum Langevin Equation," Phys. Rev. A 37, 4419 (1988).

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The macroscopic description of a quantum particle with passive dissipation and moving in an arbitrary external potential is formulated in terms of the generalized Langevin equation. The coupling with the heat bath corresponds to two terms: a mean force characterized by a memory function $\mu(t)$ and an operator-valued random force. Explicit expressions are given for the correlation and commutator of the random force. The random force is *never* Markovian. It is shown that $\tilde{\mu}(z)$, the Fourier transform of the memory function, must be a positive real function, analytic in the upper half-plane and with $\mathrm{Re}[\tilde{\mu}(\omega+i0^{+})]$ a positive distribution on the real axis. This form is then derived for the independent-oscillator model of a heat bath. It is shown that the most general quantum Langevin equation can be realized by this simple model. A critical comparison is made with a number of other models that have appeared in the literature.

209. R. F. O'Connell and G. Y. Hu, "The Few-Body Problem in Nanoelectronics," Invited paper, presented at a NATO Advanced Study Institute, Il Ciocco, ASI Series B, Vol 251, Italy, July 23-August 4, 1990, in Physics of Granular Nanoelectronics, edited by D. K. Ferry, J. Barker and C. Jacobini (Plenum Press, 1991).

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INTRODUCTION

Few electron systems are achieved by constraining electron motion so that one is no longer dealing with macroscopic bulk matter. (Similar remarks clearly apply to holes, which will be discussed specifically in our remarks on excitons). The constraints are effectively potential barriers which facilitate the creation of low-dimensional (d = 2, 1 or 0) systems. The zero-dimensional systems are the archetype of few electron systems but few electron aspects also play an important role in all low-d-systems. However, since d = 3 (bulk matter) and d = 2 (quantum well, semiconductor-insulator interface) systems have been extensively reviewed in the recent literature our emphasis will be on d = 1 (quantum wires) and d = 0 (quantum dots or boxes). We will concentrate on transport and noise properties but, in the case d = 0, we will also review other topics such as magnetic susceptibility, energy levels etc.

214. G. W. Ford and R. F. O'Connell, "Radiation Reaction in Electrodynamics and the Elimination of Runaway Solutions," Phys. Lett. A 157, 217 (1991).

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Communicated by J.P. Vigier

The familiar Abraham-Lorentz theory of radiation reaction in classical non-relativistic electrodynamics exhibits many problems such as "runaway solutions" and violation of causality. As shown by many authors, such problems can be alleviated by dropping the assumption of a point electron. We also drop this assumption (by introducing a form-factor with a large cutoff frequency Ω) but we present a new approach based on the use of the generalized *quantum* Langevin equation. For an electric dipole interaction, an exact treatment is possible and we obtain a new equation of motion which, in spite of being third order, does not lead to runaway solutions or solutions which violate causality (the sole proviso being that Ω cannot exceed an upper limit of $3Mc^3/2e^2 = 1.60 \times 10^{23}\ s^{-1}$). Furthermore, Ω appears in the third-derivative term but we show that, to a very good approximation, this term may be dropped so that we end up with a simple second-order equation which does not contain Ω and whose solutions are well-behaved.

223. G. W. Ford and R. F. O'Connell, "Relativistic Form of Radiation Reaction", Phys. Lett. A 174, 182(1993).

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Communicated by J.P. Vigier

We present a relativistic extension of the new form which we have recently obtained for the equation of motion of a radiating electron.

244. G. W. Ford and R. F. O'Connell, "Derivative of the Hyperbolic Cotangent", Nature 380, 113 (1996).

SIR — The derivative of the hyperbolic cotangent is a standard result which appears in essentially every compilation of mathematical formulas[1]. Here we point out that this result is incomplete; there is, in fact, an additional term which is proportional to the Dirac delta function. We present the correct formula, outline its proof and give an example of its importance in the analysis of a physical problem.

The correct formula is

$$\frac{\mathrm{d}}{\mathrm{d}y}\coth y = -\operatorname{csch}^2 y + 2\delta(y) \qquad (1)$$

where $\delta(y)$ is the Dirac delta function.

253. G. W. Ford and R. F. O'Connell, "There is No Quantum Regression Theorem", Phys. Rev. Lett. 77, 798 (1996).

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The Onsager regression hypothesis states that the regression of fluctuations is governed by macroscopic equations describing the approach to equilibrium. It is here asserted that this hypothesis fails in the quantum case. This is shown first by explicit calculation for the example of quantum Brownian motion of an oscillator and then in general from the fluctuation-dissipation theorem. It is asserted that the correct generalization of the Onsager hypothesis is the fluctuation-dissipation theorem.

268. R. F. O'Connell, "Noise in Gravitational Wave Detector Suspension Systems: A Universal Model", Phys. Rev. D 64, 022003 (2001).

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In a recent review of gravitational wave detectors, Ricci and Brillet discussed models for noise in the various suspension systems and concluded that ‘‘ . . . there is probably no universal model . . . .’’ Here we present such a model which is based on work carried out by Ford, Lewis, and the present author [Phys. Rev. A **37**, 4419 (1988)]; the latter work presents a very general dissipative model (which has been applied already to many areas of physics) with the additional merit of being based on a microscopic Hamiltonian. In particular, we show that all existing models fall within this framework. Also, our model demonstrates (a) the advantages of using the Fourier transform of the memory function to parameterize the data from interferometric detectors such as the Laser Interferometric Gravitational Wave Observatory (rather than the presently-used Zener function) and (b) the fact that a normal-mode analysis is generally not adequate, consistent with a conclusion reached by Levin [Phys. Rev. D **57**, 659 (1998)].

272. G. W. Ford, J. T. Lewis and R. F. O'Connell, "Quantum Measurement and Decoherence", Phys. Rev. A 64, 032101 (2001).

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Distribution functions defined in accordance with the quantum theory of measurement are combined with results obtained from the quantum Langevin equation to discuss decoherence in quantum Brownian motion. Closed form expressions for wave packet spreading and the attenuation of coherence of a pair of wave packets are obtained. The results are exact within the context of linear passive dissipation. It is shown that, contrary to widely accepted current belief, decoherence can occur at high temperature in the absence of dissipation. Expressions for the decoherence time with and without dissipation are obtained that differ from those appearing in earlier discussions.

273. G. W. Ford, and R. F. O'Connell, "Exact solution of the Hu-Paz-Zhang master equation", Phys. Rev. D 64, 105020 (2001).

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The Hu-Paz-Zhang equation is a master equation for an oscillator coupled to a linear passive bath. It is exact within the assumption that the oscillator and bath are initially uncoupled. Here an exact general solution is obtained in the form of an expression for the Wigner function at time t in terms of the initial Wigner function. The result is applied to the motion of a Gaussian wave packet and to that of a pair of such wave packets. A serious divergence arising from the assumption of an initially uncoupled state is found to be due to the zero-point oscillations of the bath and not removed in a cutoff model. As a consequence, worthwhile results for the equation can only be obtained in the high temperature limit, where zero-point oscillations are neglected. In that limit closed form expressions for wave packet spreading and attenuation of coherence are obtained. These results agree within a numerical factor with those appearing in the literature, which apply for the case of a particle at zero temperature that is suddenly coupled to a bath at high temperature. On the other hand very different results are obtained for the physically consistent case in which the initial particle temperature is arranged to coincide with that of the bath.

297. G. W. Ford and R. F. O'Connell, "Is there Unruh Radiation?", Physics Lett. A, 350, 17 (2006).

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Communicated by P.R. Holland

Abstract
We present an exact analysis of an oscillator (the detector) moving under a constant force with respect to zero-temperature vacuum and coupled to a one-dimensional scalar field. We show that this system does not radiate despite the fact that it thermalizes at the Unruh temperature. We remark upon a differing opinion expressed regarding a system coupled to the electromagnetic field.

298. G. W. Ford and R. F. O'Connell, "A Quantum Violation of the Second Law", Phys. Rev. Lett. 96, 020402 (2006).

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An apparent violation of the second law of thermodynamics occurs when an atom coupled to a zero temperature bath, being necessarily in an excited state, is used to extract work from the bath. Here the fallacy is that it takes work to couple the atom to the bath and this work must exceed that obtained from the atom. For the example of an oscillator coupled to a bath described by the single relaxation time model, the mean oscillator energy and the minimum work required to couple the oscillator to the bath are both calculated explicitly and in closed form. It is shown that the minimum work always exceeds the mean oscillator energy, so there is no violation of the second law.

304. G. W. Ford and R. F. O'Connell, "Measured quantum probability distribution functions for Brownian motion," Phys. Rev. A, 73, 032103 (2007).

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The quantum analog of the joint probability distributions describing a classical stochastic process is introduced. A prescription is given for constructing the quantum distribution associated with a sequence of measurements. For the case of quantum Brownian motion this prescription is illustrated with a number of explicit examples. In particular, it is shown how the prescription can be extended in the form of a general formula for the Wigner function of a Brownian particle entangled with a heat bath.

309. R. F. O'Connell, "Gravito-Magnetism in one-body and two-body systems: Theory and Experiment", Invited Lecture, in "Atom Optics and Space Physics", Proc. of Course CLXVIII of the International School of Physics "Enrico Fermi", Varenna, Italy, 2007, ed. E. Arimondo, W. Ertmer and W. Schleich, (IOS, Amsterdam, 2009).

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Summary. — We survey theoretical and experimental/observational results on general-relativistic spin (rotation) effects in binary systems. A detailed discussion is given of the two-body Kepler problem and its first post-Newtonian generalization, including spin effects. Spin effects result from gravitational spin-orbit and spin-spin interactions (analogous to the corresponding case in quantum electrodynamics) and these effects are shown to manifest themselves in two ways: (a) precession of the spinning bodies per se and (b) precession of the orbit (which is further broke down into precessions of the argument of the periastron, the longitude of the ascending node and the inclination of the orbit). We also note the ambiguity that arises from use of the terminology frame-dragging, de Sitter precession and Lense-Thirring precession, in contrast to the unambiguous reference to spin-orbit and spin-spin precessions. Turning to one-body experiments, we discuss the recent results of the GP-B experiment, the Ciufolini-Pavlis Lageos experiment and lunar-laser ranging measurements (which actually involve three bodies). Two-body systems inevitably involve astronomical observations and we survey results obtained from the first binary pulsar system, a more recently discovered binary system and, finally, the highly significant discovery of a double-pulsar binary system.

313. G. W. Ford and R. F. O'Connell, "Decay of Coherence and Entanglement of a Superposition State for a Continuous Variable System in an Arbitrary Heat Bath," Inter. J. Quantum Information 8, 755-763 (2010).

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Revised 6 May 2010

We consider the case of a pair of particles initially in a superposition state corresponding to a separated pair of wave packets. In contrast to a previous related work, we avoid a master equation approach and we calculate exactly the time development of this non-Gaussian state due to interaction with an arbitrary heat bath. We find that coherence decays continuously, as expected. We then investigate entanglement and find that at a finite time the system becomes separable (not entangled). Thus, we see that entanglement sudden death is also prevalent in continuous variable systems which should raise concern for the designers of entangled systems.

314. Disentanglement and decoherence without dissipation at non-zero temperatures, Phys. Scr. 82 (2010) 038112(3pp).

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Abstract
Decoherence is well understood, in contrast with disentanglement. According to common lore, irreversible coupling to a dissipative environment is the mechanism for loss of entanglement. Here, we show that, on the contrary, disentanglement can in fact occur at large enough temperatures T even for vanishingly small dissipation (as we have shown previously for decoherence). However, whereas the effect of T on decoherence increases exponentially with time, the effect of T on disentanglement is constant for all times, reflecting a fundamental difference between the two phenomena. Also, the possibility of disentanglement at a particular T increases with decreasing initial entanglement.